Fire Management *today*

Volume 67 • No. 3 • Fall 2007

How Much Fuel Is Acceptable?

Page 6

United States Department of Agriculture
Forest Service

Looking Back...

The Future of Fire Control – 70 Years Ago

". . . Forestry's present store of information and accepted skills and techniques in fire control is meager. Consequently, the instruction provided in professional schools is entirely out of proportion to the importance of fire control in the field of forestry practice. The young forester finds himself ill-prepared for the job which often consumes the greater part of his efforts—fire control."

John R. Curry, senior silviculturist, Forest Service, California Forest and Range Experiment Station, from his article "The Future of Fire Control" published in *Fire Control Notes,* Volume 1(5) August 1937. *(Fire Control Notes* is the forerunner of *Fire Management Today.)* For more of Curry's insightful observations seven long decades ago, see "Looking Back" on page 31.

Coming Next...

The next issue of *Fire Management Today* (68[1] Winter 2008) will feature wildland fire equipment. From the early 1900s—when retrofitted horse-drawn farm equipment served as rustic apparatus—to today's state-of-the-art remote control devices, dedicated researchers and developers have continuously challenged themselves by devising high-quality and safe fire-fighting equipment. Today, some equipment is still retrofitted or recycled from surplus military equipment, while other fire apparatus proves to be the conception of innovation. With today's ever-advancing technology, wildland fire equipment centers located across this country supply the resources and support to meet the demands of the 21st century.

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On the Cover:

On the Cover: *Firefighter Jeremy Dempsey of the Baker River Hotshots falls hazard snag during mop-up operations on the Pot Peak Fire, Wenatchee National Forest, Wenatchee, WA. In falling this snag, wearing a pack would reduce Dempsey's ability to quickly retreat to safety. Photo: Eli Lehmann, Mount Baker–Snoqualmie National Forest, Concrete, WA, 2004.*

Inset Photo: *A 20-foot (6-m) tall woody debris pile following harvest in a mature lodgepole pine and white spruce stand in west-central Alberta, Canada. For an insightful discussion surrounding the question "How much fuel is acceptable?" see article on page 6. Photo: Gary Dakin, Forest Engineering Research Institute of Canada, Wildland Fire Operations Research Group, Hinton, Alberta, 2001.*

The Forest Service's Fire and Aviation Management Staff has adopted a logo reflecting three central principles of wildland fire management:

- *Innovation:* We will respect and value thinking minds, voices, and thoughts of those that challenge the status quo while focusing on the greater good.
- *Execution:* We will do what we say we will do. Achieving program objectives, improving diversity, and accomplishing targets are essential to our credibility.
- *Discipline:* What we do, we will do well. Fiscal, managerial, and operational discipline are at the core of our ability to fulfill our mission.

Firefighter and public safety is our first priority.

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Anchor Point

by Tom Harbor
Director, Fire and Aviation Management
Forest Service

Unless We Change Our Path, It's Going To Get Changed for Us

Looking at current and out-year budgets is a shock to the system. Believe me, I know. But it's time we all transitioned from being worried about our capability—to taking *action*. And it's time to acknowledge that we can't sustain these billion-dollar fire suppression efforts.

Be assured, unless *we* change our path, it's going to get changed for us.

After last year's *third* billion-dollar fire season in 5 years, the issue of meaningful cost reduction is no longer a long-term goal that we'll continue to *think* about. Let's face it, folks, that kind of money is just *not* there anymore. And, our Forest Service mission as conservation leader suffers when one program dominates our time, our talent, and our funds. We all know this truth. So do our partners.

Our Forest Service mission as conservation leader suffers when one program dominates our time, our talent, and our funds.

I will never believe that we are helpless to change course. Yes, this year's planning and operations brought some big changes. By now, I know you folks in fire and aviation are, nonetheless, *moving forward*.

The 300-Pound Gorilla

So let's look at what you are empowered to alter. The price of jet fuel and diesel, the growth of the wildland/urban interface, and the costs of equipment and overhead are generally out of all of our hands—although we can make, and *are* making, some contracting changes. Inflation and El Niño we can't fight effectively, either. But there is one big-ticket item that we *can* alter. It's always been there. Like the 300-pound gorilla lurking over in the corner of the room:

We can change *us*.

To help attack our rising costs, I recently asked a diverse group of fire and aviation managers and line officers to develop new (yes, *new*) "Management Efficiency" proposals. I wasn't referring to a change jar on the dresser, either. I *was* referring to some substantial savings through *major* alterations in how we direct and implement our fuels and fire management program. Right now.

We need to change: *us*.

Some of their proposals made us all collectively wince. Others created a palpable enthusiasm.

Action: Now

These Management Efficiency proposals for large fire-cost containment were grouped into three primary categories: Leadership, Operations, and Management. The identified cost-saving measures included actions that are now being implemented, like the increased use of decision support tools (Wildland Fire Decision Support Systems) to show the array of options and anticipated fire progress and the centralization and use of national shared resources, ensuring that they truly go when and where they are needed through a central command and control. The benefit will be the better use of our mobile resources to support initial attack, which is always less expensive when successful.

We all know that big changes won't happen through paper proposals. My focus is action *now*—every day, every incident. Real advances will take the common sense—and the community relationships—of our leadership, of our line officers, of all of our fire management folks, and of our incident commanders.

Fully implementing the spirit and use of Appropriate Management Response reflects the foundation of the Fire Suppression Doctrine. This will allow us to make more cost-conservative decisions in those gray areas, too. Somewhere along the line, we somehow adopted an "either/or" decision mindset regarding suppression or fire use. We took a lot of discretion out of the hands of our line officers and fire managers.

Don't get me wrong. Interagency Federal fire policy does say it's either a suppression fire or a wildland fire for resource benefit (wildland fire use). But it never says to throw everything you can get your hands on to suppress the fire, either. Here's what our fire policy *does* tell us. It says to provide for firefighter and public safety first, *then* protect property and natural resources. Those goals provide a myriad of options that lead to success.

Waxing Our Skis

How we provide for those priorities is where we must be flexible, creative, and, most of all, articulate. All types of fire—point protection, contain/confine, natural barrier use, or consistent monitoring—are all part of appropriate management actions. They all need to be used based on the individual situation.

Some of their proposals made us all collectively wince. Others created a palpable enthusiasm.

Appropriate Management Response is the umbrella that offers alternatives to digging line the way we've always done it—and getting what we've always got: high management costs and high demand, or expensive resources disappearing into the depths of mega-fires when they could be ready elsewhere for initial attack. There comes a point of diminishing return when dealing with mega-fires, especially when our predictive services folks tell us that the fire will be controlled when we are waxing our skis.

Articulating the sometimes difficult path to the appropriate—the right—response to fire management based on values and cost is where leadership is challenged *and* honed. When fire is active on the landscape, there can be temporary inconveniences in travel, persistent smoke, and reduced opportunities for recreation. There also remains an unfortunate expectation that we'll save every house—whether it is defensible or not.

We all know that big changes won't happen through paper proposals.

The relationships that our leadership in line and fire management have now—and will continue to build over time—can turn a community's passive observation of firefighting into an active dialogue about fire management and the relevant tradeoffs. Then, as leaders, we can do what our common sense and defined budgets tell us is the right thing to do. Wayne Gretzky once said, *"I skate where the puck is going to be, not where it's been."*

You and I—all of us—are now expected to step forward onto the trail of common sense and innovation. Communicate with your local folks to start doing things differently. Do it today. ■

Simple Question; Difficult Answer: How Much Fuel Is Acceptable?

Natural Resources Canada / Ressources naturelles Canada
Canadian Forest Service / Service canadien des forêts
University of Alberta
FERIC

M.E. Alexander

Fire managers commonly want to know what quantity of wildland fuel is acceptable (Noble 1979). But this question—simple as it may seem—is difficult to answer. A host of factors are involved.

Fire behavior depends not only on fire potential at one location, but on a range of associated factors that include the distribution and characteristics of the individual and collective elements comprising the fuel complex (table 1) and fire behavior potential across surrounding areas that could encompass one or more drainages.

Acceptable fuel loads depend on resource values, management objectives for the land, pattern of land ownership, and suppression capability (fig. 1). In some stands, acceptable fuel load might depend on the resistance of trees to crown scorch and cambium kill (Outcalt and Wade 2004; Weatherspoon and Skinner 1995). Sound professional judgment (Haas 2003) is certainly

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This article is adapted in part from Brown and others (1977).

Sound professional judgment is needed to determine what can be considered acceptable fuel loads.

Dr. James K. Brown, seen here inventorying dead-down woody debris, was a research forester with the Forest Service who pioneered many techniques for sampling ground, surface, and crown fuels. This article is adapted, in part, from his work (Brown and others 1977). In March 2007, Dr. Brown received the second annual "Ember Award" from the International Wildland Fire Association. Photo: Forest Service.

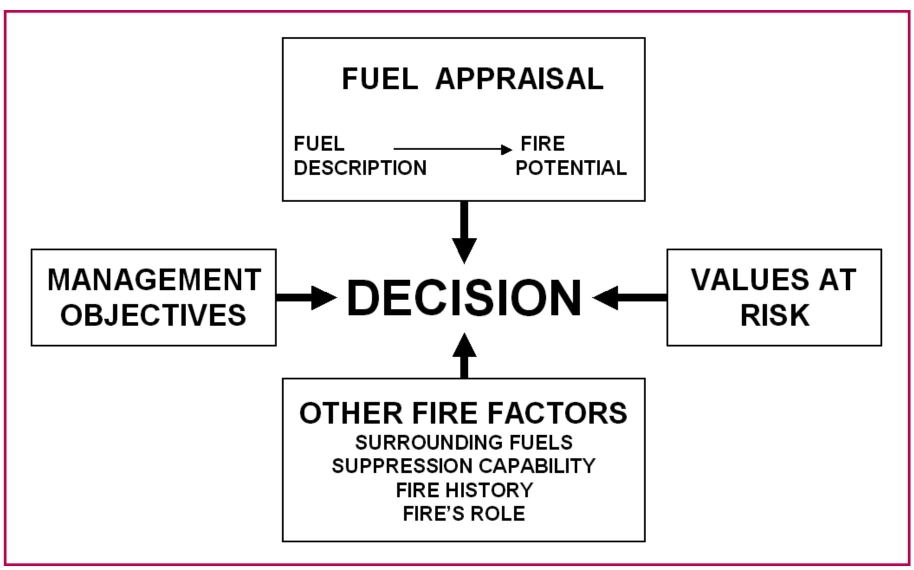

Figure 1—*Factors to consider when deciding how much fuel is considered acceptable (Brown and others 1977).*

Table 1—Fuel properties affecting various elements of fire potential and their relative influence (Anderson 1975).

Fuel properties (dimensionless)	**Ignitability**		**Fire spread**		**Energy release**							**Physical obstruction**	
	Ignition probability	Spot fire ignition	Linear	Size	Fire intensity	Flame height	Scorch height	Crowning potential	Firebrand generation	Fire duration	Fire persistence	Ground	Aerial vegetation
PARTICLES:													
Size (diameter, length)	X	X	X	X	X	X	X	X	X	X	X	X	X
Shape (geometric factor, surface area/volume)	X	X	X	X	X	X	X	X	X				
Density (weight/volume)	X	X	X	X	X	X	X	X	X		X	X	
BEDS:													
Load (weight/unit area)	X	X	X	X	X	X	X	X		X	X	X	X
Depth (thickness)			X	X	X	X	X	X		X	X	X	
Continuity:													
Vertical (length)		X					X	X					X
Horizontal (length)	X	X	X	X				X				X	
Live/Dead ratio	X	X	X	X	X	X			X				X
Extent (% of land area)		X		X								X	X

needed to determine what can be considered acceptable fuel loads.

Decision Steps

To decide how much fuel is acceptable requires the integration of many factors (fig. 1). This can be done systematically in a three-step process (Brown and others 1977):

Step 1: Consider management objectives and values-at-risk. For the latter, both resource values *and* risk of a fire during periods of critical fire weather and fire danger causing damage are jointly considered.

Step 2: Appraise fuels by (a) describing fuels from inventory (Brown and others 1982), prediction (Brown and others 1977), or ocular estimation using a photo series (Wendell and others 1962; Fischer 1979) and (b) interpreting fire behavior and fire impact potential such as rate-of-spreading, intensity, flame length, crown scorch height, and degree of flame defoliation.

Step 3: Consider other fire-related factors, such as fuel and fire behavior potential on adjoining lands, suppression capability, frequency and severity of historical fires, and fire's ecological role.

Acceptable fuel loads can depend to a high degree on the factors considered in *Step 3*. For example, a very high fuel load would be acceptable on a unit surrounded by sparse fuels with little chance of ignition than on a unit surrounded by very heavy fuel loads with a more certain probability of ignition. Once management objectives have been

Too much reliance can be placed on models. After all, predicting fire behavior is a science *and* an art.

Explosive Potential

"Fuels contain energy, stored over extended periods through photosynthetic processes, that is released rapidly, occasionally explosively, in combustion."

–From Martin and others (1979)

specified, Omi (1996) has suggested a conceptual framework that can be used for assessing the viability of landscape-scale fuel treatments (fig. 2).

Fuel Appraisal

Appraising the potential fire behavior of fuels is often termed "fuel appraisal" (Brown 1972, 1978) and is the process of: (1) describing fuel characteristics, such as quantity and size (table 1) and (2) interpreting the fuel in terms of fire behavior, such as rate-of-spread, fire intensity, and flame length (fig. 3).

Thus, the appraisal process attempts to answer the question: Given steepness of slope and weather conditions, what is the expected fire behavior for different fuels?

This question is difficult to answer, partly because the answer is made up of different elements of fire behavior (Anderson 1974)—including rate-of-spread, intensity, flame dimensions, torching potential, crowning potential, spotting potential, blowup potential, and duration of heat (flame front residence time and burn-out time, or smoldering potential).

One or more of these elements may have to be appraised when a specific fuel management situation is being evaluated. Furthermore, the overall assessment of fire behavior potential must ultimately be interpreted in terms of the implications for fire suppression (Murray 1983).

Potential fire behavior of litter, downed woody debris, and understory vegetation can be appraised by (fig. 3): (1) mathematical modeling, (2) experienced judgment, and (3) comparison (such as case studies). Mathematical modeling of

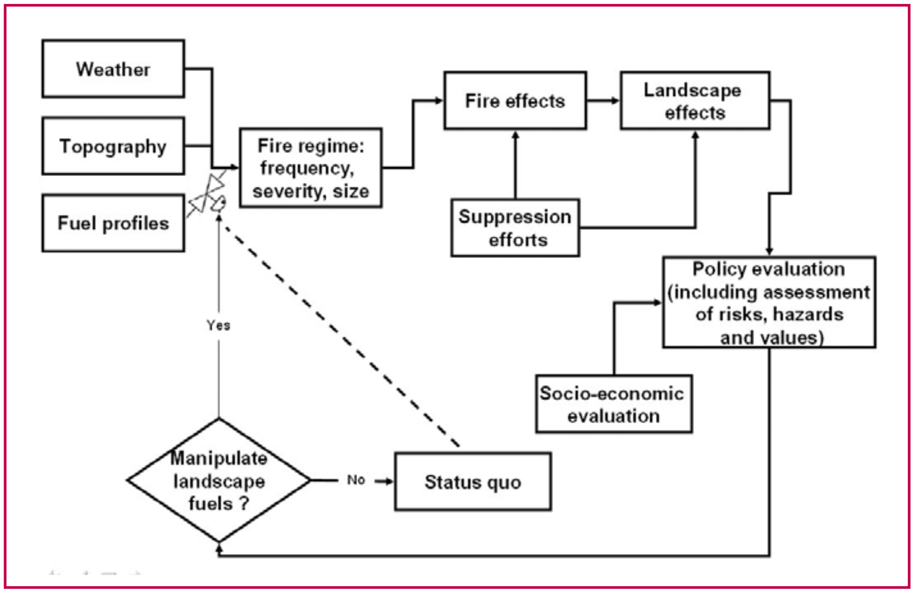

Figure 2—*Framework for assessing the impact of landscape-scale fuels management versus status quo (Omi 1996).*

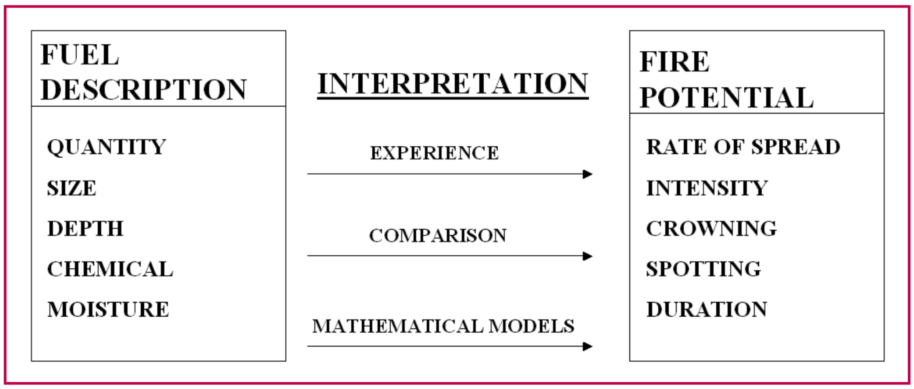

Figure 3—*The process of fuel appraisal (Brown 1972).*

fire behavior characteristics such as rate-of-spread, fire intensity, flame length, crowning potential, and fire size (Alexander 2006; Anderson 1974; Brown 1974; Brown and Johnson 1987; Hirsch and others 1979; Lavoie 2004; Radloff and others 1982; Salazar and Bevins 1984) offers the most objective means of appraising potential fire behavior.

Systems have been developed specifically for this purpose (Hirsch and others 1981; Puckett and others 1979; Radloff and others 1982; Roussopoulos and Johnson 1975).

Such modeling, however, does have its limitations (Albini 1976; Alexander 2004a). Furthermore, too much reliance can be placed on models (Alexander 2004b). After all, predicting fire behavior is a science *and* an art (Alexander and Thomas 2004).

Experienced Judgment

Experienced judgment is an important means of appraising fuels. An experienced person can integrate many factors that elude quantification. Even when more sophisticated methods are available, judgment is still important. However, even experienced judgment has its limitations (Gisborne 1948).

One way of using experienced judgment is to establish a reference fuel

Forest Fuels and Free-Burning Fire Behavior

"The ignition, buildup, and behavior of fire depends on fuels more than any other single factor. It is the fuel that burns, that generates the energy with which the firefighter must cope, and that largely determines the rate and level of intensity of that energy. Other factors that are important to fire behavior (that is, moisture, wind, and so forth) must always be considered in relation to fuels. In short, no fuel—no fire!

Discussion of fuels is significant only in relation to fire, yet the makeup of forest fuel complexes must be understood before the interactions between fire and its environment can be examined constructively. To achieve this, the student must be able to appraise forests and wildlands in general from the point-of-view of their fire potential. In figurative terms, it is like viewing the forest through a different pair of glasses—the kind worn constantly by skilled fire control men [and women]. The vegetative cover, living and dead, is then perceived as potential fuel, capable of being ignited and burned under certain conditions."

–From Brown and Davis (1973)

Experienced judgment is an important means of appraising fuels. An experienced person can integrate many factors that elude quantification.

load that can be used to compare against other fuel loads. The reference fuel load could represent fuels for which a consensus of fire control-experienced land managers could agree on a rating. This might be in terms of resistance to fireguard construction or resistance to control (Murphy and Quintilio 1978; Ponto 1990).

Alternatively, wildland fire research may suggest a reference fuel load. For example, Wendell and others (1962) indicated that the probability of blowup fires decreased rapidly when "available fuel" loads—those readily consumed in the active flaming front—were less than 6 tons per acre (13.5 tons per hectare).

Ratings, for example, might be for low-, medium-, or high-fire intensity potential (Fahnestock 1968; Fischer 1979), or for fuels being either acceptable or unacceptable regarding the ability of an initial attack crew to gain control (McCarthy and Tolhurst 1998).

After setting a reference fuel load, fuels are then appraised on a relative basis. For example, for material less than 3.0 inches (7.6 cm) in diameter, if a load of 10 tons per acre (22.4 tons per hectare) is established as the reference fuel load, then a load of 20 tons per acre (44.8 tons per hectare) would exhibit approximately twice the potential fire behavior.

Case-study knowledge (Alexander and Thomas 2003a, 2003b, 2006) coupled with experienced judgment and fire behavior modeling is considered an effective operational technique for appraising fire potential for fuels management (Brown 1978). The article written by Salazar and Gonzalez (1987) represents a good example of the wildfire case study approach regarding fuel management.

Fuel Load Standards

No single fuel load may be acceptable for a large administrative area. Herein lies the dilemma of setting fuel load standards. Establishing standards would permit the setting of clear objectives for residue management and provide benchmarks with which to measure accomplishments. However, standards could easily circumvent professional judgment for determining the maximum acceptable level of fuel for specific sites.

One approach to determining acceptable fuel levels is to develop different standards for each of the major decision circumstances encountered on a large administrative unit. To accomplish this, the various factors noted in figure 1 need to be evaluated for the different management circumstances found on a large administrative unit.

Acceptable loadings of debris also depend on requirements of other disciplines for attaining land management objectives. Thus, even if fuel load standards are set, the final decision on how much downed debris is acceptable needs to be coordinated among all management interests (e.g., Graham and others 1994; Brown and others 2003).

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Fire Dynamics and Wildland Fuel Complexes

"The best chance for success in fire behavior prediction requires a mix of fire experience with analytical modeling methods. But in situations where conditions are beyond the limits or outside the assumptions of the models, fire predictions must rely even more on intuitive judgements. Such judgements could be more easily made if managers know general patterns of fire behavior through a full range of burning conditions."

–From Williams and Rothermel (1992)

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Summary of the 2006 Wildland Fire-Related Deaths

A total of 24 wildland fire management-related deaths occurred in this country in 2006, according to the National Wildfire Coordinating Group. In 2005, a total of 12 wildland fire management-related fatalities occurred.

The 24 2006 deaths were attributed to:

- **Aviation.** Eight fatalities occurred in two helicopter accidents and one lead plane accident.
- **Entrapments/Burnovers.** Seven fatalities occurred when firefighters were entrapped or burned over by fire.
- **Driving/Motor Vehicle:** Four persons were killed in driving-related accidents.
- **Heart Attacks:** Three individuals died when they suffered heat attacks while firefighting.
- **Hazard Tree/Felling:** One person was killed when a snag fell during a prescribed fire operation.
- **Other/(Fall):** One person died from injuries that occurred by falling from the stairs of a fire lookout tower. ■

For more information, contact <michelle_ryerson@nifc.blm.gov>.

How Much Fuel Is in That Pile or Windrow?

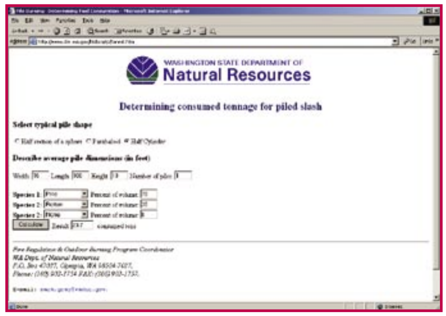
M.E. Alexander

I've often been asked by both fire managers and other fire researchers how to sample the fuel weight in woody debris piles and windrows. Certainly, the planar (Anderson 1978; Brown 1974; Brown and others 1982) or line intersect techniques (McRae and others 1979; Taylor 1997; Van Wagner 1982) are not very efficient methods for sampling in these kinds of fuel complexes. Other more practical techniques exist (e.g., Hardy 1996; Johansen 1981; Johnson 1984; McNab 1980; McNab and Saucier 1980; Mohler 1977).

In this brief article, I will list the relevant literature and highlight the existence of a simple, freely available computer program now available for calculating the fuel weights of woody debris piles and windrows.

The Washington Department of Natural Resources has developed a user-friendly, online calculator program for determining the fuel weights of debris piles and windrows (<http://www.dnr.wa.gov/htdocs/rp/tonest.htm>). The program is based on Hardy's (1996) publication. If you have a need to know preburn fuel weights of debris piles or windrows, this calculator offers a quick and easy approach.

Users are required to input one of three possible pile or windrow shapes—i.e., half section of a sphere, paraboloid, or a half-cylinder (Alexander 2006)—as well as the length, height, and width of the pile or windrow (either measured or estimated) and the number of piles or windrows with these attributes. Finally, the user is required to specify the percent volume by tree species based on ocular estimates.



Sample screen from the online fuel weight calculator for piled debris and windrows developed by the Washington State Department of Natural Resources.

Sample Calculation

A sample screen capture from this program is presented here for the case of a single, half-cylinder shaped windrow 16 ft (4.8 m) in width, 100 ft (30.3 m) in length, and 10 ft (3 m) high. This windrow is comprised of (volume) 70 percent pine and 30 percent rotten wood. The final output is in tons of total fuel consumed (tons x 0.9 = tonnes), which is assumed to be equivalent to 85 percent of the total preburn fuel weight.

This follows Hardy's (1996) statement that: *"The percentage of wood mass consumed when piles are burned typically ranges between 75 and 95 percent"* (Gray 2005). Thus, for the sample screen of capture below of 23.7 tons, the total preburn fuel weight would be 27.9 tons (i.e., (23.7 x 100)/85 = 27.9). This is equivalent in the International System (SI) of units to 25.1 tonnes (i.e., 27.9 x 0.9 = 25.1).

This calculator program is oriented toward tree species in the Pacific Northwest. Obviously, if sufficient interest and need existed, a similar program could be developed (including a SI unit option) for other tree species—based on wood density values found in published sources (e.g., Mullins and McKnight 1981) (if such precision was deemed necessary).

However, I believe that reasonable estimates can still be made with the current program by using Pacific Northwest tree species that are anatomically similar (e.g., use Sitka spruce for black spruce and white spruce; alder for trembling aspen).

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SCIENCE-BASED STRATEGIC PLANNING FOR HAZARDOUS FUEL TREATMENT

David L. Peterson and Morris C. Johnson

A scientific foundation coupled with technical support is needed to develop long-term strategic plans for fuel and vegetation treatments on public lands. These plans are developed at several spatial scales and are typically a component of fire management plans and other types of resource management plans.

> The focus of fuel treatment is typically on reducing hazardous surface fuel and crown-fire hazard. The effects of fuel treatment on vegetation, wildlife, aquatic resources, and economic values also need to be considered.

Such plans need to be compatible with national, regional, and local strategies for fuel treatments, as well as other aspects of resource management.

Scientific documentation provides principles and tools that inform management decisions about fuel treatments (Peterson and others 2005), contribute to the application of best management practices (Johnson and others 2007), and support implementation of treatments to attain desired conditions.

Science-based fuel treatment planning by land management agencies includes:

- A *consistent decision process* for identifying and planning fuel treatments,
- *High-quality data* for landscapes where treatments are proposed, and
- An *accountability process* for documenting and evaluating treatments.

A Consistent Decision Process

We propose a management/science collaboration framework for decisionmaking with an interdisciplinary (ID) team (table 1) comprised of:

1. Local resource managers (such as from a Forest Service ranger district or Bureau of Land Management district or field office)—it is helpful to have

David Peterson is a research biologist and Morris Johnson is an ecologist with the Forest Service Pacific Northwest Research Station, Pacific Wildland Fire Sciences Laboratory, Seattle, WA.

Table 1—*Primary responsibilities of members of an interdisciplinary team working to develop an integrated fuel treatment plan.*

Team member	Responsibilities
Local Resource Managers	Geospatial data bases (fuel, vegetation, historical fire occurrence, wildlife, hydrology), natural resource expertise, management objectives and desired conditions, guidance on local regulatory and political issues (sensitive species, air quality, etc.).
Resource Specialists	Consistent ID team process, guidance on national and regional regulatory and policy issues including NEPA, natural resource expertise.
Research Scientists	Scientific expertise in natural resources, modeling and decision support, consistent application of scientific data, ongoing scientific consultation.
Local Stakeholders	Opportunities for collaboration with local residents and business; economic, esthetic, and environmental concerns.
Facilitator	Efficient and productive ID team meetings, documentation and reporting of proceedings, communication among ID team members.

technical specialists in fire, silviculture, wildlife, hydrology, economics, and social science;
2. One or more high-level resource specialists with expertise in planning and National Environmental Policy Act (NEPA) processes;
3. One or more research scientists;
4. Local stakeholders (municipal officials, business representatives, nongovernmental organizations); and
5. A facilitator.

This is an ideal team composition that might not always be attainable. It is also desirable to have an upper-line manager or someone on the team with clear decisionmaking authority.

Decisions about fuel treatment planning vary according to spatial scale and are prompted by different issues and decision criteria (table 2). Most available information and analyses have been developed for small-scale application. It is inappropriate to simply expand these to broader spatial scales. Scaling up information and analyses can be done, but only with the knowledge

Table 2—*Different strategic questions are appropriate for fuel planning at different spatial scales.*

Spatial Scale	Issues and Decision Criteria
One to a few forest stands	What is the potential for unplanned fire with unacceptable results or costs? What are desired fire behavior and fire effects, and which fuels should be removed to attain them?
	Which kinds and spatial arrangement of treatments would most effectively modify fire behavior, allow fire to be successfully suppressed, and attain desired future conditions for multiple resource objectives?
	What are specific options for fuel treatments and the quantitative and qualitative costs/benefits associated with each?
	What is the expected duration of effectiveness for each fuel treatment?
	Which logistic considerations and risks must be addressed to successfully conduct the fuel treatment?
Small to moderate watersheds (approx. 5th to 6th field hydrologic unit code [HUC])	Which stands or groups of stands are at highest risk for crown fire due to fuel accumulation?
	Which resources (such as habitat, water quality) and other assets (such as buildings, communication facilities) are at high risk from fire due to fuel accumulation?
	Which locations, if treated, would allow the creation of fuel conditions that would reduce fire hazard and facilitate successful fire suppression?
	Where are fuel treatment options limited or restricted due to administrative prohibitions, limited access, high risk, or low probability of success?
Large watershed (approx. 4th field HUC and larger)	Which resources (such as habitat, water quality) and other assets (such as buildings, communication facilities) are at high risk from fire due to fuel accumulation and require priority allocation of effort?
	Which locations provide the greatest strategic opportunity for fuel treatments that would facilitate attainment of desired conditions (such as reduce large-scale fire hazard, facilitate successful fire suppression)?
	Do opportunities exist for long-term biomass utilization and other sustainable means of revenue production?
	Where are fuel treatment options limited or restricted due to administrative prohibitions, limited access, high risk, or low probability of success?

that error (or larger confidence intervals) will likely be introduced into decisionmaking.

The ID team needs to consider which decision systems and tools are most appropriate to inform the decision process at each spatial scale (Peterson and others 2007). The focus of fuel treatment is typically on reducing hazardous surface fuel and crown-fire hazard, but the effects of fuel treatment on vegetation, wildlife, aquatic resources, and economic values also need to be considered.

A Decision Framework

NEPA analyses or similar types of decision frameworks are required for many aspects of forest management, including fuel treatments. A framework (outlined below) can be used for the analysis of individual fuel treatments, as well as for broad-scale fuel treatments across landscapes:

1. *Desired conditions* must be clearly defined for fuel treatments at all spatial scales for which treatments are considered. Attainment of these conditions normally includes:
   - Reduced fuel loading at locations that currently have heavy accumulations of hazardous fuel;
   - Reduced potential for crown fire, intense surface fire, and undesirable fire effects on vegetation and other resources; and
   - Reduced potential for adverse fire effects on local communities and structures.

2. *Consequences of fuel treatments* can be evaluated through a series of questions for alternative fuel treatment options (table 3). Most of the categories and questions in table 3 can be applied to most scales at which fuel treatment planning is done. To ensure that specific needs are addressed, other categories and questions can be added.

> The expert knowledge of local fire managers is critical in estimating large-scale fire behavior and fire patterns—with or without fire-spread modeling.

Interdisciplinary Team Process

Evaluating fuel treatment alternatives requires synthesis of existing information and expert knowledge.

> Testing of strategic placement of treatments by resource managers will add data in the years ahead and provide information that can be shared and applied in other locations.

Map-based evaluation of alternatives should focus primarily on:

- Spatial patterns of existing fuel and vegetation,
- Likely ignition sources,
- Potential fire spread,
- Fire suppression strategy,
- Fire effects, and
- Future resource conditions.

While simulation models such as FARSITE (Finney 1998) can be used to measure potential fire spread, individual ID teams need to decide if they have sufficient technical capability to reliably run simulation models. Expert knowledge of local fire managers is critical in estimating large-scale fire behavior and fire patterns—with or without fire-spread modeling.

Because such information is needed to develop long-term spatial strategies for fuel treatments, spatial patterns of fuel treatments that effectively control fire spread across large landscapes are a topic of great interest. At present, empirical data on which to base optimization of spatial patterns are sparse. The scientific basis for addressing placement of fuel treatments across complex landscapes is minimal. However, testing of strategic placement of treatments by resource managers will add data in the years ahead and provide information that can be shared and applied in other locations.

Elimination rules—including steep slopes, riparian areas, and higher elevation forests with high fuel moistures—exclude these portions of the landscape where fuel treatments are unlikely. While removing these locations from consideration reduces the area where fuel treatment is evaluated and constrains the pattern of fuel treatment options, the eliminated locations can still affect (and be affected by) how treatments influence fire patterns.

Fire spread is an important analytical issue at larger spatial scales, but other fire effects (such as tree mortality and smoke emissions) must also be evaluated. The decision framework described above can also

Table 3—*A series of questions can be used to evaluate the consequences of fuel treatments.*

Category	Questions
Wildfire and Fuel	What are the effects on crown fire hazard? What are the effects on surface fire hazard? Can future fires be suppressed when necessary? At what interval will fuel need to be treated in the future? Which treatments will be needed? What are the cumulative effects of multiple treatments on wildfire potential?
Vegetation	What are the effects on large trees and snags? What are the effects on sensitive plant species? What are the effects on exotic species? What patterns of forest species, habitats, and structures will develop?
Wildlife	What are the effects on critical habitat structures and animal populations? What are the effects on sensitive animal species? What patterns of animal habitat will develop through time?
Aquatic Systems and Water	What are the effects on water quality? What are the effects on water supply? What are the effects on fish habitat? What are the effects on riparian systems?
Soils	What are the effects on sediment production and delivery? What are the effects on soil fertility and long-term productivity? What are the effects on long-term soil carbon dynamics?
Air	What are the effects on the production of particulates and gases? What are the effects on visibility? What are the effects on carbon emissions? What are threats to air quality if no action is taken?
Cultural Resources	What are the effects on archeological sites and other cultural resources?
Local Community Involvement	Are there opportunities for collaboration with local citizens? What are the effects on recreational activities? What are the effects on resource-based activities (livestock grazing, hunting, etc.)?
Economics	What is the economic cost of the proposed treatment? What is the potential economic benefit of the proposed plan to the Federal Government? What is the potential economic benefit to employment and revenue in local communities? What kinds of contracts and institutional arrangements can be used?
Health and Safety	What are the effects on the health and safety of people in local communities? What are the effects on the health and safety of Federal employees, contractors, and firefighters?
Regulatory	Is any significant legislation, including HFRA, relevant to the proposed plan? Which local governmental units will be affected? Which local organizations, institutions, and individuals need to be informed of the proposed plan?

be used to consider specific ecological, social, and economic effects.

High-Quality Data

Landscapes being considered for fuel treatments need accurate geographic information system (GIS) coverage of fuel properties. It is ideal to have as much real fuelbed data as possible with amount and resolution of the data appropriate for the specific application (Peterson and others 2007). If recent and accurate fuelbed data are not available, they can be derived for multiple fuel strata from the Fuel Characteristic Classification System (<http://www.fs.fed.us/pnw/fera/fccs>).

Some national forests have mapped stylized fuel models that provide a low-resolution classification of surface fire behavior adequate for current fire spread modeling. Sometimes, existing vegetation classifications and other management data (such as stand inventory) can be used to infer fuel properties.

The required accuracy and resolution of fuel data depend on the scale of application. For forest stands and individual projects, accurate high-resolution data are needed. If onsite data are unavailable, the Natural Fuels Photo Series (<http://www.fs.fed.us/pnw/fera/research/fuels/photo_series>) can be useful for rapid, yet accurate, assessment of fuelbed properties. For large watersheds and national forests, more generic fuel classifications may be sufficient. Classifications from remote-sensing imagery can also be useful.

The ID team should assess existing data and, if necessary, recommend collection of new data and development of fuel classifications. Cooperation between fuel specialists and scientists can be especially helpful in developing accurate maps. The ID team needs to state criteria for data quality on any given management unit. ID team members need to also agree on how much time and budget should be allocated to develop the fuel database. Derivation of the data should be carefully documented, regardless of the accuracy and resolution of final databases.

Accountability Process

Accountability is required for fuel treatment programs by the Healthy Forests Restoration Act of 2003 (HFRA). This is a logical component of science-based management. Measuring the outcomes of fuel treatment programs provides feedback to the adaptive management process, ensuring that long-term decisionmaking and planning can be continually improved.

Three types of fuel treatment monitoring guarantee accountability:

1. Implementation monitoring,
2. Effectiveness monitoring, and
3. Validation monitoring.

> Resource management personnel have the responsibility to ensure that this technical communication occurs and that credible scientific information is available.

Monitoring is implemented as follows:

1. *Implementation Monitoring: When, where, and how are treatments conducted?* All treatments are tracked in a database including date, location, area, type of treatments, and lead personnel. Accurate data on thinning prescriptions, burning prescriptions, and surface fuel treatments are especially valuable. It is critical that all treatments are georeferenced so that they can be included in GIS coverages compatible with adjacent management units.

2. *Effectiveness Monitoring: What change in condition of fuel and other resources was attained?* The condition of fuel and other relevant resources is quantified before and after treatments. Although HFRA requires only a representative sample, monitoring 100 percent of treatments is a more credible approach to documenting effectiveness. Pre- and post-treatment measurements of forest structure, surface fuel, and crown fuel are critical. Periodic post-treatment monitoring can measure temporal changes in forest structure, fuel, plant species composition, wildlife habitat, erosion, and hydrology. The interval for subsequent measurements will vary by resource.

3. *Validation Monitoring: Did the treatment meet objectives for desired conditions?* To attain desired conditions, long-term performance of fuel treatments must be documented to achieve full accountability. If a wildfire spreads through a treated area, then fire characteristics can be

documented. For example, if a crown fire drops to a surface fire (under severe weather conditions), the treatment could be considered successful. Or, if a crown fire is not impeded, the treatment could be considered unsuccessful. Objectives for vegetation, wildlife, and hydrology can also be assessed. Validation is best tracked through a GIS database in which wildfire locations and fire effects (such as severity classes in terms of tree mortality) are overlain on fuel treatment locations. The number of validations in the empirical database will increase over time, providing feedback to adaptive management.

Adaptive Learning Through Collaboration

The efficiency and value of collaboration will improve with experience. As methods are refined, the quantitative rigor and consistency of specific applications will improve over time. It is anticipated that this effort will grow from case studies and demonstrations to formal collaboration between management and research.

Empirical data are critical for improving fuel management at all spatial scales. These data and learning experiences should be communicated in a timely way through scientific publications, reports, meetings, and Web-based materials. Resource management personnel have the responsibility to ensure that this technical communication occurs and that credible scientific information is available.

Instituting science-based strategic planning for integrated fuel and vegetation treatment is a challenging but necessary requirement for both the implementation of the HFRA and sustainable resource management. Applying science-based approaches will contribute to high-quality plans and reduce the likelihood of appeals that challenge scientific credibility.

Applying science-based approaches will contribute to high-quality plans and reduce the likelihood of appeals that challenge scientific credibility.

If sufficient progress is made in developing successful fuel treatment programs—including science-based documentation of planning and on-the-ground applications—good models for fuel planning will emerge. To enhance adaptive fuel management, successful models of collaborative planning need to be broadly shared.

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Inviting Other Professions To Help Reduce Wildfire Property Losses

Anne Fege and Jim Absher

Preventing structure loss has become a major focal point of wildland firefighting. Most days, it feels like wildland fire professionals and land managers are becoming more and more responsible for reducing property losses in the wildland/urban interface (WUI).

What if this impression—and reality—could change?

What if architects, insurance underwriters, and other professionals considered this responsibility a part of their jobs, too? What if this fire risk prevention charge also became important to real estate agents, property managers, and others in the business sector—and they actually found creative, cost-effective solutions?

For instance, it just might be that we can frame some of the WUI changes as sound investments. Broadly stated, the hope is that we can work with nonwildland fire professionals and the business community to ensure that this also matters to them. Maybe they can—*and want to*—change their business practices to reduce wildfire losses.

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If so, what prevents us from working—better—together? As you'll see in this article, that's what we set out to discover.

In short, fire management professionals know how to greatly reduce property losses during wildfires. The rest of us know how to construct or remodel "fire-safe" houses. We can reduce fuel loads around houses. And we can avoid building houses and developments in fire-prone locations. Yet most of us are frustrated because too few homeowners and businesses are making these changes.

The hope is that we can work with nonwildland fire professionals and the business community to ensure that reducing wildfire losses matters to them, too.

Moving toward this "ideal" outcome for firefighters—mile after mile of FireSafe* WUI homes—requires that we give greater recognition to the fact that this is a socially constructed landscape, which necessarily involves many issues and tradeoffs. Thus, our operating assumption became that the folks who are the source of the "problem" are also the source of the solution.

* Formed in 1993, the California FireSafe Council's mission is to provide leadership and support that mobilizes all Californians to protect their homes, communities, and environment from wildfires. The council is comprised of 50 public and private organizations.

Three Workshops

To gain further insight into *"why we don't do what we know needs to be done,"* we rounded up 155 southern California professionals who represent land management agencies, as well as those people who advise homeowners and make decisions in their communities about risk reduction in chaparral WUI settings. Three workshops were held during June 2005.

These workshops were part of a larger prior effort—in response to the fatal southern California wildfires of 2003 that claimed 23 human lives—by the Forest Service Pacific Southwest Research Station's Riverside Fire Laboratory. The specific focus of this 2003 effort was to improve the knowledge of fire ecology, WUI dynamics, and decisionmaking in chaparral ecosystems. Initial findings from these 2003 workshops were presented in January 2006 (Padgett and others 2006).

We identified our 2005 workshop attendees by searching the Internet for professional, community, and environmental groups. We placed announcements in newsletters and business publications and used contact lists for wildfire professionals. Our research design called for participants who represent a broad cross-section of disciplines and affiliations. They did.

There's no question that we enlarged the traditional circle of voices that are usually heard. While a total of 53 percent of our attendees were wildland fire professionals and land managers, the rest were landscape architects and architects, environmental consultants, city and county staff, media, educators, FireSafe council leaders, and other professionals (see table 1).

Guided Discussions

At each workshop, guided discussions were held on three central issue areas:

1. House and Homesite,
2. Habitat and Watershed, and
3. Policy and Planning.

At the end of each discussion, participants completed individual feedback forms. They were asked to identify the main benefits to individuals, communities, and agencies when these issues are addressed, as well as to describe the resulting effects when they are *not* addressed.

We also asked what keeps these issues from being resolved and what each profession can do to help or influence homeowners, land managers, fire services, and community planners. The resulting 274 individual feedback forms and notes from our three issue/discussion topic areas were content-coded for the text analysis software from SPSS (Statistical Package for the Social Sciences).

Table 1—*List of professions that were represented at the 2005 workshops and were identified as future cooperators in reducing wildfire property losses. These workshops were part of a larger prior effort by the Forest Service Pacific Southwest Research Station's Riverside Fire Laboratory in response to the fatal southern California wildfires of 2003 that claimed 23 human lives—22 wildland/urban interface residents and 1 firefighter.*

Profession	Workshop Attendees	Professions That Workshop Attendees Want To Work With More*
Fire Managers	20%	28%
County, City, State, Federal Agencies**	33%	13%
Builders, Developers	1%	10%
Planners	0%	8%
Biologists	0%	8%
Insurance Industry, Agents	0%	6%
Homeowners' Associations, FireSafe Councils	5%	6%
Architects, Landscape Architects	3%	6%
Consultants	14%	0%
Educators	7%	3%
Environmental Organizations	6%	4%
Other	11%	20%

*List of professions that the workshop attendees stated they wanted to work with more.
**Includes biologists, planners, and land managers.

> Our operating assumption became that the folks who are the source of the "problem" are also the source of the solution.

Homesite Defensible Space Conflicts

Most vegetation and brush reduction codes start with "Zone 1" where flammability must be reduced in the first 30 (9 m) to 50 (15 m) feet from a structure. Most conflicts arise in "Zone 2," the area beyond the immediate homesite.

Is it enough to extend and maintain the "defensible space" 100 feet (30 m) beyond the house? Under what conditions are more than 100 feet (30 m) needed for "defensible space?" What basis do insurance companies have for demanding that policyholders reduce vegetation within 300 (91 m), 500 (152 m), or even 1,000 feet (305 m) of their house?

We quickly realized that we had a host of even more questions that needed answers.

Like, how should vegetation be pruned and cut to reduce fuel loads *without* losing a homesite's habitat and aesthetic values? How can we prevent homeowners from removing too much vegetation and roots? How can we prevent scraping or grading the soil that causes erosion, landslides, flooding, wildlife habitat loss—and converts vegetation to nonnative flashy-fuel annuals?

Analysis of the feedback and discussion notes also identified the desire for more open dialogue with regulatory agencies, as well as concerns that fire agencies are too "single-minded" (fig. 1). Comments generally focused on:

- The difficulty of balancing habitat and watershed protections with safety,
- How chaparral and watersheds are often forgotten when planning decisions are made, and
- How neither environmental planning documents nor habitat conservation plans address wildfire risks and impacts.

Most of us are frustrated because too few homeowners and businesses make these changes.

Regulation or Education?

Of course, both regulation and education are necessary. Neither, however, is sufficient by itself.

The workshop discussions highlighted the importance of uniform, simple codes and the resources to enforce these codes (fig. 2). Some communities are well on their way with such uniform codes. For example, the State of California, County of San Diego, and City of San Diego all require 100 feet (30 m) of vegetation reduction around structures. These jurisdictions are now undertaking the tasks of both enforcement *and* education. In doing so, they are searching for resources and optimum methods for reaching millions of home and property owners.

Analysis of the feedback identified the desire for more open dialogue with regulatory agencies, as well as concerns that fire agencies are too "single-minded."

Our southern California workshop participants identified the need for information about several aspects of property risk reduction:

- Product research concerning the fire resistance of various materials,
- Demonstrations of vegetation reduction activities,
- Science-based insurance requirements,
- Disclosures in real estate transactions,
- Impacts of vegetation management and development on watersheds and water quality, and
- The realities of "shelter-in-place" (staying in home when wildfire approaches) situations.

The job of wildfire risk reduction education is too large for any one profession to undertake. It's, therefore, time for wildfire professionals and land managers to enlarge the circle—and help make the case that wildfires affect *everyone* in the community.

When asked which professions they expect to work more with, the workshop professionals still considered fire managers to be their best cooperators. They also expressed the desire to have local agencies,

- *We need to take a fresh look at how we interface with the natural environment. Fuel management adjacent to housing doesn't work because it requires long-term maintenance.* **Water Conservation Manager, San Diego.**
- *High fire frequencies destroy indigenous landscapes. Current patterns of development do not account for their true costs.* **Architect, San Diego.**
- *Developers are not getting comprehensive information about watersheds, water quality, and fire-defensible space.* **Land Manager, San Diego.**
- *Continue to advocate for proactive building materials, reducing the need for long-term fuel modification.* **Biologist, San Diego.**
- *Agencies can't control maintenance issues over time. Their real (and almost only) power is at the time of initial development.* **Landscape Architect, San Diego.**
- *We need one message/one voice about building standards and vegetation management.* **Fire Manager, San Bernardino.**

Figure 1—*Workshop participant comments about homesite defensible space.*

builders, planners, and others more involved as cooperators in reducing wildfire property losses (table 1).

Analysis of the workshop feedback forms and discussion notes also surfaced a need for more practical—*what works?—and* theoretical knowledge needed—both scientific and human—especially regarding urbanization and community development.

Participants advocated moving away from strict regulation and narrow agency-specific viewpoints to shared decisionmaking and collaboration. In other words, one size doesn't fit all. As expressed by workshop participants, to accommodate a diversity of viewpoints and professions, coordination should be achieved without excessive centralization.

In addition, workshop attendees said that they wanted education, research, and outreach to achieve more integrated results. For example, they voiced support for promoting safety and environmental practices that complement each other. They also recognized the benefits of placing more emphasis on:

- Education;
- Communities as well as homeowners; and
- The development of government/industry partnerships, such as consulting services for FireSafe designs.

The job of wildfire risk reduction education is too large for any one profession to undertake. It's time for wildfire professionals and land managers to enlarge this education circle.

Public or Private Responsibility?

Public versus private responsibility debates run deep and seem to never end. Under the broad umbrella of this deliberation, our workshops illuminated many dilemmas and complexities:

- No one agrees on what is best,
- People are going to do what they want,
- Land use regulations can't take away property rights, and
- Don't regulate if you can't enforce.

Perhaps the complexity of this dilemma can best be analogized as a proverbial Gordian knot*: the pattern is so complex that it cannot be solved. But, in this case, it can. We must strive to ensure that this happens.

So, what do we use as our "sword" to cut the Gordian knot of wildfire risk?

Research suggests that our answers can be found in the values, beliefs, and attitudes of the homeowners, professionals, and managers. The social values relating to wildfire are indeed important—such as sense of place, sense of belonging, property, and public environmental resources (Absher and Vaske 2007; Kumagai and others 2004; Cheng and Becker 2005).

Public education campaigns can better reach homeowners if they acknowledge and address these social values. In addition, investments to reduce property risks will be made only if business values and interests are understood. At the same time, because they influence how business interests and investments are attracted (Cheng and Becker 2005), the institutional issues affecting public engagement must also be examined.

- *Homeowner Association did not understand 50 percent reduction in 50- to 100-foot (15- to 30-m) zone, didn't get clearer understanding after phone calls to fire department, and ended up cutting down everything to 5 inches (13 c) above ground.* Land Manager, San Diego.
- *Buyers and new property owners should be made aware of potential fire hazard and issues of living in fire-prone areas as part of disclosures.* Architect, Simi Valley.
- *"Letters of compliance" should be required for fuel modification; if not submitted, then fines should be imposed to cover the costs of sending someone to check and do the work.* Consultant, Simi Valley.
- *We need to balance codes, enforcement, property rights, building material lobbies, and politics.* Land Manager, San Bernardino.
- *Fuel loads are truly a regional issue, not restricted to areas "near" each home.* FireSafe Council Member, San Diego.

Figure 2—*Workshop participant comments concerning regulation and education.*

* The Gordian knot comes from the tale of King Gordius of Phrygia who presented Alexander the Great with a knot so complex it could not be untied. After hearing an oracle promise that whoever could undo it would be the next ruler of Asia, Alexander the Great swung his sword to cut the knot.

Our workshop participants also noted that organizational culture; interagency and intergovernmental relations; and laws, policies, and administrative rules must fit together as much as possible (fig. 3). They also suggested that to facilitate the insurance industry and homeowners collaborating together to reduce property losses, discounts or incentives might be established.

Engaging Other Professionals

So how can wildland professionals and land managers invite more professionals from more sectors to help share the load of reducing wildfire property losses? How can other professionals be invited to think about the tradeoffs between defensible space practices, regulation and education, and private and public responsibilities?

The social science literature supports the central ideas that were surfaced by our southern California workshop participants:

- Brooks and others (2006) examined the social issues in relation to wildland fire risk mitigation in Colorado's WUI communities. They suggest that opportunities might exist to work with such nontraditional partners as realtors, homebuilders, planners, insurance agents, and retail businesses.
- Absher and Vaske (2007) focused our attention on the cognitive processes involved, especially the attitudes and beliefs of homeowners—as they are the ultimate actors and decisionmakers.
- Toman and others (2006) emphasized the local community context in establishing ongoing relationships.

- *Set up community service districts for landscape maintenance.* Aide to Elected Official, San Bernardino.
- *California Environmental Quality Act documents should include regional fire zone maps, standardized FireSafe manuals, and response times.* Water Agency Official, San Diego.
- *Suburban development greatly externalizes costs onto government.* Planner, Simi Valley.
- *We have more common ground than expected. Everyone is facing similar challenges and needs to communicate better.* Urban Forester, San Bernardino.
- *We need to reach a consensus among land managers, environmentalists, and land planners to influence policymakers and elected officials.* Landscape Architect, San Diego.

Figure 3—*Workshop participant comments about private and public responsibilities.*

In southern California, to further this work, the San Diego Natural History Museum is engaging and educating the business sector about reducing wildfire property losses while sustaining natural habitats. This Joint Fire Sciences Project undertaking began in early 2006 with a marketing survey of local professional organizations, including architects, builders, landscape architects, property managers, landscape contractors, realtors, and insurance agents. Next, in the communities where defensible space action is most needed, cross-disciplinary trainings with business professionals will be developed and conducted. Curriculum was developed and cross-disciplinary training classes were offered in March 2007 to address the interests of these professionals—as well as many of the concerns and conflicts that surfaced in our 2005 workshops.

If the cast of defensible space actors is expanded, new business practices may emerge for design, construction, maintenance, and service to clients. For there's no question that architects, landscape architects, realtors, insurance agents, and property managers also want safer communities. They will seek creative solutions for code compliance that save them—or their clients—money.

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An Ozone Alert System That Guides Prescribed Fire Permits

James T. Paul, Daniel Chan, and Alan Dozier

While ozone is not a direct product of biomass burning, nitrogen oxides and volatile organic compounds emitted from the combustion of forest fuels (Southern Forest Fire Laboratory Staff 1976) can nonetheless interact under sunny skies, high temperature, and low wind speed to produce ozone (Dye and others 2003).

According to a presentation by representatives of the Georgia Institute of Technology at an air quality briefing in May 2003 in Macon, GA, managed and prescribed fire account for 0.25 percent of the nitrogen oxide budget in the middle section of the State of Georgia. (The entire briefing is available at <http://cure1.eas.gatech.edu/~faqs/faqs_macon_5-7-03.ppt>.)

However, because ozone is a health problem (Dye and others 2003) and some parts of Georgia do not meet Federal ozone guidelines, the Georgia Department of Natural Resources Environmental Protection Division Air Quality Branch (GAEPD) evaluates *all* sources as potential targets for regulation.

For instance, in 1996, GAEPD issued a summertime ban on all open burning in 19 metropolitan Atlanta, GA, counties (fig.1). In 2001, the ban was expanded to include a second tier of 26 additional counties in the greater Atlanta area (fig. 1). This ban remains in effect today.

> Ozone forecasts are produced by various governmental agencies to alert the public when potential health problems exist.

In 2005, Macon, GA, was declared a nonattainment area by the Federal Environmental Protection Agency (EPA). In other words, it was determined that the Macon area's ozone level had exceeded the National Air Quality Standard. In response, GAEPD held a series of public meetings in which it was proposed to expand the existing summer

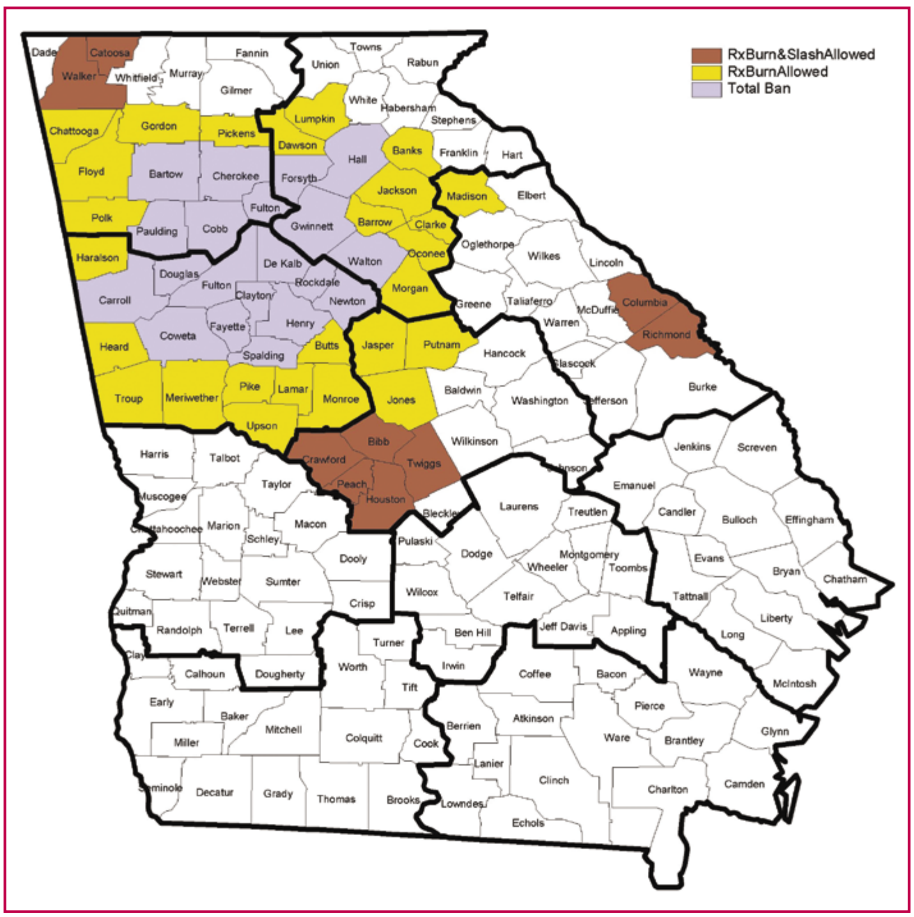

Figure 1—*Georgia summertime burn ban rules in 2005.*

Blue counties are the original Atlanta area counties where all burning is banned. Brown counties are where understory prescribed burning is now allowed. Yellow counties are those where the Georgia Department of Natural Resources Environmental Protection Division Air Quality Branch now allows episodic burning based on the ozone forecast.

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burn ban to cover even more Atlanta-area counties—as well as counties surrounding Macon and Augusta, GA, and nearby Chattanooga, TN (fig. 1).

The forestry community expressed deep concern regarding this proposed burning ban.

Deep Concern

The forestry community expressed deep concern regarding this proposed burning ban. Its members cited a number of adverse impacts that such action could have on the practice of forestry—especially the potentially negative effects imposed on wildlife management. They warned that such a ban on burning could have destructive consequences on endangered species management, including on species like the red cockaded woodpecker.

In this part of the country, less prescribed burning occurs in the summer than other times of the year (fig. 2). However, the small amount of acreage that *is* burned during the summer months is important to forest management, especially to wildlife.

Such a ban on burning could have destructive consequences on endangered species management, including on species like the red cockaded woodpecker.

Ban Is Reevaluated

Following the 2005 series of public meetings, the GAEPD reevaluated the proposed summer burn ban. It then worked with the Georgia Forestry Commission to establish a system that would allow open burning in those 26 second-tier counties around Atlanta, as well as the counties surrounding Macon, Augusta, and Chattanooga—except on days when ozone concentrations would likely exceed the EPA 8-hour standard of 0.084 ppm (parts per million—one of the measures dictated and regulated by the Clean Air Act).

Ozone forecasts are produced by various governmental agencies to alert the public when potential health problems exist. These forecasts, where available, were used by the Georgia Forestry Commission to identify high ozone potential days surrounding Atlanta, Augusta, and Macon, GA; and Chattanooga, TN (fig. 1).

Ozone forecasts for Atlanta, Augusta, and Chattanooga were downloaded from <ftp.airnowdata.org>. These forecasts were also available from the EPA's AirNOW Web site (<http://www.airnow.gov/>).

Regression Equation

Because official ozone forecasts were not available for the Macon area in 2005 from GAEPD, the Georgia Forestry Commission developed a regression equation to forecast ozone concentrations that followed EPA guidelines (Dye and others, 2003). As an EPA-recommended method, regression has a history of success. Of course, as with all methods, there are times when this process will also return erroneous values.

For this application, the equation development objective was to identify those days when there was a high probability of ozone exceeding the EPA's 0.084 standard. The regression coefficient (R^2) of the equation is 0.59, with a standard error of 0.0108. (Specific details of the equation are outlined in table 1.) To capture all the potential high ozone days in Macon, when the forecast ozone value was above 0.065 ppm, we considered that a *high* ozone day.

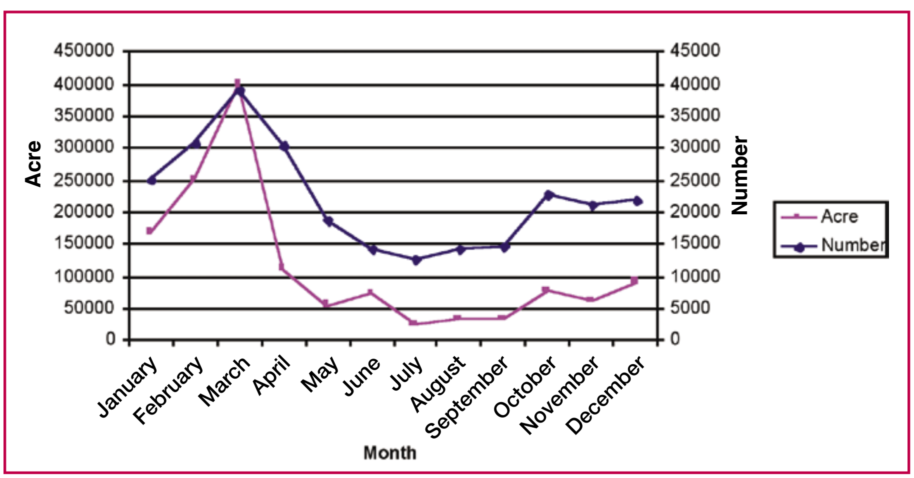


Figure 2—*Average prescribed burns and burn acres in Georgia, from fiscal years 1987 through 2005.*

A sample district forecast with a warning was issued on July 25, 2005 (fig. 3). This forecast is produced automatically and does not require manual intervention. Because prescribed burning and slash burning are not allowed from May through September under any circumstances in the 19 metro-Atlanta counties, the warning statement does not appear in the forecast for these counties.

Summary Results

Ozone season, from May through September, has a total of 153 days, all of which even if a completed burn ban was in place would have

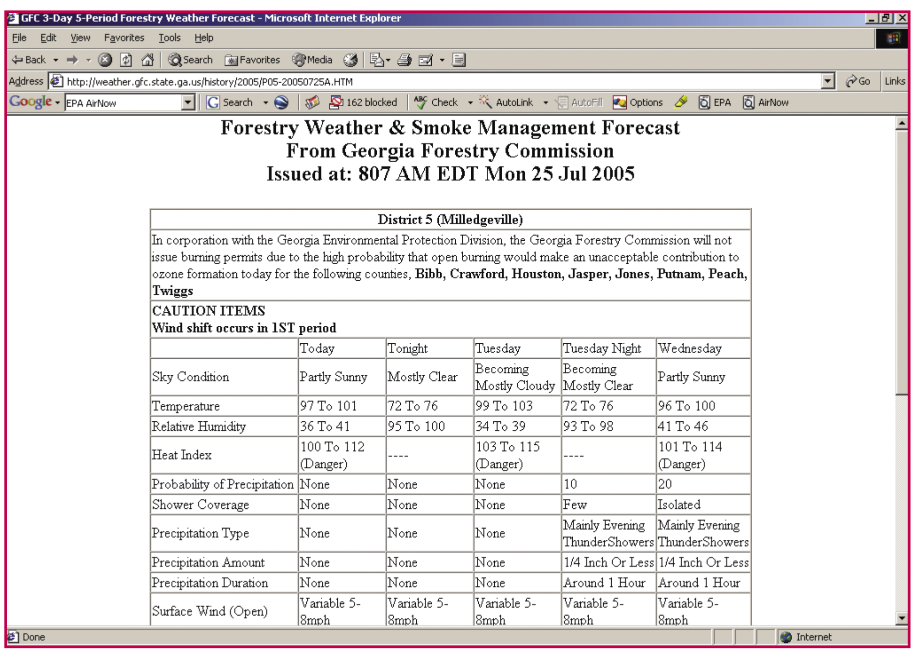
> Because ozone forecasts were not available for the Macon area, the Georgia Forestry Commission developed a regression equation to forecast ozone concentrations that followed Environmental Protection Agency guidelines.

been *unavailable* for prescribed fire. However, with the reevaluated summer burn ban rules, prescribed burning was restricted on only a fraction of these 153 days.

1. **Macon.** Using 0.065 ppm as the threshold for a high ozone day, there were 38 days when the Georgia Forestry Commission did not issue prescribed burning permits in the middle part of the State of Georgia. Although high ozone levels did not occur on 37 of the 38 days (false alarm),

Table 1—*Regression parameters and their value used to predict daily maximum 8-hour ozone at Macon, GA.*

Variable	Regression Coefficient	Correlation
Intercept	+0.0005510425	
Month	-0.0006646487	-0.48
Temperature – lower-bound (F) from Georgia Forestry Commission (GFC) district forecast.	+0.0003423772	+0.38
Chance of precipitation in percent from GFC district forecast.	-0.0001311436	-0.44
Wind direction (azimuth) from GFC district forecast.	+0.0000099574	-0.13
Wind speed – upper-bound (mph) from GFC district forecast.	+0.0002361759	-0.02
Mixing height (meters) from GFC district forecast.	+0.0000027441	+0.44
Newnan Ozone, yesterday hourly maximum (ppm) from Georgia Department of Natural Resources Environmental Protection Division Air Quality Branch (GAEPD).	+0.1986779660	+0.67
Macon Ozone, yesterday hourly maximum (ppm) From GAEPD.	+0.3166396811	+0.65



Forestry Weather & Smoke Management Forecast
From Georgia Forestry Commission
Issued at: 807 AM EDT Mon 25 Jul 2005

District 5 (Milledgeville)

In corporation with the Georgia Environmental Protection Division, the Georgia Forestry Commission will not issue burning permits due to the high probability that open burning would make an unacceptable contribution to ozone formation today for the following counties, **Bibb, Crawford, Houston, Jasper, Jones, Putnam, Peach, Twiggs**

CAUTION ITEMS
Wind shift occurs in 1ST period

	Today	Tonight	Tuesday	Tuesday Night	Wednesday
Sky Condition	Partly Sunny	Mostly Clear	Becoming Mostly Cloudy	Becoming Mostly Clear	Partly Sunny
Temperature	97 To 101	72 To 76	99 To 103	72 To 76	96 To 100
Relative Humidity	36 To 41	95 To 100	34 To 39	93 To 98	41 To 46
Heat Index	100 To 112 (Danger)	----	103 To 115 (Danger)	----	101 To 114 (Danger)
Probability of Precipitation	None	None	None	10	20
Shower Coverage	None	None	None	Few	Isolated
Precipitation Type	None	None	None	Mainly Evening ThunderShowers	Mainly Evening ThunderShowers
Precipitation Amount	None	None	None	1/4 Inch Or Less	1/4 Inch Or Less
Precipitation Duration	None	None	None	Around 1 Hour	Around 1 Hour
Surface Wind (Open)	Variable 5-8mph	Variable 5-8mph	Variable 5-8mph	Variable 5-8mph	Variable 5-8mph

Figure 3—*An example of Georgia Forestry Commission morning district weather forecast that carried the prescribed burn ban message.*

Table 2—*Ozone exceedance days in 2005 in Atlanta, Augusta, and Macon GA; and Chattanooga, TN.*

Location	Forecasted exceedance days	Forecasted exceedance days, yet did not occur	Exceedance days that occurred, but were not forecast	Actual exceedance days
Atlanta, GA	26	17	8	17
Augusta, GA	0	0	1	1
Chattanooga, TN	4	4	2	2
Macon, GA	38	37	1	2

the commission's method did capture 1 of the 2 high ozone days (table 2). Because the commission's ozone forecast method was designed to over forecast exceedance days in order to minimize the possibility of issuing permits on high ozone days, we considered the results acceptable. (If the 0.085 ppm standard had been used, the number of forecast high-ozone days would have been reduced to only 1 day.)

2. **Atlanta.** There were 26 days forecast to be high ozone days, with 17 days when this was forecast but did not occur. There were 8 days where an ozone exceedance occurred but was not forecast (table 2). Under the reevaluated summer ban rules, prescribed burnings were allowed on 127 days during the ozone season in the 26 second-tier counties around Atlanta. If a total burn ban had been applied, there would have been no burning days during ozone season in these 26 counties.

3. **Augusta.** There were no days forecast to be in exceedance. All 153 days were therefore available for burning (table 2).

4. **Chattanooga.** Four days were forecast to be high ozone days, with two actually occurring (table 2). Therefore, 149 days were available for burning.

Today, during the burn ban period of May 1 through Sept. 30, prescribed burning is only allowed in the Atlanta area's 26 second-tier counties when the ozone potential is low. In addition, during low ozone potential days, both prescribed burning and slash burning are allowed in the newly added counties around Macon, Augusta, and Chattanooga.

As advances are made in ozone forecasting, the number of false alarms will likely decrease, further reducing lost burning days in the summer. By working together, the forestry community and the GAEPD have developed a method that protects air quality and preserves limited prescribed fire during the summer months.

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How Much Fuel Is in That Pile or Windrow?

Continued from page 12

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Franklin Awards Salute Achievements in Cooperative Fire Protection

Melissa Frey

Every year the Forest Service's Fire and Aviation Management staff presents the prestigious Franklin Award to the agency's State fire protection partners who have illustrated exceptional achievement in reaching underserved communities.

"Ensuring that *all* citizens benefit is a critical part of our Cooperative Fire Protection programs," explains Tom Harbour, Forest Service Director of Fire and Aviation Management. "Increased interaction with underserved communities by our State forestry fire service cooperators is vital."

Four Award Categories

The Franklin Award, initiated in 1999, is named for Benjamin Franklin, the founder of America's volunteer firefighting forces. Each year, four categories are considered for this award:

- **Volunteer Fire Assistance**
  Volunteer fire assistance is designed to help smaller communities improve—or begin—fire protection. The Volunteer Fire Assistance Award is for the State that demonstrates the best outreach to help underserved communities improve their fire protection.

Melissa Frey is the Federal Excess Personal Property Program Manager and the General Manager of Fire Management Today *for the Forest Service, Fire and Aviation Management, Washington, DC.*

- **State Fire Assistance**
  State fire assistance provides financial assistance, technical training, and equipment to ensure that Federal, State, and local fire agencies can deliver a coordinated response to wildfire. The State Fire Assistance Award is given to the State that has demonstrated the greatest and best utilization of this assistance.

> We gratefully acknowledge the outstanding efforts to ensure fire protection for all Americans by our State partners.

- **Management of Federal Excess Personal Property**
  Federal excess personal property is made available to help State and local fire services obtain equipment that might otherwise be unaffordable. The Federal Excess Personal Property Award acknowledges the State that demonstrates the best outreach to help underserved communities equip themselves to improve fire protection.

- **Overall Excellence in Reaching Underserved Communities**
  The Director's Award represents overall excellence in reaching underserved communities. It is presented to entries with the best overall effort in at least two of the four Franklin Award categories.

Franklin Awards are not necessarily given for each category every year. For instance, in 2006, the award was presented in only three of the four categories.

All of the 2006 awards were presented at the September 2006 National Association of State Foresters' annual awards luncheon in Anchorage, AK. James Hubbard, Deputy Chief for State and Private Forests of the Forest Service, presented the Federal Excess Personal Property (FEPP) Award, the Volunteer Fire Assistance Award, and the State Fire Assistance Award.

2006 FEPP Award

Mike Long, State forester, Florida Division of Forestry (FLDOF), accepted the FEPP Award for his agency's efforts. Under the guidance of FEPP manager William Gifford, more than 2.5 million dollars' worth of FEPP equipment has been placed in Florida's small rural communities—areas with populations of less than 10,000 and with little or no tax base.

In addition to providing FEPP equipment, FLDOF mechanics assist in trouble shooting, repairing, painting, and transporting this equipment to the rural and volunteer fire departments. To keep crucial fire department equipment in service, when FEPP equipment can no longer be utilized, FLDOF cannibalizes unserviceable trucks for usable parts.

The Florida Division of Forestry has been working closely with rural communities around the State to provide needed equipment to these small, underserved communities. In 2005, FLDOF acquired 64 skid units and provided them to fire departments to be mounted on FEPP trucks for wildland fire suppression efforts. To keep up with the demand for its FEPP services, the division hopes to continue to expand this equipment lease program.

2006 State Fire Assistance Award

The Florida Division of Forestry also received the State Fire Assistance Award in recognition of its "wildfire prevention campaign." This campaign was established in the aftermath of two catastrophic hurricane seasons to educate the public in the prevention of wildfires. This prevention effort served the entire State of Florida as a mass-market campaign. Its main focus was on the more rural, underserved communities—as well as areas severely impacted during the last two hurricanes.

With the State Fire Assistance grant:

- FLDOF placed vinyl billboards on its major interstates and roadways in 16 locations.
- The division also reached out to all ages by advertising the prevention message in over 410 theaters throughout the State.
- National "Cinemedia" was able to provide free lobby advertising on plasma television screens in 67 theaters.
- Agriculture Commissioner Charles H. Bronson recorded 60-second and 30-second public service announcements on hurricane debris and Firewise tips throughout Florida on various radio stations.
- The FLDOF developed a "fire danger weather kit" to educate the public on the affects of weather on fire behavior.
- FLDOF teamed up with television weather anchor employees throughout Florida to discuss weather and fire during nightly weather forecasts. As an added bonus, viewers could go onto the Internet and register to win a fire danger weather kit containing a rain gauge, thermometer, brochures and various other weather-related items.

> Increased interaction with underserved communities by our State forestry fire service cooperators is vital.

2006 Volunteer Fire Assistance Award

The Texas Forest Service (TFS) conducted a statewide survey in 2001 that determined 1,464 of the State's 1,802 fire departments were volunteer operations. The survey also determined that Texas had 59,140 firefighters—of which 40,740 are volunteers. The survey also revealed that more than 37,000 firefighters in the State (63 percent) did *not* have the proper personal protective equipment (PPE).

Due to the critical safety issue identified in this survey and the need to help underserved communities, TFS offered a cost share of 90 percent (45 percent Federal and 45 percent State) with a 10-percent local cost for the purchase of wildland PPE.

In April 2005, Texas endured an extremely active wildland fire season. With the dire predictions for a dry winter, TFS began an emergency funding initiative for wildland PPE. Using a simple two-page application, volunteer fire departments across the State could apply for this PPE. Once eligibility was established, the departments were funded and allowed to purchase the PPE immediately. The PPE award notification turnaround time was less than 1 week.

Under this emergency funding initiative, 2,041 volunteer fire departments received grants and purchased 2,257 complete sets of wildland PPE, along with numerous miscellaneous items.

For their outstanding use of volunteer fire assistance funding under the direction of Mark Stanford, TFS fire operations chief—with support from James Hull, Texas State forester—the TFS has shown exemplary efforts in getting PPE and supplies out to underserved communities throughout the State. ■

Software Can Assess Fuel Treatment Effectiveness on Crown Fire Behavior

CFIS—Crown Fire Initiation and Spread—is a new (nonprofit) software system that incorporates several recently developed models designed to simulate crown fire behavior (Alexander and others 2006).

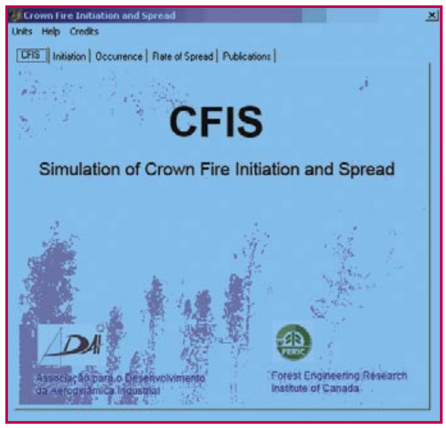
> This new software application can serve as a decision support aid in a wide variety of fire management activities—ranging from near real-time prediction of fire behavior to analyzing the impacts of fuel treatments on potential crown fire behavior.

The main outputs of CFIS are its ability to determine the:

- Likelihood of crown fire initiation or occurrence,
- Type of crown fire (active vs. passive) and its rate-of-spread, and
- Minimum spotting distance required to increase a fire's overall forward rate-of-spread.

The onset of fire crowning can be predicted through two distinct approaches via this software tool. One method relies on the knowledge of canopy base height and certain components of the Canadian Forest Fire Weather Index System or the 10-m (33-feet) open wind speed. The other requires the 10-m (33-feet) open wind, the estimated fine fuel moisture, fuel strata gap (or canopy base height), and an estimate of surface fuel consumption as inputs.

Required inputs to predict crown fire rate-of-spread are 10-m (33-feet) open wind speed, estimated fine fuel moisture, and canopy bulk density. The minimum spotting distance to affect overall crown fire rate-of-spread—which assumes a point ignition and subsequent fire acceleration to an equilibrium rate-of-spread—requires the predicted crown fire spread rate and an ignition delay as inputs.



CFIS is available for downloading—at no charge—at <http://www2.dem.uc.pt/antonio.gameiro/ficheiros/CFIS.exe>.

The primary models incorporated into CFIS have been evaluated against experimental and wildfire observations (Alexander and Cruz 2006; Cruz and others 2005), as well as other available fire behavior decision support systems with good results (Alexander 2006).

In addition, CFIS has applicability as a decision support aid in a wide variety of fire management activities—ranging from near real-time prediction of fire behavior to analyzing the impacts of fuel treatments on potential crown fire behavior.

The development of CFIS was a joint venture between the Forest Fire Research Centre of the Association for the Development of Industrial Aerodynamics in Coimbra, Portugal (a private, nonprofit research organization linked to the Department of Mechanical Engineering at the University of Coimbra), and the Wildland Fire Operations Research Group of the Forest Engineering Research Institute of Canada.

CFIS is available for downloading—at no charge—at <http://www2.dem.uc.pt/antonio.gameiro/ficheiros/CFIS.exe>.

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The Future of Fire Control – 70 Years Ago

John R. Curry

(Editor's Note: How times change—or, do they? In 1937—70 years ago—John R. Curry, senior silviculturist with the Forest Service California Forest and Range Experiment Station, penned this [excerpted] forward-thinking article "The Future of Fire Control" for Fire Control Notes *Volume 1(5) August 1937.* Fire Control Notes *is the forerunner of* Fire Management Today. *The text from this 1937 piece has been reprinted largely verbatim and therefore reflects the style and usage of the time.)*

The emergency aspects of fire control loom large. The ever-present possibilities of disaster tend to confine fire control thinking to matters of the moment, the day, the season. Seldom, therefore, do foresters stand off to consider this problem in broader aspects, or to consider the gains which fire control is making relative to long-time needs.

It would be well for the men interested in this field to scrutinize our present attitude toward this work and our organization for it, to determine whether this problem is being approached logically. Does our organization, such as is, enable us to obtain the maximum improvement within this field? Does fire control offer to professional foresters the opportunities found in other fields of forest administration? Should forest fire control be regarded as a major field of the profession of forestry in America? If so, is it gaining this recognition?

Should forest fire control be regarded as a major field of the profession of forestry in America?

In the opinion of the writer, fire control development is handicapped by the old idea that the fire problem is one of temporary importance; that eventually, as a result of certain emergency measures to be taken during the present or the near future, this activity will rapidly diminish in importance. There seems to be a hope that fire in America will eventually reach the minor status which it has always held in the managed forests of Europe. This line of reasoning I hold to be wholly fallacious. Not only do present trends in fire business indicate this fallacy, but our increasing knowledge of fire behavior also points out the error.

It is a matter of record that the fire problem is increasing steadily in importance with increasing use and higher values. The time may arrive when fire losses will be reduced to a point where they do not offer a serious obstruction to forestry practice. But the period when fire problems will not challenge—to the utmost—the ability and ingenuity of American foresters will arrive only if American climate, American forests, and American people change essentially from what they are today.

Men who have been engaged in fire control work for the past 15 or 20 years, I believe, are ready to agree on the long-time, continuing importance of fire problems. If so, these men as a group should make their feelings known, that this activity may receive equal consideration with other professional problems.

The failure of foresters to recognize the long-time characteristics of the fire control job is responsible for the present lack of specialized organization and development in this field. Foresters have not approached the problem in a professional manner because they have hoped from the beginning that the fire problem could be solved by a

The period when fire problems will not challenge—to the utmost—the ability and ingenuity of American foresters will arrive only if American climate, American forests, and American people change essentially from what they are today.

few years of intensive educational effort. Despite such efforts, a fire problem still exists.

. . . The attempt to organize the branches of fire control in certain western regions was, I believe, a move in the right direction—and one which should be revived. At present, fire control is ordinarily administered by an assistant to an assistant regional forester. It is placed, along with miscellaneous or general jobs, in the "operation" division. Fire control consequently does not receive the attention which it should in the formulation of administrative policies and plans.

> *"There seems to be a hope that fire in America will eventually reach the minor status which it has always held in the managed forests of Europe. This line of reasoning I hold to be wholly fallacious."*
>
> –John R. Curry, senior silviculturist with the USDA Forest Service California Forest and Range Experiment Station; from his 1937 article—excerpted here—in *Fire Control Notes.*

. . . Considering the amount of money spent in the field, the lack of administrative overhead is obviously inefficient management.

> Forestry's present store of information and accepted skills and techniques in fire control is meager.

A Division of Fire Control has been created in the Washington Office. This is a big step toward recognition of this field. As yet, however, this division comprises only 3 men, a force which is obviously inadequate to promote this activity on a national basis.

. . . If able men are assigned to fire control jobs, the art will develop rapidly. It cannot develop until men of this type are given the opportunity to work on these problems to the exclusion of other pressing jobs.

. . . If men in the profession recognize fire control work as a permanent pressing problem and as a real part of professional forestry work, it can and should be organized on an adequate basis. The sooner fire control is thought of in this light, the sooner will knowledge and success in the field increase . . . ■

Web Sites on Fire*

Southern Center for Wildland/Urban Interface Research and Information Center

The Southern Center for Wildland/Urban Interface Research and Information Center opened in Gainesville, FL, in January 2002. The center's mission is to develop and communicate guidelines, models, and tools needed by natural resource managers, policymakers, planners, and citizens to reduce risks to ecosystems and human communities in urban and urbanizing landscapes.

The center's Web site provides access to information that includes a monthly bulletin and a Wildfire Risk Assessment Guide. This popular Web site also facilitates the exchange of ideas and opportunities and links people and projects involved with wildland/urban interface issues.

Found at <**www.interfacesouth.usda.gov**>.

* Occasionally, *Fire Management Today* briefly describes Web sites brought to our attention by the wildland fire community. Readers should not construe the description of these sites as in any way exhaustive or as an official endorsement by the Forest Service. To have a Web site described, contact Cindy White, at 360-436-1155 ext. 231, cwhite@fs.fed.us (e-mail).

Our Chance To Repay the Debt

(Editor's Note: The following letter was sent by the National Multiagency Coordinating Group in Boise, ID, to the 150 individual U.S. wildland firefighters before they journeyed off to Australia this January—under a "mutual assistance" pact between the two countries—to help fire suppression efforts during drought-stricken Australia's severe fire season. By mid-January (Australia's summer), more than 4,247 square miles [1.1 million ha] had burned in the country's southeast—with more sustained searing temperatures and gusting winds predicted.)

To: American firefighters deployed to Victoria, Australia

From: National Multiagency Coordinating Group

Subject: Standards of Conduct for International Deployment

You have been chosen by your agency to represent the United States of America, your agency, and American wildland firefighters in support of the State of Victoria's Department of Sustainability and Environment. This is a great honor for you and a great responsibility.

Australia and the State of Victoria are experiencing a difficult and demanding fire season and they have asked for our help in reinforcing and supporting their own fire forces. When we have asked Australia for help in the past, they have responded quickly and professionally. This is our chance to repay the debt.

By now, you have all read and signed the NMAC Standards of Conduct for International Deployment, so you know our expectations for your performance and conduct while in Australia. You must remember that for every minute of the next 30 days, whether on the fireline, in camp, or in town, you are representing your agency, your profession, and your country.

We expect you to be professional, diplomatic, and courteous. We expect you to set a high standard and an outstanding example of who you are and who you represent. And we expect you—when given the chance—to work [wholeheartedly] to support the Victorian firefighting effort.

Please remember that, in this environment, your Australian counterparts are the experts and *you* are the rookies. Focus on listening and learning—instead of telling people how much you know and how good you are. Remember how much you *don't* know about the fuels, weather, terrain, and tactics of Australian firefighting and take this opportunity to learn from the experts.

Remember how much you *don't* know about the fuels, weather, terrain, and tactics of Australian firefighting and take this opportunity to learn from the experts.

Look for opportunities to solve problems and to make things better for the weary Australian firefighters. Look for opportunities to leave a positive impression of who we are and how we get our jobs done. Above all, be safe and enjoy the great adventure of this opportunity.

Thank you for taking on this assignment and this responsibility. Please remember how many thousands of your fellow American firefighters you are representing and make us proud. Take care of yourselves and each other, and return home safely. ■

Remember how many thousands of your fellow American firefighters you are representing and make us proud.

Guidelines for Contributors

Editorial Policy

Fire Management Today (*FMT*) is an international quarterly magazine for the wildland fire community. *FMT* welcomes unsolicited manuscripts from readers on any subject related to fire management. Because space is a consideration, long manuscripts might be abridged by the editor, subject to approval by the author; *FMT* does print short pieces of interest to readers.

Submission Guidelines

Your manuscript may be hand-written, typed, or word-processed, and you may submit it either by e-mail or by mail to one of the following addresses:

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Do not embed illustrations (such as photos, maps, charts, and graphs) in the electronic file for the manuscript. We will accept digital images if the image was shot at the highest resolution using a camera with at least 2.5 megapixels or if the image was scanned at 300 lines per inch or equivalent with a minimum output size of 5 × 7 inches. Submit each illustration in a standard interchange format such as EPS, TIFF, or JPEG, accompanied by a high-resolution (preferably laser) printout. For charts and graphs, include the raw data needed to reconstruct them.

Style. Authors are responsible for using wildland fire terminology that conforms to the latest standards set by the National Wildfire Coordinating Group under the National Interagency Incident Management System. *FMT* uses the spelling, capitalization, hyphenation, and other styles recommended in the *United States Government Printing Office Style Manual*, as required by the U.S. Department of Agriculture. Authors should use the U.S. system of weight and measure, with equivalent values in the metric system.

Try to keep titles concise and descriptive; subheadings and bulleted material are useful and help readability. As a general rule of clear writing, use the active voice (e.g., write, "Fire managers know…" and not, "It is known…"). Provide spellouts for all abbreviations. Consult recent issues (at <http://www.fs.fed.us/fire/fmt/index.html>) for placement of the author's name, title, agency affiliation, and location, as well as for style of paragraph headings and references.

Tables. Tables should be logical and understandable without reading the text. Include tables at the end of the manuscript.

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