THE SCIENCE OF PRESCRIBED BURNING

Prescribed Burning - Ecology Workshop
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Presented by:

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BIOGRAPHY

R.R. Lafferty graduated from the University of Montana in 1968 with a Bachelor of Science degree in Wildlife Technology and a Master of Science degree in Fire Sciences.

Between 1968 and 1974 he worked for the Canadian Forest Service in Victoria as a Fire Ecologist. From 1974 until 1977 he was Fire Protection Officer for CanFor. For the next four years Randy was a consultant involved with contract slashburning and fire suppression.

April 1981 to the present Randy has worked for MacMillan Bloedel Limited at Woodlands Services as their Fire Officer in charge of Fire Management.

I. INTRODUCTION

Prescribed burning is defined as "the knowledgeable application of fire to a specific land area to accomplish designated land management objectives" (anonymous 1975).

Separate papers on the "Science of Prescribed Burning," referring specifically to prescription burning of debris left after logging on the southwest quarter of British Columbia are being presented by Bruce Lawson and myself.

As with other speakers, details of my talk are found or referenced in the handout and the subject matter hopefully will generate questions and discussions during the workshops.

Vegetation zones and fire behaviour used as examples in this paper may be related indirectly to some of our "problem" sites and directly to our fire behaviour concerns on the coast. Fire intensity can be related to duff reduction, fuel reduction, mineral soil exposure and other variables. I will define fire intensity as we go along using codes of the Fire Weather Index and relating those codes to measured environmental parameters noted above.

Some reasons for prescribed burning are:

- fire hazard reduction
- reduced cost of planting
- optimum distribution of planted seedlings
- higher seedling survival and growth rates when species are matched to site
- insect and disease control
- increased soil temperatures
- nutrient cycling - oxidation of biomass
- reduction of competing vegetation
- species conversion, site rehabilitation
- ungulate habitat manipulation
- reduced spacing costs
- reduced personnel injury during spacing.

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My next statement shows my bias for prescribed burning in areas that I am familiar with. Nearly all sites in the Tshe-Thpl, Tshe-Abam, Thpl-Pico and Abam-Tshe vegetation zones can be successfully burned if proper consideration is given to aspect, slope, soil depth, time of year, fuels, fuel moisture and atmospheric parameters; also timing which is one of the most important tools used by prescribed burn personnel.

Limestone sites are very controversial in the Tshe-Abam vegetation zone and there have been successful prescribed burns near Nimpkish Lake and Port McNeill and, conversely, there are two examples of destructive fall burns on limestone strata in the Benson River and Artlish River drainage. Prescribed burns come in different intensities and create different effects.

Wildfires come in different intensities also and have various effects on the ecosystem. What we learn from them can be applied to the "science of prescribed burning."

II. WILDFIRE AND NATURAL REFORESTATION

The 6,800 ha Pent Fire in the Penticton watershed is germain to this discussion because measurements of various parameters were made in areas burned at different intensities. Canadian Forest Service personnel (Muraro, Lawson, Lafferty) observed and measured fire behaviour over several days in July 1971 during the fire and one year postburn (observations and data are in Canadian Forest Services files). Observations and data show:

A. The fire burned at various intensities depending on cover type, fire history of stand, aspect, slope, weather variables, elevation, topography, fuel moisture, ground moisture, etc.

B. Litter fuel moisture contents were as low as 5%, relative humidity averaged 30 to 40% during the day, temperatures were 27 to 32°C and the duff moisture code was over 100.

C. Stands were of variable ages and age did not relate to average stem diameter. Stands examined contained 60 to 120 year old lodgepole pine

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with some Douglas-fir. Below the canopy sparse amounts of pinegrass were present. At lower elevations ponderosa pine and western larch grew and at higher elevations Englemann spruce and Abies lasiocarpa were dominant.

D. Fire intensity was described using various factors. The slide shows the color changes which indicate fire intensity in this scenario.

- Grey Area - Severe Burn
  - All fuel and most organic matter consumed.
  - Soil grey
  - More than 90% mineral soil exposed.
  - Average regeneration from 1 m radius plots
    . 4 conifers and 10 fireweed and willow
  - Severe burn sites were less than 1% of total area. Cat fire guards and subsequent salvage logging caused more soil erosion into the Penticton watershed creek than factors directly attributable to fire effects.
  - Fire hazards will be non-existent in the future in this area. Shrubs and herbs will be most prevalent for years and many of the first and second-year conifer germinants will probably die because of high soil surface temperatures and low soil moisture.
- Black Area - High Intensity
  - All conifers dead, but most standing with some viable seed.
  - Estimate 50% duff reduction.
  - Most ground fuels consumed.
  - Average regeneration per 1 m radius plot
    . 15 conifers, 240 fireweed and willow
  - Black areas will remain a considerable fire hazard and present difficulty of control problems when the dead standing trees fall. Until then, they will release some seed, furnish shade and be non-competitive. Most conifer germinants will survive because there will be little competition for limiting factors. Wildlife browse will be abundant in this area for some years, as in the grey area. The soil has an organic mantle and will not erode easily.

- Red Area - Moderate Intensity
  - Fire charred most of the forest floor.
  - 10% mineral soil exposure.
  - Estimate 20% duff reduction.
  - 90% of conifers dead leaving the dominants alive.
  - Average regeneration from 1 m radius plot
    . 391 conifers, 2,215 willow and fireweed
  - Fire hazard here will be greatest because of the remaining fuel that will fall. Future success of pine germinants is thought to be poor because of limiting factors. The surviving dominants are released and will continue to be thrifty.
- Red and Green Area - Low Intensity
  - Most of forest litter layer charred.
  - Little mineral soil exposed.
  - Only deciduous shrubs, smaller Douglas-fir and pine killed.
  - Average regeneration from 1 m radius plots
    . 390 conifers, 2,200 shrub and forbs
  - Ground fire crept through this area. It is believed that all germinants will die because of lack of light, space and competition for life sustaining nutrients. Fire hazard has changed little, and some conifers may increase their growth rates.
- Green Area - Non-Burned
  - 2 to 5 cm duff
  - regeneration - none
  - Fire hazard, etc., in this area obviously has not changed. Within inches of the low intensity burn area, the number of conifer germinants changed from 391 to zero in the non-burned area. The burn line separated these plots by inches. I suppose this is an example of lodgepole pine's adaptability to release seed after fire and the seed's germinating ability on burned ground.

Prescription burning should not exhibit the extreme fire effects shown above because of our ability to light and manipulate fire with some predictability. Admittedly, it takes a concerted effort and requires trained and skilled personnel to light and manipulate prescribed fire successfully.

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III. PRESCRIBED FIRE

In 1971 Canadian Forest Service personnel burned two areas at two different prescribed fire intensities on Sandhill Creek about two miles east of Wickaninnish Lodge (Muraro, Lawson, Lafferty, Turner, Egglestone and Federal Fisheries) within the Thpl-Pico vegetation zone. Fire physics, plant ecology, soils and the fish habitat were studied or monitored. Bruce Lawson may have a comment on the results of the Fisheries study.

Shown in this slide is setting 604 which we visited yesterday and which is nearby. Most of the treed areas in the foreground are logged today.

These slides of our study area show the two burn areas, one control, and Sandhill Creek. The low intensity burn was lit in July and the moderate intensity one in August. It was our intention to create two different effects by prescribing two different Canadian Fire Weather Index Prescriptions (Table 1).

Table 1. CFWI Prescription

Fire Intensity	Wind Speed	FFMC	DMC	DC	BUI	FWI
Low	Calm	87		80	20	8
Moderate	11 kph	87	22	193	45	15

Results

- Duff reduction was variable and dependent on preburn duff depth, which was variable because of humics and swails. Generally, humics were dry and swails wet. Hard pan was usually found 15 cm below the swails. All litter layer and some fermentation layer was consumed in both areas where the fire occurred.

  Where fire occurred, 5.4 to 5.9 cm of duff was consumed in both areas.

- Fuel reduction was significantly different (Table 2).

Table 2. Fuel Reduction (%)

Fire Intensity	<2.5 cm	2.6-8.8 cm	>8.9cm
Low	40	11	13
Moderate	100	45	9

- Mineral soil exposure was not increased by burning.
- pH in both areas increased less than 0.5 units on burned areas.
- Soil temperatures were measured with the intention of relating energy incident on the soil to plant mortality. In a previous study at Mission, temperatures 30 cm above ground were in the range of 482° to 1200°C.

Temperatures of 57°C for periods exceeding five minutes cause denaturing of proteinase in most plants. The temperature plant mortality level varies depending on moisture content of tissue, threshold of heat capacity, thickness of root, epidermis and cork (Hare 1961).

Four thermocouples in the litter layer registered:
- 204°C for 100 seconds
- 700°C for 20 seconds
- 830°C for 6 seconds
- more than 57°C for 23 minutes

Two sensors at 5 cm below the mineral soil surface registered:
- 806°C for 20 seconds
- 532°C for 20 seconds

Only one sensor 10 cm below the mineral soil surface registered a change. It was
- 184°C for 20 seconds.

It started registering 17 minutes after fire arrival and was between 57°C and 184°C for 95 seconds.

Other thermocouples registered, but much less than 57°C; some did not register.

- Plant mortality was generally the same on both plots where there was fire. Increased mortality of plants growing in shallow duff layers was observed compared to plant mortality in deep duff. The low intensity area had more live residual vegetation because fire only covered about 75% of the area.

Conclusion

At Long Beach, a prescribed fire produced predictable results within broad objectives, i.e., minimal impact on soil pH, mineral soil exposure, duff and fuel reduction.

IV. PRESCRIBED FIRE AND REFORESTATION

From 1968 to 1974 a fire physics and ecology study was carried out by CFS researchers (Henderson, Russell, Turner and Lafferty). This area is in the Tshe-Thpl and Abam-Tshe vegetation zone. A preliminary report was written with a more recent update on plant succession and tree growth (Lafferty, 1972 and 1980 respectively).

Two areas will be compared today to demonstrate fire effects and the science of prescribed burning. They are near each other in the Tshe-Thpl vegetation zone and at the same elvation. One is on a west apsect and the other on a north aspect.

Results

Some results are presented below.

- Fire Weather Index at burn time:

	Date Burned	Wind Speed	FFMC	DMC	DC	BUI	FWI
T6	May 22/69	Light 1300/hr	89	22	125	63	21
T7	Sept 9/68	Nil 1600/hr	92	63	111	29	11

- Total fuel reduction - 48% on both areas. Total fuel loading preburn
  - T6 - 16 M g/m^2 (8 M g/m^2 burned)
  - T7 - 30 M g/m^2 (15 M g/m^2 burned)

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- Mineral soil exposure increase over preburn
  - T6 - 35%
  - T7 - 16%

- Duff reduction

	Initial Duff Depth	Duff Reduction	Postburn Depth
T6	7.8 cm	44%	3.4 cm
T7	11.7 cm	33%	3.9 cm

- Soil pH change (average pH over 18 months)

	Pre	First 1 Week Postburn	Second 4-6 Months Postburn	Third <18 Months Postburn
T6	4.6	5.6	5.7	4.5
T7	5.0	5.3	5.6	4.4

Change in soil pH at 5 and 15 cm depths was not significantly different, but the surface pH was at the time of the first measurement. At 18 months postburn pH was the same and near preburn levels at all depths on both areas.

Our Mission studies showed that there were periods when temperatures 1 m above ground reached between 482°C and 1200°C, however, only for very short periods (soil temperatures not recorded). Tarrant (1954) found that once soils reached a temperature over 482°C for any length of time the pH will not change. He found the maximum pH was 8.8 in samples heated in a muffle furnace. Our highest pH was 9.1 in soil burned orange-red. If Tarrant is correct, then our soils, with relatively low postburn pH, did not come close to reaching a temperature of 482°C for a significant length of time.

From the pH change data the following conclusions were made:
- small changes in soil pH are a general effect of burning in the Mission forest types
- increased soil pH persists for almost two years, peaking shortly after the burn and quickly tapering off

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  - in isolated instances of severe burning, soil pH may reach 9.1 immediately after the fire and return to preburn levels in about two years; the highest pH is found for a short period after burning. This type of burning involves less than 1% of the site.

- Plant succession was followed for 10 years at Mission. Initial effects of different fire intensities are most dramatic. On T6 fire set succession back to the annual stage and on T7 it retarded perennial plant growth. The resultant plant species are there because of:
  - preburn plant species
  - fire intensity
  - site
  - adjacent vegetation
  - canopy closure.

  More information is presented in Mission reports referenced earlier.

- Above and below ground postburn ambient temperatures - briefly, above ground temperatures were highest in slash, then over a burned area and least in an adjacent stand. Below ground temperatures were highest in burned area, then in slash and least in the adjacent timber (Lafferty, mimeographed report on file with CFS 1973).

Assuming that increased soil temperatures were significantly beneficial to seedling growth under the environmental conditions of vegetation, climate, site, etc., experienced in the Mission study, a site treatment that allows soil temperatures to increase in the rooting zone in desirable. In fact, results of a preliminary review of seedling growth data on a burned area showed that 2-0 Douglas-fir planted five years previous to measurement grew 1 m more than similar seedlings on the adjacent nonburned area (data on file, CFS, Victoria).

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- Seedling success - average seedling height growth 1968-1973

	Average Height 1972	Second Year Annual Growth	Third Year Annual Growth	Average Total Height Last Measurement (1973)
T6[1]	165[2]	50 cm	100 cm	315 cm
C6[1]	dead	-	-	-
T7	197[3]	42 cm	99 cm	338 cm
C7	102[3]	13 cm	46 cm	161 cm

Seedling growth on burned areas was similar four years postburn.

Higher seedling growth rates the first few years postburn on T7 opposed to C7 may be attributed indirectly or directly to burning. Fire effects are assessed to be:

- increased nutrients
- less competition
- warmer site (note early flush on T7)
- increase in microbial activity.

- The original stocking and planting rate of planted Douglas-fir was about 1,300 trees per hectare. Mortality averaged 20% four years after planting.

- The average height growth rate for planted stock on 11 areas at Mission 9 and 10 years after planting was 46 cm per year, and average basal area was 32 cm^2 per hectare per year. Douglas-fir grew highest on areas burned with the hottest fires and least on unburned areas. Basal area growth rate was similar on all treatment and one control plots.

  Data indicate that planted Douglas-fir has little competition for light, space and other life sustaining factors on burned areas at Mission. On one north aspect (T6), burned at high intensity and where postburn soil and above-ground temperatures were monitored, good Douglas-fir growth was attributed to increased soil temperatures as well as increased light, space and life sustaining elements.

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[1] T designates treatment (burned), C designates control (unburned)

[2] Planted 1969

[3] Planted 1968

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- These data are not unique. For instance, 7 out of 8 settings examined on Vancouver Island showed seedling and sapling growth rates equal to or better on burned areas as compared to non-burned areas. The exception was on a severely burned area (Pope 1981).

- On C6 control unburned, most planted stock was killed by rabbits and trees which survived are insignificant and depressed by deciduous vegetation. This is a common event in the Mission area where burning and planting have not been part of a Douglas-fir reforestation effort.

V. FIRE INTENSITY

I have shown some examples of the effect of burning on some ecological parameters and several times implied that fires of different intensity do in fact create different conditions. Once the decision has been made to use fire to meet a management objective, the prescribed burning project becomes technical.

VI. TECHNICAL PROCESSES AND FACTORS

Outlined below are some technical processes and factors that should be considered for successful prescribed burning.

> "A successful prescribed burn is one that: 1) meets the basic requirements of the objective, 2) stays within the boundaries described in the burn plan, 3) causes few problems because of spotting and, 4) is mopped up and in the patrol stage within 72 hours after ignition."

- Pre-Logging

  Pre-logging assessment of the stand should be made to determine:
  - need for post-logging treatment and land management objectives
  - probability that post-logging treatment will be prescribed burn, if more than 50% chance then:
    - . block layout to beneficial topographic features, same position on slope and aspect
    - . consider using fuel breaks for boundaries and compensate for high hazard areas
    - . determine fire impact requirement

- <u>Logging Stage</u>
  - Ensure woods foreman and grade foreman are aware of intention to burn, they can ensure
    - . snags are felled in adjacent timber
    - . upper setting boundary and gullies are cleared of tops and hazardous non-commercial wood while logging
    - . landings are bunched and cleaned up while the loader is on site
    - . salvage truck completes his job shortly after loader has left the setting
    - . cat fire guards are in place, access is possible, heliports are available and water sumps are dug.
  - Submit Section 88 forms.

- <u>Post-Logging</u>
  - Make all post-logging assessments and re-assessments of setting immediately after logging.
  - Prepare a burning plan, including a topographic map in detail so someone less familiar with the setting can carry out the burn in your absence.
  - Notify all levels of management of your intention to burn
  - Write a FWI prescription and determine probability of those weather conditions occurring.
  - Assess fuel loading and note location on map of Class I and II fuels. Note species and relative abundance.
  - Assess adjacent hazards, nearby equipment and other values.
  - Set up weather station and put fuel moisture sticks in timber.
  - Ensure sprinkler lines and fire guards are in place.
  - Consider competence of personnel, equipment, back-up supplies, etc., at your disposal.
  - Ensure that a formal chain of command is known and accepted.

- <u>Ignition</u>

  Ensure everyone involved is aware of intentions to burn, i.e., manager, general foreman, dispatcher, switchboard, back-up fire fighters, FIFT, industrial neighbors, Ministry of Forests and helicopter companies that will be helping.

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When burning conditions are within your prescription guidelines, set activities in motion to ensure permits, people and equipment are on site. Timing is the most important tool you have during the organization of men and equipment to control fire behaviour.

Items that should be included in the burning plan and assessed now are:
- wind direction and how to use it in managing the fire
- air stability for smoke dispersal and fire behaviour
- soil moisture and its effect on surface fuels
- check fuel moisture sticks in and out of timber
- men and equipment, stand-by force
- weather report
- CFWI codes
- adjustment in plan due to on-site changes
- ignition technique
  . heli-torch
  . AID
  . remote mass ignition
  . flame thrower
  . hand-held drip torch.

  Which one is best depends on experience of user, availability and personnel safety considerations.

Burn pattern may be adjusted to suit present conditions. Balancing energy latent in the wind, slope and available fuels in combination with timing (seasonal, diurnal, hourly and by the minute) will determine burn pattern or ignition sequence. Light-up is the time when burning becomes an art and the fire boss is similar to an orchestra conductor. He conducts each point of ignition; first light fuels, then heavy ones; start-stop; fast-slow. If he mistimes his moves a mistake will be as apparent as a miscued violin in a symphony.

Standard burn patterns are known to all fire bosses and all fire bosses know they have to be adjusted to suit local conditions. Control of fire may be active or passive depending on fire behaviour and weather conditions. You do not want to extinguish a fire before it has exhausted all available fuels. Control people must be ready to attack spot fires.

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All aspects of the burn should be under the direction of the fire boss with authority regulated to junior assistants. The fire boss must have a formal chain of command.

Use commonsense and experience. Check weather forecast in anticipation of mop-up.

- Mop-up
  - Mop-up should start at daybreak the following morning unless weather factors dictate otherwise.
  - Mop-up should be complete within 72 hours and the infra-red scanner should be used on spring, summer and some fall burns.
  - Techniques vary with size of work force, equipment, available water, weather, size of area, etc.

VII. GENERAL

When it gets right down to it, prescribed burning is hard work and requires long hours, weekend work and stamina amongst other things. Also, experience, training, confidence and a good sense of timing usually separate the good fire bosses from others; seniority has nothing to do with making a good prescribed burn boss. Yes, a fire boss with fire knowledge, experience and talent stands out as do people who are proficient as woods managers, industrial relations supervisors and other leaders.

A fire boss cannot carry out his duties properly without support from his supervisor, staff and the Ministry of Forests. Not only is morale and financial support necessary, but so is timing. If a burn is held up two hours because of lack of crew, reluctance to issue a burn permit, etc., the burning chance could be lost. Also, if a setting is in contention it may never be burned in which case the Company loses, i.e., pays $75/ha for not burning or possibly loses valuable stumpage because of factors mentioned earlier in this report.

The burn boss is the only person capable of making the decision to burn and how to do it. He is responsible for failures as well as successes. Often he must overcome external pressure to change his go-no go plan and at the

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same time assimilate and analyze new input.

The fire boss, and the people who planned the burn must take advantage of all factors to ensure a successful burn. Many of them have been mentioned above.

Scientists have converted research results into usable guides in many instances where pressure has demanded. However, usable information is needed to help prescribed burners interpret upper air movement, adiabatic lapse rates; effect of fog, aspect, coastal conditions and heavy fuels on fire behaviour. I also believe an empirical, definitive guide should be developed for what I refer to as "energy balance for improved prescription burning."

- Post-Burn

  Measure the degree of success in achieving your objective.
  - adjustments to burning plan
  - mineral soil exposure
  - fuel reduction
  - duff reduction
  - stability of site
  - impact on vegetation

A copy of postburn information should be recorded and submitted to the MoF for attachment to burning plans.

RRL:kcbm

March 22, 1982

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