Prescribed Fire Case Studies, Decision Aids, and Planning Guides

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Fire Management Today and its predecessors collectively have a 70-year record of publishing on all aspects of wildland fire management. While early on the emphasis was placed on subjects related to fire protection and fire suppression, it wasn't too long before articles dealing with prescribed fire began to appear. Bunton (2000) has identified and subject-indexed all the prescribed-fire-related articles published in *Fire Control Notes, Fire Management,* and *Fire Management Notes* between 1970 and 1999. The articles published on the subject of prescribed fire from 1936 to 1969 were not so handily cataloged, although summary indexes were published by *Fire Control Notes* in 1942, 1955, 1963, and 1969.

Starting with *Fire Management Notes* volume 57, number 1 (Winter 1997), all issues have been posted for downloading from the Internet at the journal's website (http://www.fs.fed.us/fire/fmt/). This action has greatly increased the exposure of the journal within the global wildland fire management community. The collection of downloadable issues now extends back to 1991. In time, the entire collection of all issues will be available for downloading from the *Fire Management Today* Website. This will be a very valuable resource to the wildland fire community.

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> The use of fire by humans has a long and storied history, as has been chronicled globally by noted fire historian Stephen Pyne.

Meanwhile, seeing the need for a compendium of relevant articles on prescribed fire, the authors prepared this special issue of *Fire Management Today*, selecting 28 previously published articles from past issues of *Fire Control Notes, Fire Management,* and *Fire Management Notes*. We chose case studies as well as pertinent decision aids and planning guidelines; and, because space limited our selection of articles, we sprinkled titles of others throughout the issue (beginning in the sidebar on page 6).

Prescribed Fire Defined

The term "prescribed fire" has also been referred to as "control burn" or "prescription fire." Although many different definitions of prescribed fire exist globally (e.g., BCRC 2004; CIFFC 2003; NWCG Incident Operations Standards Working Team 2005), they all have a central theme. Merrill and Alexander (1987), for example, defined prescribed fire as "any fire deliberately utilized for prescribed burning; usually set by qualified fire management personnel according to a predetermined burning prescription." They in turn defined prescribed burning, following Muraro (1975), as "the knowledgeable application of fire to a specific land area to accomplish predetermined forest management and other land use objectives."

Although subtle variations do exist in how the terms "prescribed fire" and "prescribed burning" are defined by different individuals and organizations, the most important points to remember are that, according to Wade and Lunsford (1989), prescribed fire is the application of prescribed burning:

- In a skilled manner,
- Under exacting weather conditions,
- In a definite place, and
- To achieve specific results.

The definitions above refer to traditional, planned-ignition prescribed fires versus chance- or random-ignition prescribed fires (Alexander

Additional References on Prescribed Fire

The following articles related to prescribed fire, published in *Fire Control Notes* and its successors, could not be reprinted in this issue of *Fire Management Today* due to space constraints. Similar lists are sprinkled throughout this issue (see pages 34, 37, 40, 46, 53, 59, 61, 68, 78, 82, 89, and 100).

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and Dube 1983). In some cases, naturally ignited wildland fires can produce beneficial results in terms of attaining land management objectives, and they are sometimes allowed to burn with limited intervention, provided they meet predefined criteria (Parsons and others 2003). In the United States, such events or incidents are called "wildland fire use" (NWCG Incident Operations Standards Working Team 2005).*

Prescribed Fire Uses

The use of fire by humans has a long and storied history, as has been chronicled globally by noted fire historian Stephen Pyne (1982, 1991, 1995, 1997, 2001, 2004). However, the fact that fire is both a management tool and a process was generally unappreciated until about 30 years ago; and, to a certain extent, full recognition of this point is still lacking today. Wright and Heinselman (1973), for example, outlined the principles of fire as an ecosystem process in fire-dependent northern conifer forests:

- Fire influences the physical–chemical environment (e.g., by volatilizing some nutrients, directly releasing mineral elements as ash, and reducing plant cover and thereby increasing insolation and, in turn, soil temperatures);

* In keeping with the definition adopted by the National Wildfire Coordinating Group in the United States—and therefore with usage required in *Fire Management Today*—this article refers to planned-ignition prescribed fires simply as "prescribed fires."

> A prescribed fire can, if properly executed, accomplish many beneficial purposes.

- Fire regulates dry-matter accumulation (i.e., in terms of fuel consumption and production);
- Fire controls plant species and communities (at the individual and stand level as well as at the landscape scale);
- Fire determines wildlife habitat patterns and populations (indirectly through vegetation as opposed to fire-induced mortality);
- Fire influences forest insects, parasites, fungi, etc. (directly by sanitization and indirectly by regulating vegetation); and
- Fire controls major ecosystem processes and characteristics (e.g., nutrient cycles and energy flow, succession, diversity, productivity, and stability).

Several authors have applied this broad framework with specific examples to various ecosystems (e.g., Alexander and Euler 1981; Wade and others 1980).

Wade and Lunsford (1989) considered the following as the most common reasons for using prescribed fire in forest resource management in the Southern United States:

- Reducing hazardous fuels;
- Preparing sites for seeding and planting;
- Disposing of logging debris;
- Improving wildlife habitat;
- Managing competing vegetation;
- Controlling insects and disease;
- Improving forage for grazing;
- Enhancing appearance;
- Improving access;
- Perpetuating fire-dependent species (ecosystem restoration);
- Cycling nutrients; and
- Managing endangered species.

These objectives are similar to those in other regions of North America (e.g., Beaufait 1966; Green 1981; Martin and Dell 1978; Sando and Dobbs 1970) and globally. To this list we could add, for example, increasing water yields (Green 1977; Pase and Granfelt 1977).

Experimental outdoor or prescribed fires have also been undertaken exclusively for the purpose of generating fire behavior data in relation to prevailing environmental conditions in order to develop new predictive models or guides (e.g., Bruner and Klebenow 1979; Davis and Dieterich 1976) and/or validate existing ones (Alexander and Quintilio 1990). Such fires might also be set to examine fire suppression effectiveness (e.g., Crosby and others 1963; Johansen 1965; Murphy and others 1991).

Prescribed burning can also serve as a valuable aid for training firefighting personnel. Many new firefighters are unfamiliar with fire control methods and need training in fire suppression. Prescribed fires can provide an excellent opportunity to learn about fire behavior, equipment operation, and suppression crew organization. Mopup on prescribed fires is essentially the same as on wildfires, so new personnel can be made familiar with problems before their first wildfire by using them on prescribed-burning operations. Such training should probably be viewed as a secondary objective of all prescribed fires, but it might become the primary objective (Alexander 1999; Cheney 1994).

A prescribed fire can, if properly executed, accomplish many beneficial purposes (see the sidebar below). On the other hand, it can actually be damaging, depending on the fire's intensity and timing in terms of the season or time of year (Robbins and Myers 1992). The key is to develop the right burning or fire prescription during the planning process (Miller 2004).

Prescribed Fire Planning Process

Figure 1 (from Kayll 1980) shows a basic framework for employing prescribed fires in forest vegetation management. The most important element in the flow process is the explicit provision of "feedback loops" (i.e., mechanisms or proce-

Fire's Dichotomous Role in Land Management*

Prescribed fire can:

- Reduce flammable fuels
- Remove organic matter
- Expose mineral soil
- Kill viable seeds in duff
- Kill understory species
- Reduce insect numbers
- Kill pathogens
- Increase soil nutrient availability
- Open serotinous cones
- Thin overstocked stands

Or it can:

- Eventually increase fire hazards
- Contribute more organic matter
- Permit soil to erode
- Stimulate germination
- Cause their roots to sprout
- Enhance the insect environment
- Provide entry for soil fungi
- Reduce soil water-holding capacity
- Destroy other seed sources
- Promote overstocking

* From Beaufait (1962).

dures whereby one can determine why or why not managerial objectives have been met). The five-step process is as follows:

Step 1: After making the decision to use fire (fig. 2), the first and most important step is to set (and declare) the objectives relative to the site(s) and fuel type(s) you are attempting to manage.

For example, if the general objectives are wildfire hazard abatement (Muraro 1968) and improved tree-planting performance (Vyse and Muraro 1973), then the specific objectives of the prescribed burn would probably be stated in terms of the quantity of down–dead woody fuel (by roundwood size class distribution) and organic matter to be consumed (Hawkes and others 1990; Muraro 1975).

Step 2: Having defined the objectives, determine a burning prescription for achieving them expressed in terms of fire danger ratings, fire weather conditions, season, time of day, ignition pattern, etc. (see the sidebar on page 9, lower left) based on the best possible information available, such as operational case studies, research publications, decision aids and guides, expert opinion and past experience (fig. 3) or other approaches (e.g., Reinhardt and others 1992).

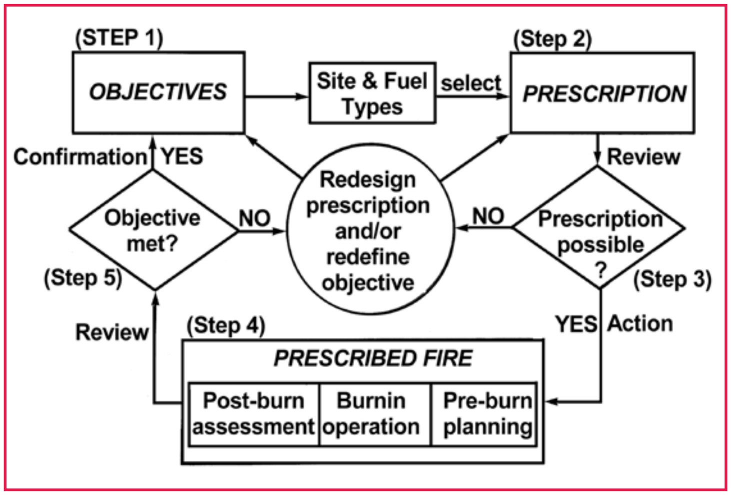

Figure 1—*Simple flowchart for employing prescribed fires in wildland vegetation management (from Kayll 1980).*

It is worth noting that case studies undertaken in one country can be applied to another, if fuel-type characteristics are relevant, by interpreting burning conditions through the other country's fire danger rating system (e.g., Alexander 1982, 1984; Alexander and Sando 1989).

Step 3: Is the "prescription" possible? That is, are there enough suitable days in an average fire season

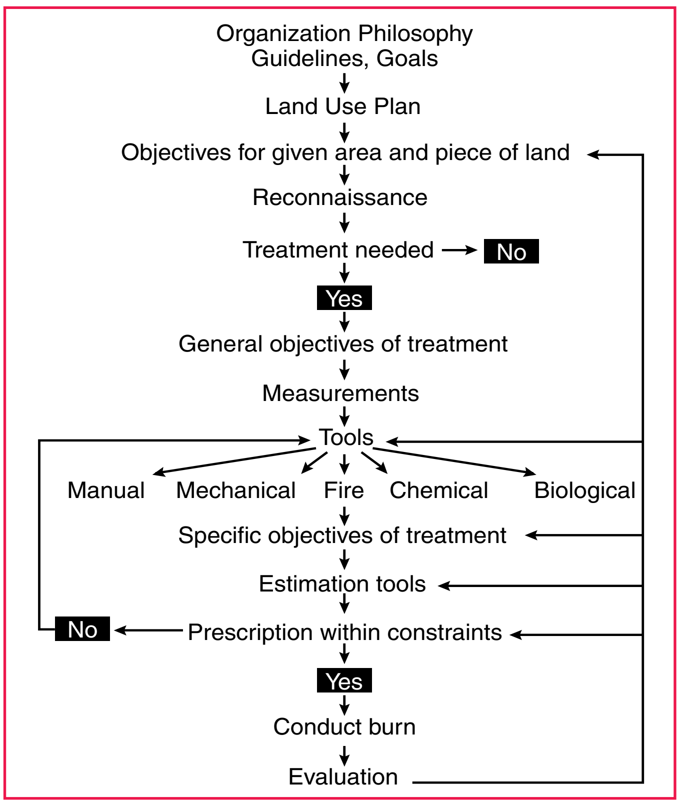

Figure 2—*The mental and management steps leading to the use of prescribed burning (from Martin 1978).*

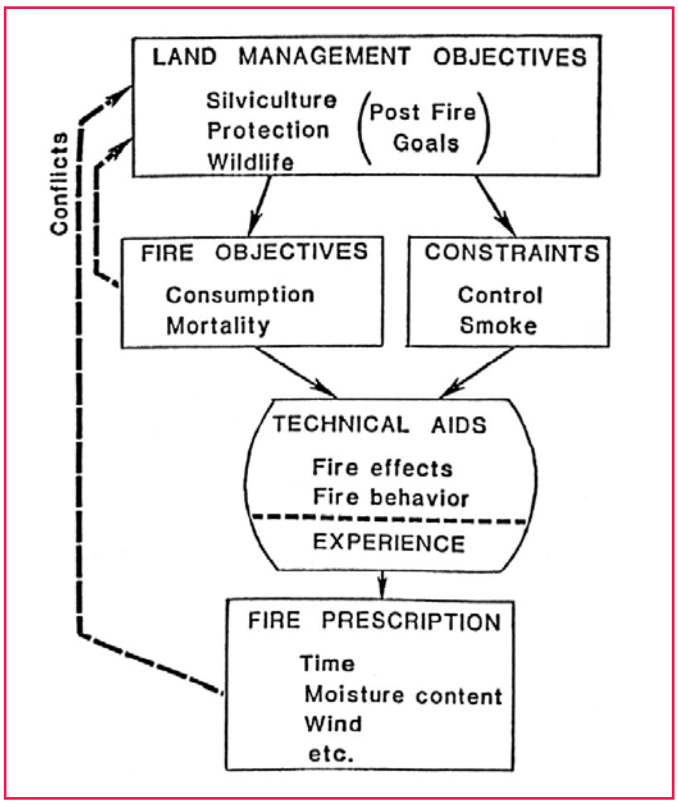

Figure 3—*Flow of information in designing prescribed burning prescriptions (from Brown 1975).*

and at the right time of the season to make it a reasonable prescription (Bradshaw and Fischer 1981; Martell 1978)? If not, then follow the feedback loops to redefine the prescription and/or the objective.

This might involve several iterations with slight changes in the range of the variables or parameters, including enlarging the ranges, before arriving at acceptable ranges that would still achieve the desired fire behavior and impact (Martell 1978). A common mistake is to include too many variables, because the probability of their simultaneous occurrence is generally quite low.

Step 4: If the prescription is possible, then proceed with the detailed planning for the operational execution of the prescribed burn, including smoke management considerations (Gorski and Farnsworth 2000; Hardy and others 2001); prepare the prescribed fire plan (see the sidebar to the right); and, as appropriate, execute the plan (see the sidebar on page 10).

A plethora of prescribed-fire-planning guidelines and guidebooks are available, including manuals on costing (Manol and others 1996) and complexity rating (NFES 2004). See, for example, Allen and others (1968), Kiil (1969), Fischer (1978), Martin and Dell (1978), NWCG Prescribed Fire and Fire Effects Working Group Team (1986), Wade and Lunsford (1989), and The Nature Conservancy (1991).

Step 5: Review performance to determine whether the stated objectives were achieved, and, most importantly, why. If the stated objectives were not achieved, it is equally important to determine why and thus close the loops. The level of detail that can be achieved in monitoring weather conditions and aspects of fire behavior during the actual burning operations will depend on ease of access and safety considerations, availability of personnel and equipment, size of the burning unit, and firing pattern (McRae and others 1979; NWCG Prescribed Fire and Fire Effects Working Group Team 1982; Rothermel and Rinehart 1983). The documentation made prior to, during, and immediately after the fire (e.g., postburn sampling) should directly link to the burning prescrip-

Three Examples of Burning Prescriptions Based in Part on the Canadian Forest Fire Weather Index System*

Open, montane lodgepole pine stand—ecosystem restoration (Dube 1977):

- Dry-bulb temperature: 61–73 °F (16–23 °C)
- Relative humidity: 25–40 percent
- 10-m (33-ft) open windspeed: 5–15 miles per hour (8–24 km/h)
- ISI: 5–12
- BUI: > 20
- FWI: 10–12

Lowland black spruce stand following harvesting—seedbed preparation (Chrosciewicz 1976):

- FFMC: ~ 91
- DMC: 22–46
- BUI: 21–45
- 10-m (33-ft) open windspeed: 5–10 miles per hour (8–16 km/h)

White and red pine stand—seedbed preparation and understory vegetation control (Van Wagner and Methven 1978):

- FFMC: 90–95
- ISI: 8–16
- BUI: < 52
- FWI: 12–24
- Time of year: May–June (ideal)

* The Fire Weather Index System components consist of three fuel moisture codes and three fire behavior indexes (Canadian Forestry Service 1984): the Fine Fuel Moisture Code (FFMC); Duff Moisture Code (DMC); Drought Code (DC); Initial Spread Index (ISI); Buildup Index (BUI); and Fire Weather Index (FWI).

Elements of a Prescribed Fire Plan*

1. Required signatures/approvals
2. Burn unit description
3. Vicinity map
4. Project map
5. Goals and objectives
6. Source of funding and estimated cost
7. Equipment and personnel
8. Fire prescription
9. Weather information
10. Preparation work
11. Protection of sensitive features
12. Smoke management
13. Preburn coordination and public involvement
14. Burn day notification
15. Public and personnel safety
16. Communication
17. Briefing guidelines and "Go/No Go" checklist
18. Test fire
19. Firing, holding, and mopup/patrol
20. Contingency
21. Monitoring and evaluation
22. Rehabilitation
23. Management of multiple prescribed fires
24. Necessary support documentation

* From NWCG Prescribed Fire and Fire Effects Working Team (1986).

tion relative to what was achieved or accomplished versus the objective(s) of burning. In other words, there are lots of things to potentially document on a prescribed fire, but one should ensure that the basics are covered off first.

Postburn monitoring can range from simple repeat photography (Magill 1989) to more detailed studies (USDI Fish and Wildlife Service 2004; USDI National Park Service 2003). A pre- and postburn fuel photo series, especially if coupled with quantitative measurements, is an invaluable tool for future prescribed-fire planning and burning-prescription formulation (e.g., Scholl and Waldrop 1999; Wade and others 1993; Wearn and others 1982). Detailed, research-level documentation and monitoring are probably justified when burning in a new fuel or vegetation type (Gilmore and others 2003). Occasionally, prescribed fires attract the attention of wildland fire researchers who are able to "piggyback" their activities onto the operational burning without causing undue interference (e.g., Stocks and McRae 1991).

Prescribed Fire Training

Three national prescribed-fire training course packages are now available through the U.S. National Wildfire Coordinating Group's National Fire Equipment System based at the National Interagency Fire Center in Boise, ID (NFES 2005):

- Prescribed Fire Burn Boss (Rx–300),
- Introduction to Fire Effects (Rx–340), and
- Smoke Management Techniques Rx–450).

For a listing of course offerings, visit the Wildland Fire Training website (http://www.nationalfiretraining.net). The National Advanced Fire and Resource Institute in Tucson, AZ (http://www.nafri.gov/index.htm) also offers the "Applied Fire Effects" course (Rx–510) on an annual basis.

Two prescribed-fire training centers have been in operation in the United States since 1998. The Southwest Fire Use Training Academy located in Albuquerque, NM, is an interagency program that offers a unique blend of formal classroom training and hands-on prescribed-burning field experience over the course of a 7-week period (http://nationalfiretraining.net/sw/futa/). The National Interagency Prescribed Fire Training Center located in Tallahassee, FL, offers a similar program oriented towards the southeastern United States (Fort and others 2000). University-level courses in fire ecology that include a prescribed-fire component and orientation are even available on the World Wide Web (Walstad and others 2003).

Prescribed-Fire-Related Information Sources

There is no shortage of technical information on prescribed fire and prescribed burning. Several books (e.g., Agee 1993; Biswell 1989; DeBano and others 1998; Kozlowski and Ahlgren 1974; Pyne and others 1996; Walstad and others 1990; Whelan 1995; Wright and Bailey 1982) and bibliographies (e.g., Crow 1982; Cushwa 1968; Greenlee 1995; Kumagai and Daniels 2002) exist, plus online sources such as the Encyclopedia of Southern Fire Science (http://forestencyclopedia.net/Encyclopedia/Fire%20Science). Numerous conference and symposium proceedings devoted to a wide range of prescribed-fire topics have also been published (e.g., Baumgartner and others 1989; Bidwell and Burke 1993; Bryan 1997; Hardy and Arno 1996; Koonce 1986; Lotan and Brown 1985; Sanders and Durham 1985; Trowbridge and Macadam 1983; USDA Forest Service 1971, 1977; Wade 1985; Wood 1981). Other excellent sources of information include fuel- or vegetation-type-specific prescribed-fire guidelines (e.g., Archibald and others 1994; Bunting and others 1987; Cheney 1978; De Ronde and others 1990; Green 1977;

The Fourteenth Prescribed Fire Situation that Shouts, "Watch out!"

Maupin's (1981) *thirteen prescribed fire situations that shout watch out!* are listed on the back inside cover of this issue. Based on past experiences (e.g., USDA Forest Service 2003), we would add a fourteenth situation to this list:

Conducting a prescribed fire without having a temporary onsite or nearby fire weather station.

This applies to some specified time prior (depending on the fuel type and representativeness of the permanent, "offsite" fire weather station(s) for startup values), during, and immediately following the prescribed fire.

> There are lots of things to potentially document on a prescribed fire, but one should ensure that the basics are covered off first.

Gruell and others 1986; Kilgore and Curtis 1987; Norum 1977; Wright and others 1979).

One of the most notable sources on prescribed fire is the proceedings of the Tall Timbers Fire Ecology Conference series organized by the Tall Timbers Research Station (Fischer 1980); the 23rd event, devoted to "fire in grasslands & shrubland ecosystems," took place in October 2005 in Bartlesville, OK. The Tall Timbers Research Station has also published other prescribed-fire-related monographs (e.g., Biswell and others 1973; Robbins and Myers 1992) and has created a computerized Fire Ecology Database on its Website (http://www.talltimbers.org/info/fedbintro.htm).

Several fire effects summaries have been prepared (e.g., Miller 1995). Perhaps one of the most up-to-date information sources on fire effects is the USDA Forest Service's "Rainbow Series," which covers the effects of fire on flora, fauna, air, soil and water, cultural resources and technology, and nonnative invasive plants. Four of the six planned publications in the series are currently available (Brown and Smith 2000; Neary and others 2005; Sandberg and others 2002; Smith 2000). The Fire Effects Information System (Fischer and others 1996) also developed by the USDA Forest Service is a computerized system that provides up-to-date information about fire effects on plants and animals (http://www.fs.fed.us/database/feis/). In addition, a Fire Effects Planning Framework has recently been developed (Black and Opperman 2005).-

Several prescribed-fire-related models exist. For example, FOFEM, a national fire effects model, predicts tree mortality, fuel consumption, smoke production, and soil heating (Reinhardt and others 1997). CONSUME also predicts the amount of fuel consumption and emissions from the burning of logged units, piled debris, and natural fuels for most vegetation types in North America (Ottmar and others 1993). With respect to modeling fire behavior, a few empirically based, fuel-type-specific models exist (e.g., Bruner and Klebenow 1979; Cheney and others 1992; Davis and Dieterich 1976; Muraro 1975; Sneeuwjagt and Peet 1985). BEHAVE, a semiphysically based fire behavior model applicable to surface fuelbeds (Andrews and Bradshaw 1990), has been formatted for prescribed-fire applications (e.g., Grabner and others 2001). Even decision support aids intended for assessing wildlfire potential, such as the Canadian Forest Fire Behavior Prediction System (Taylor and others 1997), have value in escaped-fire assessments and contingency planning.

One of the immense challenges facing prescribed burners of the future will be acquiring the skills needed to professionally sort out the staggering amount of "information" available in all the areas they are supposed to have expertise in—disturbance ecology, fire meteorology and climatology, fire behavior modeling, and decisionmaking, just to name a few. They are supposed to have not only a working knowledge of these academic disciplines, but also the ability to readily carry them out in a field setting under quickly changing environmental conditions. Many fire managers feel out of control and anxious over the sheer amount of information and data they are supposed to deal with. They may suffer from "information anxiety," defined by Wurman (1989) as the feeling of being overwhelmed by the amount of information available on a given topic. Wurman notes that even if we find the information we think we need, we might not be able to understand or evaluate it.

Inherent Risks in Using Prescribed Fire

The biggest challenge for fire managers faced with a steadily rising prescribed-burn targets is lack of practical experience within their fire organizations. Interestingly enough, this is not a new issue (Beaufait 1966). Given the decline in commercial harvesting, the generation of burn bosses that grew up igniting hundreds of logging slash units in an individual career has been lost to retirement, resulting in a huge prescribed-fire experience gap. It is common, for example, on many national forests in the Western United States to have staff that are involved in only one or two prescribed burns per year. Obviously, developing prescribed-burning expertise in this manner is slow. Perhaps recent retirees should be brought back on contracts as coaches or mentors.

Even though prescribed fire is one of the most important tools for managing fire-dependent ecosystems, little attention has been given, until recently, to understanding the lessons to be learned from past prescribed burns or the organizational psychology of the prescribed-burn team responsible for safely igniting a block of flammable vegetation. This lack of attention to burning operations is somewhat surprising, because the decision to "light the match" is always inherently risky, from both a personal and a social standpoint. (Ask any burn boss who regularly ignites prescribed fires or has been involved with an escaped fire that has resulted in a national review team looking at every judgment and decision made in the planning and execution of the prescribed fire.)

Escaped fires are a very real possibility in prescribed burning (Stock and others 1996), as a number of incidents have shown in recent years. For example:

- In May 1980, the Mack Lake Fire in northern Lower Michigan burned 29,000 acres (9,300 ha) and 39 homes (Borie 1981; Simard and others 1983);
- In August 1995, the Carmody Township Fire in north-central Ontario burned 19,296 acres (7,810 ha), with no structural losses (OMNR 1995);
- In July 1999, the Lowden Ranch Fire in central California burned 2,000 acres (800 ha) and 23 homes (USDI Bureau of Land Management 1999);
- In July 2001, the North Shore Kenai Lake Fire in southeastern Alaska burned 2,220 acres (899 ha), with no structural losses (USDA Forest Service 2002);
- In September 2003, the Cascade II Fire in north-central Utah burned 7,828 acres (3168 ha), with no structural losses (USDA Forest Service 2003); and
- In March 2004, the Impassible 1 Fire in northern Florida burned 34,660 acres (14,028 ha), with no structural losses.

However, probably the best known example of an escaped fire is associated with the Upper Frijoles Prescribed Fire on Bandelier National Monument in northern New Mexico during May 2000. The resulting Cerro Grande Fire eventually burned some 47,650 acres (19,284 hectares), including 235 homes in and around the community of Los Alamos (Paxon 2000; USDI National Park Service 2000).

At a recent workshop on high-reliability organizations (HROs) regarding wildland fire use and prescribed fires (Keller 2004), participants completed a staff ride of the Cerro Grande Fire. Under the tutelage of Drs. Karl Weick and Kathleen Sutcliffe, two experts on HROs from the University of Michigan Business School, staff ride participants used the concepts of HROs to analyze the prescribed burn and associated wildfire. According to Weick and Sutcliffe (2001), five key processes, or organizational principles, govern organizations that actively promote an HRO environment:

> One of the most notable sources on prescribed fire is the proceedings of the Tall Timbers Fire Ecology Conference series.

- *Preoccupation with mistakes/failures:* Take every opportunity to use near-misses, even so-called "minor mistakes," to see if they might indicate the beginnings of a major breakdown in prescribed burn operations.
- *A reluctance to simplify:* A prescribed burn crew should be constantly vigilant to simplifying mistakes into cause-effect relationships. They should strive to view mistakes from multiple angles in a culture that supports robust conversations.
- *Sensitivity to operations:* In prescribed-burning operations, a high-reliability work culture would be extremely sensitive to the people in the field who "light the match" and control the ensuing fire. They would not drown out what is going on at the ground level with an overemphasis, for example, on national or regional policy.
- *A commitment to resilience:* A prescribed fire organization that is highly reliable creates a work environment where personnel can easily talk about their "mistakes" and, after larger mistakes have occurred, can quickly adjust and get back to work in a timely fashion.
- *A deference to expertise:* A highly reliable burn organization pays keen attention to those who make critical decisions, regardless of their position on an organization chart.

The attentive prescribed-fire manager will hopefully use each of these five principles of HROs in order to safely and effectively conduct prescribed fires in the future (see the sidebar above). However, as Lepine and others (2003) duly note, "Regardless of how many precautions are taken, it is impossible to eliminate the risk of fires escaping from prescribed burning."

Prescribed Fire Safety

It would be fairly easy to conclude that prescribed-fire operations are not inherently dangerous. After all, major activities on a prescribed burn are completely preplanned, with all contingencies carefully thought out. In other words, every task involved with a prescribed-fire operation is "under control." Unlike a wildfire event, the prescribed burner is not at

The "Art and Science" of Prescribed Burning*

A successful prescribed fire is one that safely and effectively achieves the land and resource management objectives for which it was conducted. Such fires do not happen by accident: they are the result of careful and intelligent planning.

To plan a successful prescribed fire the planner must clearly define why he wants to burn a site and what he hopes to accomplish. He must also describe the physical and biological characteristics of the site to be treated. He must then blend this information with an understanding of the relationships between fuel, weather, topography, fire behavior, fire effects, and burning techniques. Finally, the actual fire must be evaluated in order to improve the performance of subsequent plans.

* Quoted from Fischer (1978).

the mercy of an unexpected weather event, for he can ignite his burn when the weather is favorable—or, at least, when it is expected to be favorable. But even with all this preburn control and expert weather forecasting, fatalities have resulted from burnovers and entrapments on escaped prescribed fires (Thomas 1998). The better known examples include:

- August 1979—seven fatalities on the Geraldton PB-3/79 Prescribed Fire in north-central Ontario, Canada (McCormack and others 1979) (see the sidebar on page 14);
- February 1980—two fatalities on the Willow Flat Prescribed Fire, North Island, New Zealand (Millman 1993);
- May 1980—one fatality on the Mack Lake Fire resulting from an escaped prescribed fire in northern Lower Michigan (Borie 1981; Simard and others 1983);
- April 1993—one fatality on the Buchanan Prescribed Fire in north-central New Mexico (USDA Forest Service 1993);
- June 2000—four fatalities in Kuring-gai Chase National Park, New South Wales, Australia (New South Wales National Parks and Wildlife Service 2001); and
- May 2003—one fatality on the Fort Apache Indian Reservation in northern Arizona (USDI Bureau of Indian Affairs 2003).

Furthermore, aviation-related fatalities are not limited to wildfires. On March 10, 2005, two fire managers and a pilot died when a Bell 206B-III helicopter they were in crashed while conducting a prescribed burning operation on the Sabine National Forest in East Texas (NTSB 2005).

The reality is that individuals involved in prescribed burning are exposed to the same natural and manmade hazards as those involved in fire suppression operations. For example, an interagency hotshot crew member was killed in 2004 when he was hit in the head by the top of a burning snag (USDI National Park Service 2004). Thus, the realization that fatalities can occur on prescribed fires should not be overlooked, especially in light of an escalating use of prescribed burning in many regions of North America and elsewhere (Alexander 2003). It is worth emphasizing that members of the general public have also been killed while engaged in using fire as a land management tool on their private properties (Millman 1993; Viegas 2004).

> The biggest challenge for fire managers faced with a steadily rising prescribed-burn targets is lack of practical experience within their fire organizations

The ability to predict fire behavior is essential to the safe and effective control of wildfires as well as the use of fire (Countryman 1972). In this regard, one shouldn't overlook the importance that human factors have played in past wildland firefighter fatalities (Butler and Alexander 2005). Some of the same principles associated with wildfire situations could equally apply to prescribed fires (e.g., complacency).

When one couples a general lack of burning experience with the organizational pressure to prescribe-burn more area each year, often under more severe burning conditions and on a landscape scale, a future scenario begins to unfold of increased risk of escape and potential safety problems. Even though prescribed-fire fatalities are relatively rare, deaths directly associated with prescribed burning have occurred, as outlined here.

One of the cardinal principles of HROs is "mindfulness" (Putnam 2005). Applied to prescribed burning, mindfulness involves a conscious effort by the burn boss to stop concentrating on things in the fire environment that confirm his hunches or make him feel good about what the fire is doing and to start concentrating on things that discount or contest his feelings.

It is fairly easy to start a short list

Application of Barry Turner's Disaster Model to a Prescribed Fire Fatality Case Study

On August 22, 1979, seven seasonal employees (three females and four males; six of the individuals were only 16–17 years old) of the Ontario Ministry of Natural Resources (OMNR) were killed on a prescribed fire (PB–3/79) that took place in logging slash near the community of Geraldton in north-central Ontario, Canada. An OMNR fire technician was also severely burned.

An accident is generally regarded as occuring when existing or known safety precautions haven't been followed (Whitlock and Wolf 2005). The chain of events leading to a disaster, on the other hand, is more ambiguous and less easily reconstructed. In its simplest form, a disaster occurs when the precautions that had previously been thought to be satisfactorily adequate turn out to be inadequate. A disaster nearly always catches an organization by surprise.

Fire managers in the United States have used British sociologist Barry Turner's manmade disaster model to analyze prescribed-fire fatalities, including the Geraldton PB–3/79 incident (Mutch 1982). Turner's (1976) six stages to a disaster applied to prescribed fire are as follows:

High-intensity fire behavior associated with the Geraldton PB–3/79 prescribed fire in north-central Ontario on the afternoon of August 22, 1979. Photo: McCormack and others (1979).

- **Stage I—Predisaster Starting Point:** The social, political, and environmental framework in which the prescribed-burn organization is working help set up the disaster.
- **Stage II—Incubation Period:** For a period of time, often years, small mistakes occurring in the prescribed-fire work environment become large and dangerous.
- **Stage III—Precipitating Undesirable Event:** Small mistakes accumulate during the incubation period until a major collapse occurs. In prescribed-burn operations, a "precipitating undesirable event" is often an escaped fire.
- **Stage IV—Onset:** The prescribed burn escapes and causes major damage to property and/or human life.
- **Stage V—Suppression, Rescue, and Salvage:** Control of the escaped prescribed fire begins, with primary emphasis on protecting human life and property. Towns might be evacuated and structural firefighters suppress house fires.
- **Stage VI—Full Cultural Readjustment:** After the escaped prescribed fire, new procedures and policies to prevent future escapes are adopted. If fatalities have occurred, it takes time for the burn crew and the community surrounding the escaped fire to come to terms with what has happened. Often, this is a period of grieving and healing, and it can take decades to complete.

Of the six stages of a disaster, the incubation stage is the most interesting for prescribed-fire managers. During this stage, which may go on for years, small "discrepant events" begin taking place in the prescribed-burn work environment, and they

Aerial view of the Esnagami memorial near the fatality site honoring the seven individuals associated with the Geraldton PB–3/79 prescribed fire. Photos: Terry Popowich, Ontario Ministry of Natural Resources, Dryden, Ontario, 2004.

go largely unnoticed by fire personnel. Small errors are seen as normal. When these events accumulate to a critical level, an "undesirable event" (such as a major prescribed fire escape) can occur. It causes a major cultural shift in the way an organization completes future prescribed burns.

Based on the board of review report for the Geraldton PB–3/79 prescribed fire incident (McCormack and others 1979), Mutch (1982) suggested that the associated fatalities constituted a "disaster" in Turner's terminology. Mutch (1982) described five major factors that might have played a role in the incident, including target accomplishment, haste, overconfidence, span of control, and deviation from plans. For more information on Turner's disaster model, see Turner and Pidgeon (1997).*

* Terry Popowich (2005) indicates that the OMNR "has taken many different visitors to the site of the Geraldton PB-3-79 incident in recent years to discuss and understand the true tragedy and how lapses in standard operating procedures will cascade and exponentially bring safety to the brink, and then of course fatalities." At the time of the incident, Popowich was a senior fire technician in the Geraldton District and the fire duty officer on the day of the PB-3-79 burning operation.

of items that might lead to things going wrong on a prescribed fire. For example:

- Burning aluma-gel from helitorch operations splashing on hunters within the ignition zone of a landscape-scale prescribed fire;
- Continuing to use the excuse of an "unexplained" wind event as the primary cause of prescribed fires escaping;
- A burn boss covering up his lack of experience because of pride;
- Unrealistic burning targets placed on field organizations; or
- Allowing the prescribed-fire plan to become so thick that it is nearly useless as a field guide to its execution.

It is interesting to note that even technological advances in prescribed fire have been a "double-edged sword" when it comes to safety. Take, for example, ignition devices. A vehicle-mounted terra torch requires far more vigilance that a conventional handheld drip torch (Bradshaw and Tour 1993). The introduction of the aerial drip torch or helitorch, originally conceived by Muraro (1976), has certainly increased the prescribed fire manager's firing capability (McRae 1997). Safety one was of the prime considerations in developing the helitorch, because it eliminated the need to expose ground personnel to hazardous situations such as steep terrain and/or heavy fuel concentrations (Muraro 1977). However, as noted above and elsewhere (Mutch 1985; Thomas 1998), the helitorch has also introduced a whole new set of safety problems and concerns.

Prescribed Fire Economics

Under the impetus of the Healthy Forests Initiative and the National Fire Plan, Federal natural resource management agencies have been given annual fuel management work goals to treat from 2 to 3 million acres (0.8–1.2 million ha) of Federal land per year. These annual acreage treatment targets are expected to grow.

Near the wildland/urban interface (WUI), some prescribed burning will be undertaken but machine work (e.g., thinning, chipping, or dozer-piling) will continue to be the standard method of fuel treatment. WUI treatments will generally have higher costs (Berry and Hesseln 2004). Outside the WUI, prescribed fire will be the most common method used to treat large fire-prone landscapes. Generally speaking, on a per-acre basis, prescribed fire is less expensive than machine work (Gonzalez-Caban 1997). In the Western United States, for example, average per-acre cost for prescribed fires ranges from $25 to 125 ($62–309/ha), whereas for machine work it reaches about $450 ($1,112/ha), with some areas reporting costs as high as $2,700 per acre ($6,669/ha).

Although additional research is needed (Hesslen 2000), fire managers must hone their skills to efficiently and economically accomplish ever-increasing restoration/fire hazard abatement targets. They must constantly strive to become more professional at regularly igniting, holding, and monitoring prescribed fires.

Parting Thoughts

Deep collaboration at the community level is absolutely essential to a successful prescribed-burning program. Collaboration is sometimes humorously referred to as the "C" word, because it is now used so often that its original meaning of working together to solve common natural resource problems has been lost. Prescribed-fire managers often blame regulatory constraints, such as those associated with smoke management, for not allowing them to prescribe-burn more land. We believe that the biggest obstacle (and challenge) for the future will be to effectively communicate to our local constituencies the risk and long-term consequences of *not* burning an area. There is no shortage of difficult fuel situations to tackle (Leuschen and others 2000). That said, we must also be realistic about the limitations of using prescribed fire for fire hazard reduction (see the sidebar on page 16). Prescribed burning is not a substitute for effective fire suppression (Brackebusch 1973).

We can neither take all of the risk out of prescribed burning nor eliminate the smoke, for risk is inherent in the very nature of the burning job and, unfortunately, smoke is a byproduct of the activity. What we can do, however, is become better at cooperating with our local communities and understanding the social dimension of prescribed burning while constantly working to collaboratively design risk scenarios that are supported or at least understood by our stakeholders (Brunson and Evans 2005; Loomis and others 2001; Schindler and Toman 2003; Wade 1993; Weisshaupt and others 2005; Winter and others 2002, 2004). Successful prescribed burning programs generally have few conflicting resource values, strong public education programs, and/or the support of the communities with close ties to and an understanding of the land (Taylor 1997).

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Effectiveness of Prescribed Burning on Fire Hazard Reduction*

Wildfire hazard abatement is one of the major reasons to use prescribed burning. Computer simulation, case studies, and analysis of the fire regime in the presence of active prescribed burning programs in forest and shrubland generally indicate that this fuel management tool facilitates fire suppression efforts by reducing the intensity, size, and damage of wildfires. However, the conclusions that can be drawn from the above approaches are limited, highlighting the need for more properly designed experiments addressing this question. Fuel accumulation rate frequently limits prescribed fire effectiveness to a short post-treatment period (2-4 years). Optimisation of the spatial pattern of fire application is critical but has been poorly addressed in research, and practical application management guidelines are lacking to initiate this. Furthermore, adequate treatment efforts in terms of fire protection are constrained by operational, social, and ecological issues. The best results of prescribed fire application were likely to be attained in heterogeneous landscapes and in climates where the likelihood of extreme weather conditions is low. Conclusive statements concerning the hazard-reduction potential of prescribed fire are not easily generalized, and will ultimately depend on the overall efficiency of the fire management process.

* Quoted from Fernandes and Botelho (2003).

The reality is that individuals involved in prescribed burning are exposed to the same natural and manmade hazards as those involved in fire suppression operations.

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> The biggest challenge for the future will be to effectively communicate to our local constituencies the risk of not burning an area.

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