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**ECOSYSTEM MAINTENANCE BURNING
EVALUATION AND RESEARCH (EMBER)
PILOT PROJECT**

**NELSON FOREST REGION
1993-1997**

PROBLEM ANALYSIS AND WORKING PLANS

T. Braumandl, D. Gayton, R. Stewart
BC Forest Service
Nelson Regional Office

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1.0 EXECUTIVE SUMMARY

Certain forest types in the Nelson Forest Region have evolved with frequent, naturally caused understory fires. These forest types, primarily in the Ponderosa Pine and Interior Douglas Fir biogeoclimatic zones, with lesser amounts in the Interior Cedar Hemlock and Montane Spruce zones, are identified as "fire maintained ecosystems." Approximately 575,000 hectares fall into this category.

Long-term fire suppression in these ecosystems has resulted in unhealthy, overstocked forest stands. Continued fire suppression in these areas will have serious socioeconomic impacts, due to a) increasing risk of catastrophic fires as fuel loadings increase, b) declining forest health, and c) declining understory forage production for wildlife and livestock.

The potential economic, social and natural resource benefits of an ecosystem maintenance burning program could be substantial, enhancing silviculture, forest health, protection, range, wildlife and recreation. The reintroduction of fire, in the form of "ecosystem maintenance burning" is proposed.

The Ecosystem Maintenance Burning Evaluation and Research (EMBER) is a pilot project to lay the groundwork for a coordinated Ministry program to reintroduce prescribed fire to these fire maintained ecosystems. The project is coordinated by an interdisciplinary, interministry steering committee and has a 5-year life span. The project's objectives are to plan, execute and document a series of pilot burns in conjunction with District staff, to determine the feasibility and technical merit of an expanded burning program.

At the close of the EMBER in 1997, preliminary findings will be submitted for external review and the final conclusions and recommendations will be submitted for review by Branch experts and the Regional Management Team.

EMBER COMMITTEE MEMBERSHIP

The EMBER Committee is an ad hoc committee composed of a broad cross-section of Forest Service staff from Districts and the Regional Office, plus representatives from the Ministry of Environment, Lands and Parks as well as the Ministry of Agriculture, Fisheries and Food.

The current Committee membership is as follows:

Rick Stewart, Forest Health Officer, Nelson Region MOF (Chair)

Greg Anderson, Operations Manager, Invermere District MOF

Al Bond, Fire Management Coordinator, Nelson Region MOF

Tom Braumandl, Research Ecologist, Nelson Region MOF

Don Gayton, Regional Range Ecologist, Nelson Region MOF

Don Hendren, Operations Supervisor, Cranbrook District MOF

Mike Hudock, RO Protection, Kootenay Lake District MOF

Mike Malmberg, District Agriculturalist, Cranbrook MOAFF

Gordon Keir, RO Protection, Boundary District MOF

Gary Tipper, Habitat Biologist, Cranbrook MOELP

Skip Walsh, RO Protection, Arrow District MOF

2.0 PROBLEM IDENTIFICATION

INTRODUCTION

There is a growing recognition of the ecological role of fire in the forests of western North America. High-frequency, low-intensity natural fires are now recognized as a natural and historical component of certain low elevation, dry forest communities. In the Nelson Forest Region, large parts of the Ponderosa Pine (PP), Interior Douglas fir (IDF) and smaller amounts of the Interior Cedar-Hemlock (ICH) and Montane Spruce (MS) zones are seen to be affected by this fire regime.

The historical presence of the high-frequency low-intensity fire regime in these communities is borne out by a number of dendrochronological studies. Dorey (1979) documented historical **fire periodicity**¹ in a mixed ponderosa pine-Douglas fir stand near Grasmere (Cranbrook District) to be every 6.4 years during the period 1813 to 1940. Beck (1984) determined the periodicity of a seral ponderosa pine stand in the ICHdw near Deer Park (Arrow District) to be 11.6 years in the period between 1762 and 1937. Stewart (pers comm.) analyzed a single fire-scarred veteran larch from an IDFdm2 subzone at Canal Flats (Invermere District), and found an average periodicity of 26 years, between 1589 and 1937. Parminter (1978), working in an open-grown Douglas fir/grassland type in the Chilcotin Region, found a 9.8 year average fire periodicity between the years 1759 and 1926.

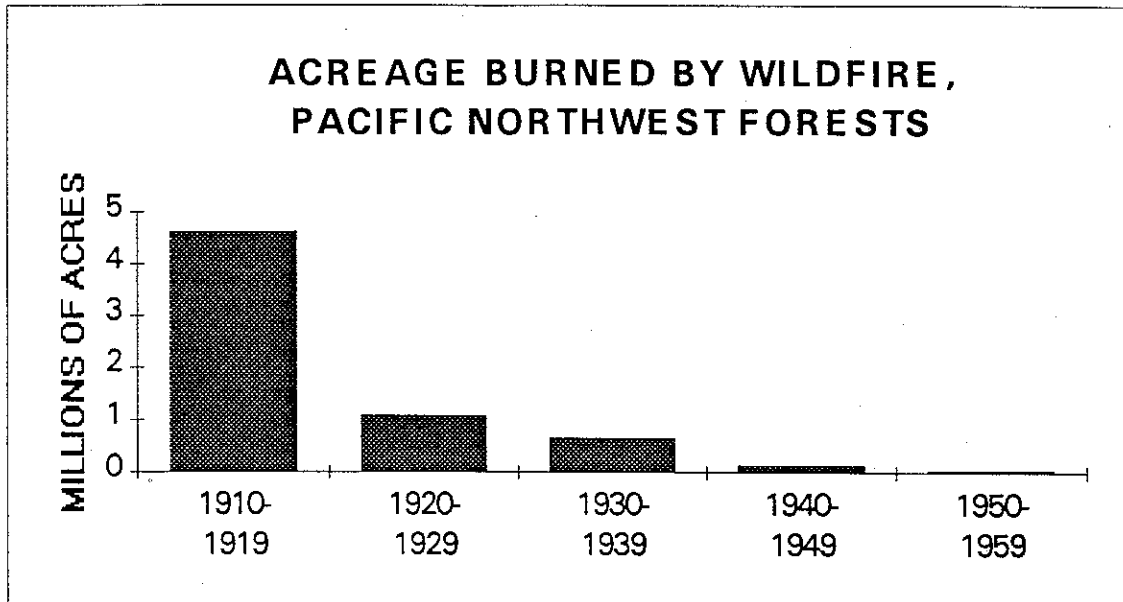
A study in the adjacent Kootenai National Forest in Montana estimates at between 12 and 27 years in ponderosa pine stands (George Curtis, pers. comm.). Another ponderosa pine stand in Eastern Washington had an 8-year historical fire periodicity (Weaver, 1974); the mixed pine/fir/larch stands of the Blue Mountains of Eastern Oregon, perhaps the most thoroughly researched in terms of fire impact, have a historical fire periodicity of 10 years (Hall, 1977).

Other wetter forest subzones in the Region certainly experience fire, but the fire events are less frequent, stand-replacement type fires.

Natural fire occurrences in the drier forest subzones would have begun sometime after the end of the last Wisconsin glaciation. The trees, shrubs, forbs and grasses, as well as the wildlife, insects and microorganisms of these subzones would have become adapted to fire over some ten thousand years, and the ecosystems they make up could now be considered to be **fire-maintained**. This is recognized as Natural Disturbance Type 4 ("ecosystems with frequent stand-maintaining fires") in the current Biodiversity Field Guide (BC Forest Service, in prep.). If this natural fire regime is dramatically altered through fire suppression, it is logical to expect that certain ecosystem processes such as succession, stand development and nutrient cycling will be affected.

¹The length of time (as measured by tree growth-ring analysis) between fire events. Also called fire return interval.

This is, in fact, what has happened. Beginning in the late 1930's, the Ministry's fire suppression activities have substantially reduced the occurrence of all wildfire. Data from the Region is not currently available, but the statistics from an adjacent jurisdiction will serve to show this pattern. The graph below shows the acreage burned by wildfire in the National Forests of Washington, Idaho and Montana over a fifty-year period (Leege, 1968):



Systematic, long-term fire suppression has virtually eliminated fire from these ecological zones, and the result has been **excess forest ingrowth**.² Many of these stands have not experienced fire for four, five and even six decades now, which means they have missed between two and four fire cycles.

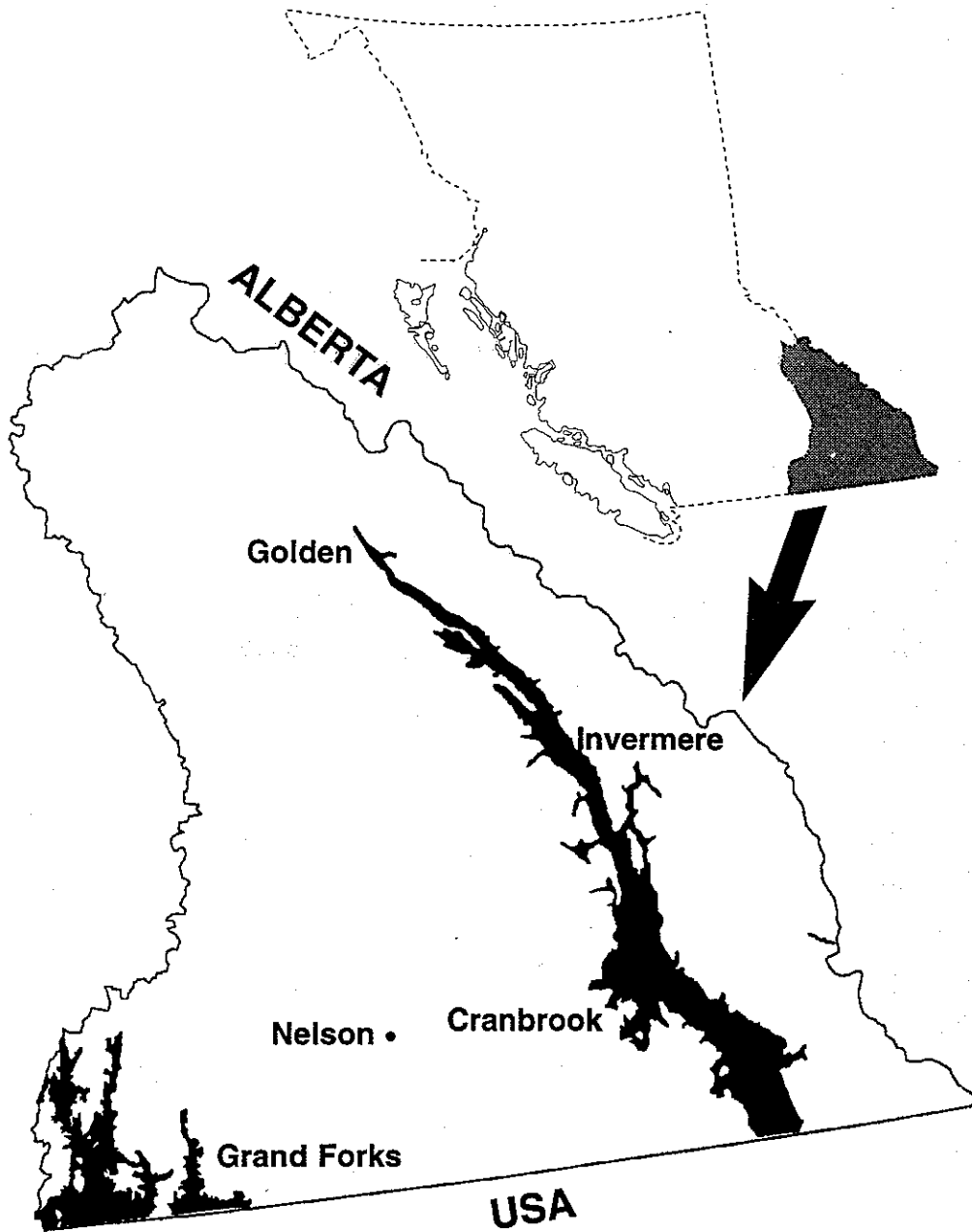
Target Stocking Standards for the four zones in question range between 400 and 1200 tree stems per hectare at free-to-grow status (Braumandl and Curran, 1992), but unmanaged, fire-excluded stands commonly average between 5,000 and 15,000 stems per hectare. In the US, Covington and Moore (1994) analyzed an unlogged high elevation ponderosa pine/oak ecosystem and estimated presettlement basal area to be in the range of 25 ft², far below the current level of 85 ft².

Douglas fir is often the primary agent of ingrowth in fire-maintained forests that have experience fire exclusion (Arno et al, 1994); however lodgepole pine is a common dominant in those areas that experienced intense fires around the turn of the century.

²An increase in tree seedling recruitment, normally through the suppression of fire, beyond the level that a particular site can support. Also known as forest ingress.

MAP OF THE NELSON REGION

(Areas of Interior Douglas fir and ponderosa pine subzones are shown in black)



Although suppression of naturally-occurring fire in these zones has certainly provided initial gains in timber values and public safety, the EMBER Committee considers that the losses, through deteriorating forest health, increased risk of catastrophic fire and degradation of understory forage and habitat, now far outweigh the gains. This conclusion is supported by other groups working in fire-maintained ecosystems in northern Arizona (Covington and Moore, *ibid*), Western Montana (Arno et al, *ibid*), Eastern Oregon (Quigley, 1992), and Eastern Washington (Everett, et al, 1993).

EXTENT OF THE PROBLEM IN THE NELSON REGION

The following table provides the Committee's estimate of the areas, by subzone variant, that are considered to be **fire-maintained ecosystems**³ prone to ingrowth as result of fire suppression, and which would be appropriate for understory burning or other ecosystem maintenance activity:

Subzone Variant	Total Area (Ha)	% Of Total Estimated As Fire-Maintained ⁴	Area of Fire-Maintained (Ha)
ICHdw	351,838	15	52,775
ICHmk1	185,724	5	9,290
ICHxw	41,581	60	24,950
IDFdm1	110,982	70	77,690
IDFdm2	315,713	70	221,000
IDFun	24,949	90	22,455
IDFxl	20,315	95	19,300
MSdk	373,918	15	56,090
MSdm1	80,907	10	8,090
PPdh1	13,804	98	13,530
PPdh2	73,860	98	72,385

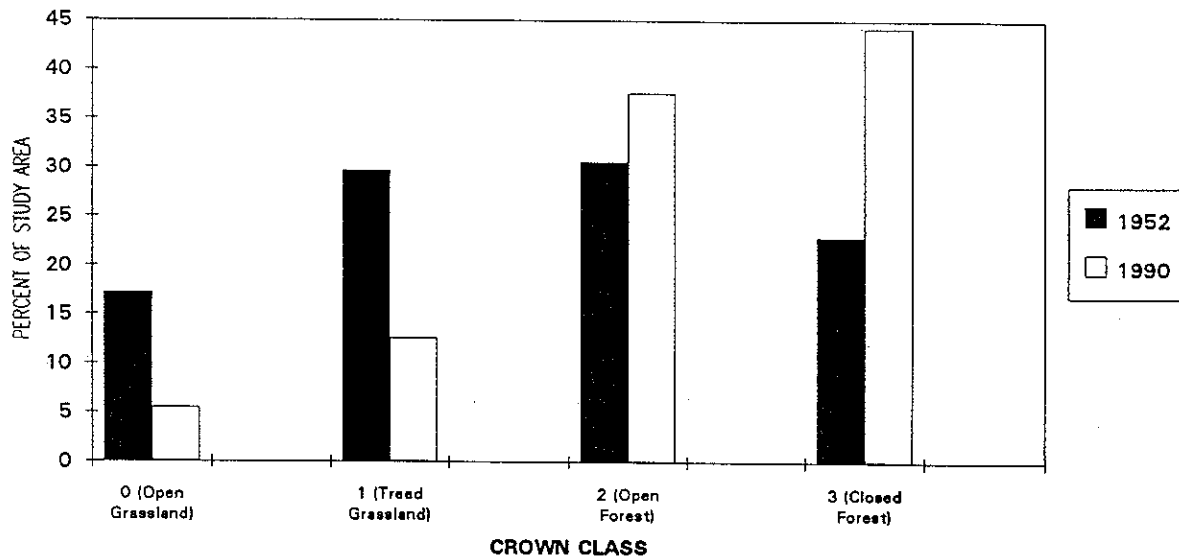
Total: 577,560 Ha

³An ecosystem that requires periodic, light surface fires to maintain proper stand structure, nutrient recycling, and vegetation health.

⁴Areas are considered to be outside the fire-maintained zone where topography, dominant tree species, soils or excess moisture would normally prevent fire entry and/or produce stand replacement type fires.

A preliminary analysis of rates of ingrowth in the Interior Douglas Fir and Ponderosa Pine zones of the Rocky Mountain Trench, from the Montana border to Golden, was undertaken by members of the Committee. 1952 and 1990 airphotos were obtained from three representative sites in the area, and each set of photos was visually stratified into polygons representing four crown closure classes: Open Grassland (0-5% closure); Treed Grassland (6-15%), Open Forest (16-40%) and Closed Forest (> 40%). The percentage of the landbase within each closure class changed dramatically over the 38-year period, as shown below.

FOREST INGROWTH (1952-1990) IN THE ROCKY MOUNTAIN TRENCH (PP and IDF Zones).



Applying the rate of change in closure classes to the roughly 400,000 hectares of PP and IDF zones in the Rocky Mountain Trench means that roughly 3000 hectares per year are converted from grassland to forest as a result of ingrowth, or 114,000 hectares since 1952⁵. This is admittedly very crude data, based on only three sample areas and two dates, but it gives some idea of the magnitude of the problem.

⁵ The rate of ingrowth and encroachment will not be constant over time. Parminte: (ibid) found a gradual increase in the number of tree seedlings establishing on grassland between 1931 and 1951, followed by two decades of declining rates of establishment.

CONCLUSION

From this analysis and other historical studies, it appears that five decades of successful fire protection in the fire-maintained ecosystems in the Nelson Region have resulted in a negative change in the structure and composition of those ecosystems, with ponderosa pine-dominated stands shifting over to Douglas fir-dominated stands, and traditional grasslands experiencing tree encroachment. Many of the traditional pine stands are now so overstocked that the use of prescribed fire becomes problematic, and any pre-burn manipulations very expensive, unless merchantable value can be removed at the same time. Occasional burns have been undertaken by Districts to control tree encroachment on open ranges, but the amount is very small--less than 500 hectares per year in the whole Region. Prior to the initiation of EMBER, no burns had been attempted in forest land to control excess ingrowth.

3.0 PROBLEM ANALYSIS: NATURAL RESOURCES

INTRODUCTION

Excess ingrowth affects many aspects of the forest resource, as well as creating a number of spinoff socioeconomic effects. This Problem Analysis Section acknowledges the multi-sectoral nature of forest ingrowth by examining Natural Resource Impacts as well as Socioeconomic Impacts.

NATURAL RESOURCE IMPACTS: SILVICULTURE

Silviculture is the science and art of cultivating the forest. Its main thrust is the establishment of new forests by site preparation, tree planting or natural regeneration, weeding and brush control. Intensive silviculture is another thrust, which includes spacing, thinning, and fertilization as well as backlog reforestation. Before any of these treatments are applied however, a vision or desired future condition of the stand and landscape must be determined.

Managing for future outputs on a site specific basis will not allow for continuity within the ecosystem. Our vision of landscapes within areas subject to forest ingrowth must be based on historical facts, photographs, and the results of past and current management practices. The successful forest manager will recognize those areas in need of treatment, based on current site conditions and the normal processes that have historically modified these areas. Definitions of stocking and composition in fire-maintained forest types where managed fire can be used should be more flexible compared to more conventional areas where timber is the primary management objective.

The current condition of the biogeoclimatic zones in the Nelson Region that are suitable for ecosystem maintenance burns is due to past activities such as fire suppression and the practice of cutting the largest, highest quality, dominant trees in the stand. These trees were usually ponderosa pine, western larch and Douglas fir that, previous to harvesting had formed a self perpetuating, fire maintained stand. In the absence of frequent fire, which is necessary to maintain high light levels and mineral (ash) seedbeds favorable for reproduction of pine and larch species, the result was regeneration and dominance of the shade-tolerant, fire-intolerant Douglas fir. Many of these areas now have multiple-storied or irregular stands of poorly growing fire intolerant species mixed in with remnants of the original stand.

Post-harvest site preparation for planting on traditionally fire-maintained sites is normally not necessary, as sufficient disturbance results from the harvesting itself to ensure natural regeneration. However, harvest-related site disturbance exposes mineral soil, which allows the establishment and eventual dominance of shade-tolerant, fire-intolerant Douglas fir and lodgepole pine. Conversely, the germination and establishment of the shade-intolerant, fire-tolerant ponderosa pine and western

larch are favored by fire. Thus the appropriate silvicultural prescription for ingrown stands is minimal soil disturbance during harvest, followed by prescribed fire to create an ash seedbed. This will ensure a return to the species mix appropriate to the site over time. An initial flush of lodgepole pine can be treated by a second prescribed burn.

The use of fire to promote regeneration will avoid the problems associated with disturbed-soil regeneration described in the preceding paragraphs. Fire-stimulated regeneration will ensure genetic suitability to the site. Natural selection of individuals best suited to their microsite to form the mature stand will occur naturally by the selective capabilities of successive fires. Occasionally, ingrown stands may be encountered where past harvesting activities have "highgraded," leaving only inferior trees for natural regeneration. In these cases, replanting of other species and genotypes should be considered as well.

Spacing or thinning is a possible alternative silviculture method for restoration of areas where fire once played a major role in their formation and maintenance. In today's overstocked and low vigor stands it is now realized that the development of good quality timber and other resource values will demand an investment of time, money and energy. Today's (1994) average cost for thinning one hectare of land is over \$1000. Efficient landscape level burning--designed to achieve thinning--is anticipated to be under \$50 for one hectare. In other words, 20 hectares of burning could be equivalent to a single hectare of thinning. It should be realized however, that burning will have to be done more than once, and may involve the use of other manipulations to ensure the initial burn achieves its stated objective.

Manual thinning achieves the desired level of stocking in one pass, and allows the manager to achieve desired tree species composition of tree species, if there are enough stems to begin with, and if they are distributed evenly throughout the stand. However, this creates a serious fuel loading problem on the forest floor, which has the additional negative effect of suppressing grass, herb and shrub growth. Furthermore, the use of commercial thinning in many fire-maintained/fire excluded stands will be prevented by the fact that the stems removed are those most desired to form the future crop. In these stands the use of fire to select thin barked species comprising the under story will produce immediate changes to the stand environment that will encourage faster growing tree species.

Burning is unlikely to create the desired level of stocking on the first try. Successive attempts will be needed to reduce initial fuel loads and eliminate the small diameter, shade tolerant stems that are more susceptible to damage from fire. These burns will reduce the fuel hazard and promote regeneration of desired grasses, herbs, shrubs and tree species. The cautious introduction of fire will be necessary in many heavily overstocked areas and as many as three burns may be required to reduce stocking to the desired level and promote the establishment of desired species. These fires are

known as **reduction burns** and are the most expensive form of burning, with costs as high as \$250.00/ha if pre burn slashing is required.

Once the desired stand condition is reached, subsequent burning will be done to maintain conditions. This type of fire is a **maintenance burn** which is much cheaper. Burning costs of as little as \$15.00/ha are possible if the area treated is of a size that permits good economy of scale, burning crews are experienced and units take advantage of natural terrain features to reduce the risk of escape. Slashing or other pre treatment is not required and fire intensities are not a problem if done on a regular cycle of approximately 20 to 30 years.

Intensive silviculture is performed on established and "free growing" stands. This type of silviculture is expensive but will usually produce a more valuable crop at rotation. Typical treatments include thinning (spacing), fertilizing and pruning. Costs for conventional treatments range from \$200/ha for fertilizing and pruning, to \$1000/ha for thinning. In overstocked fire based ecosystems, thinning treatments are necessary for basic stocking control that does not happen in the absence of fire. Fire on the other hand is a natural stocking control agent that will favour removal of dense regeneration, the sick and diseased, and fire susceptible species. Natural pruning also occurs as low limbs are readily consumed and fuel ladders are eliminated.

Fertilizing is also a common treatment to ensure the speedy growth of high value timber. In fire-excluded stands, nutrients tend to get "locked up" in excessive stocking, standing dead material, and duff. Harrington (pers comm) described the effects of thinning followed by prescribed burning on nitrogen availability on a ponderosa pine stand in Western Montana. Prior to burning available N levels in the soil were 1ppm: immediately after burning, 18ppm, and one year after burning, 5ppm. Increased postburn N availability may not always be the case, however; Landsberg et al (1984) showed decreases in foliar N content after burning in a ponderosa pine stand in central Oregon. Prescribed burning should be examined as a low-cost alternative to the expensive and potentially unsustainable practice of fertilization.

Canopy closure and duff accumulations as a result of fire exclusion can affect growth by reducing ground-level solar gain and insulating the soil, effectively shortening the spring growing season as the soil remains cooler for a longer period of time. With the use of fire, the critical spring growth period can be extended.

NATURAL RESOURCE IMPACTS: FOREST PATHOGENS AND INSECTS

During the last decade alone, the intensity and frequency of insect and disease outbreak has increased dramatically. Some of these occurrences are found in areas where they have never been previously recorded. Forest health managers have recognized that many of these outbreaks occur in areas frequently exposed to fire in the past, and there are several cases where these occurrences are symptomatic of a greater problem. (This section excludes introduced biota that create anomalous situations.)

Most native insects and pathogens that cause mortality in our forests are triggered by stress. As in humans, trees under stress have a reduced capacity to defend themselves against disease. With the exclusion of fire in fire based ecosystems, stocking and species composition have changed altering predator/prey balances and enhancing insect and disease populations. It is now realized that this will increase the cost of control programs to protect our forests from not only insects and disease but wildfire itself, which would almost surely be a stand replacement event under the current fuel loads and multi-level stand structure.

Macro-scale diversity is becoming increasingly rare in our ponderosa pine forests, which are now densely stocked with Douglas fir. In IDF stands, ingrowth is primarily with Douglas fir itself, or in the case of past stand-replacement fires, lodgepole pine. These forests are in an overcrowded and suppressed state, due to competition for moisture (which is subject to canopy interception and further reductions in availability), nutrients (which are in a limited supply to begin with), and sunlight (which is limited by the increased canopy cover). This condition has elevated stress levels and made the trees more susceptible to abiotic events such as drought, and biotic events such as bark beetle and fungal attack, not to mention the decrease in growth and reduction of future yields.

The very persistence of ponderosa pine in fire-maintained ecosystems within the Nelson Forest Region is threatened. Past high grading during the railway and mining tie hack heydays of the early 1900s was the first assault, followed by post-WWI harvesting, which put the fate of future forests in the hands of the logger. High-grading and loss of good genetic stock was a frequent result. Increased fire suppression capabilities have allowed the successful establishment of other species. The presence of relatively dense lodgepole pine in these stands threatens the ponderosa pine as mountain pine beetle drawn to lodgepole pine can and will attack older ponderosa pine that is resistant in the open stands it normally inhabits. This dramatic and continuing reduction of ponderosa pine, the gene pool has narrowed substantially, placing the remaining stems at higher risk of mortality from insects and disease.

Where natural fire accomplished stocking control, a diversified structure, and an enhanced the forest mosaic, forest ingrowth has the reverse effect. Following on the heels of ingrowth, bark beetles then further simplify canopy structure, control stocking from above, thus reducing vertical diversity, and dramatically increasing the threat of crown fires by increasing fuel loading. Douglas fir, which now occupies a large portion of these altered stands, is being increasingly attacked by defoliators such as western spruce budworm which prefers densely stocked multistoried stands of low vigor host. As Douglas fir stands increase in age, so does the stress from defoliation, growth loss and mortality from the Douglas Fir Bark Beetle. This scenario has destroyed over half of the Blue Mountain National Forest in Eastern Washington, and is becoming an increasing problem in the Nelson Forest Region. Prescribed fire in these stands can both thin and improve the vigor of the residual stand. Observations on these types of burns have shown a high degree of growth-release with effects persisting for several years. With the continuation of current wildfire policies the need for prescribed fire in these stands will be needed to prevent excessive vulnerability to insect pests.

Fire exclusion allows for the development of vertical stand structures which enhance the spread and damage by mistletoe. All three mistletoe species (*Arceuthobium douglasii*, *laricis*, and *americanum*) in the Nelson Forest Region benefit from these fire excluded areas and will contribute to future wildfire intensity through increased litter fall, heavy brooms and mortality. The use of prescribed fire to create open stand structures will eliminate the stagnated and infected understory, greatly reduce the ability of this obligate parasite to spread, and reduce the risk of future wildfire. Douglas fir and lodgepole pine heavily infested by mistletoe will nearly always be attacked by bark beetles as their resistance to attack declines. Larch however, has no primary bark beetles and due to extreme fire resistance, will usually linger until killed by root disease or other secondary insects.

Past removal of trees best suited to these ecosystems through selective cutting has undoubtedly contributed to reductions of the gene pool and increased the chance of higher mortality from insects and disease. Insects and pathogens may be an important genetic screening agent to improve future stands, but the process may cause higher timber losses in the interim.

Historic levels of *Armillaria* in fire-maintained ecosystems were low due to minimal stress levels, higher species resistance, fewer stems, less root-to-root contact and the absence of logging which created a food source for this pathogen. Today's dense stands of susceptible species such as Douglas fir are literally being ripped apart by high levels of this root disease. Attempts to improve the situation through silviculture treatments such as thinning have resulted in even higher levels and mortality in the leave trees.

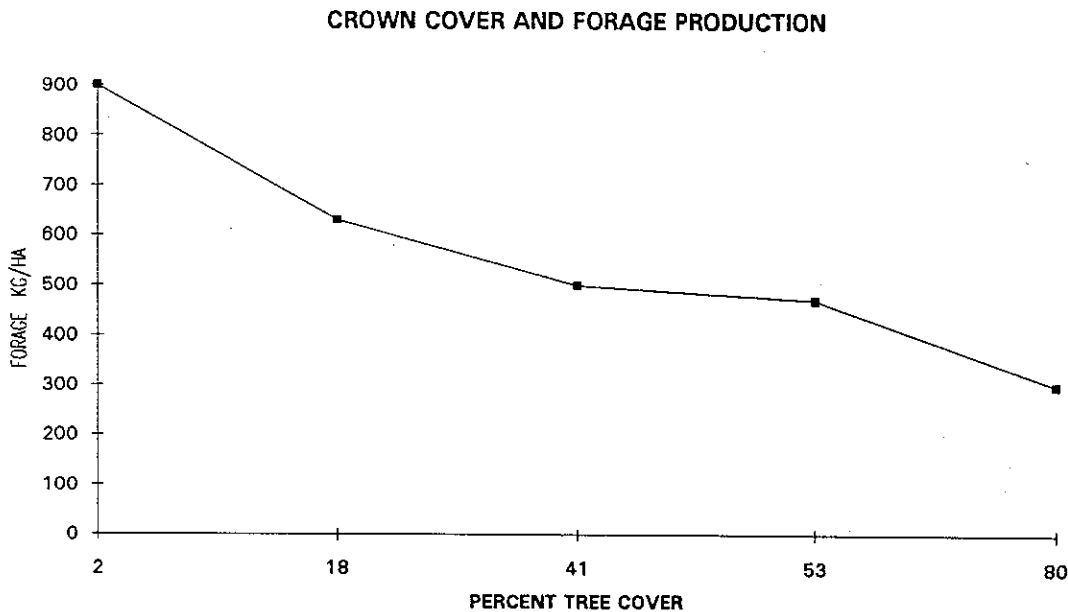
Failure to adjust silvicultural approaches such as harvesting, site preparations, species and genetic fitness to site conditions will negate what would otherwise be an effective

forest health program. Insect and disease activities increase the flammability of fire-maintained/fire excluded ecosystems stocked with shade tolerant species. The longer the return to normal fire periodicity is postponed, the more severe the inevitable natural adjustment becomes. Highly productive sites that can support the stress longer will eventually experience the most severe fire. These stands increase the flammability of the entire landscape to the degree that even communities with long duration fire cycles are at risk.

NATURAL RESOURCE IMPACTS: LIVESTOCK PRODUCTION

A long-established ranching industry of some 250 tenures is dependent on the grasslands of the Nelson Forest Region. True open grasslands are almost nonexistent here; other than temporary forest cutblock seedings, livestock and wildlife are totally dependent on the understory forage and browse produced in open PP and IDF stands. These areas are used by cattle for summer (May-October) grazing and wildlife for winter (February-April) grazing. Much of the material presented in this Section applies equally to the Wildlife Section.

The relationship between understory forage production and forest ingrowth, as measured by canopy closure, is an inverse linear one. Dodd, McLean and Brink (1971) documented this at various IDF and lodgepole pine sites in the Kamloops and southern Cariboo Regions. The graph below (an IDF site at 1100 meters, 22 km nw of Kamloops) is typical of their findings.



In going from an open parkland stand structure of under 30% crown closure to a closed forest structure of 70% or greater closure, roughly 40% of the understory productivity is lost, through restricted sunlight, moisture, and nutrients. A similar analysis, although of a very preliminary nature, was recently done in the East Kootenay Trench area, using the four crown closure categories described on page 9.

Understory Forage Production at Old Kimberley Airport Site

CLASS	AVERAGE PRODUCTION		RANGE, KG/HA
	G/M ²	KG/HA	
0 Open Grassland	103	1030	500 - 1500
1 Treed Grassland	192	1920	1000 - 2500
2 Open Forest	27	270	150 - 500
3 Closed Forest	7	70	10 - 150

An increase in production is noted between Open Grassland and Treed Grassland; the explanation for this is likely that the few Open Grassland sites have never experienced forest ingrowth because they have very poor soil and microclimatic conditions for vegetative growth in general.

Using these figures, the livestock forage loss due to excess ingrowth in the 400,000 Ha low-elevation Trench ecosystem is approximately 11,000 AUM per year. This equates to 4350 tons of forage, or 1840 beef cows grazing for five months.

In addition to a quantity loss, a dramatic forage quality loss also occurs. Under open-grown PP or IDF sites, the dominant forages are bunchgrasses such as bluebunch wheatgrass, rough fescue and stipa species. These bunchgrasses contain relatively high protein levels during the growing season, and because of a quirk in bunchgrass physiology, the protein "cures on the stem" and remains available through the fall and winter. In contrast, the understory forage in closed and ingrown sites is primarily the rhizomatous pinegrass, which contains lower levels of protein during the growing season and does not cure on the stem in the fall.

Fire exclusion converts open PP and IDF stands to closed stands through ingrowth. Fire exclusion also results in tree encroachment into open grasslands. This is evident in the small natural grassland openings that occur in the valley bottoms. Active encroachment by young Douglas fir and ponderosa pine seedlings can be seen in virtually all of these openings. As a result, livestock (and wild ungulates) become restricted to smaller and smaller areas of productive forage, and overgrazing results. Movement between areas of productive forage also becomes restricted, since there is often a "biological desert" of ingrown forest between these areas. This makes proper livestock rotation and distribution more difficult.

District staff has also noted a reduction in the water table in recent years, to the point that springs and small sloughs have dried up, further complicating livestock movement. There is a

possibility that some of this reduction of the water table is due to forest ingrowth, although no research is available to confirm this.

The grazing of livestock and wild ungulates can work in tandem with prescribed fire in maintaining the proper balance between trees and forage understory. Moderate levels of grazing in grasslands and open forests prevents the buildup of grass litter, which would otherwise insulate the soil and provide favorable conditions for tree seedling germination. This process is plainly obvious at the McLean Range Exclosure near Skookumchuk, where total protection from grazing since 1960 has resulted in dramatic ponderosa pine ingrowth into what was previously a dry grassland site.

Forest cutblock grazing has increased substantially in the Region over the past decade, to a certain degree in response to declining forage availability in the ingrown forests and encroached grasslands. Cutblock grazing has generated a number of complex integrated resource management (IRM) issues that involve ranchers, forest companies, Silviculture staff and Range staff. Excess ingrowth and the resulting decline in the traditional forage base has meant an increase in demand for cutblock grazing, inadequate resolution of the IRM issues, and the potential for management "wrecks" in the cutblocks.

Environmental group pressures to reduce or eliminate livestock grazing in sensitive sites such as alpine, riparian, and domestic watershed areas contributes to the urgency of resolving the forest ingrowth and encroachment problem.

The presence of a certain amount of fine or "flash" fuel (dry grasses, forbs and shrubs) was an integral part of the traditional fire-maintained open forest. The flash fuels (primarily dry grasses) a method of fire spread through open or fuel-deficient patches within the forest. Livestock (and, to a lesser extent) wildlife grazing tends to reduce the amount of flash fuels. However in most cases sufficient flexibility exists to exclude a candidate area from livestock grazing for a season to allow flash fuels to build up.

NATURAL RESOURCE IMPACTS: WILDLIFE

A number of wildlife species, deer and elk in particular, favor open-grown, parkland forest habitats. These animals are particularly attracted to the seral, fire-adapted shrubs, such as Saskatoon, that do well in burned areas. Demarchi (1971) estimates that 58% of the area of productive seral vegetation in the East Kootenay Trench has been eliminated by the unmanaged secondary forest succession brought on by fire suppression.

Elk and, to a lesser extent deer, do depend on the nutritious bunchgrasses for winter grazing, and they are, like the livestock, impacted by the conversion of bunchgrass ranges to pinegrass ranges. Several threatened and endangered species, such as the horned lark, long-billed curlew and yellow badger require open grassland habitat. The Columbian sharptailed grouse, another grassland-dependent species, has already been extirpated from the East Kootenays.

An additional factor reducing quantity and quality of understory forage production (for both wildlife and livestock) in fire maintained/fire excluded stands is the amount of nutrient capital tied up in standing dead or decadent woody material. The low temperatures associated with ecosystem maintenance burns will mean that some of this capital is returned to the soil rather than volatilized. Other partially burned materials will fall to the ground, become available for microbial breakdown, and contribute to longer-term nutrient cycling.

There is a growing problem of wild ungulate depredation of private land agricultural fields in the valley bottoms in the Nelson Region. In part, this is due to the declining quality and quantity of forage in the adjacent forest lands. Much of the current conflict between agricultural and wildlife interests in the East Kootenay Trench can be traced back to the problem of forest ingrowth and the resulting competition for dwindling forage resources.

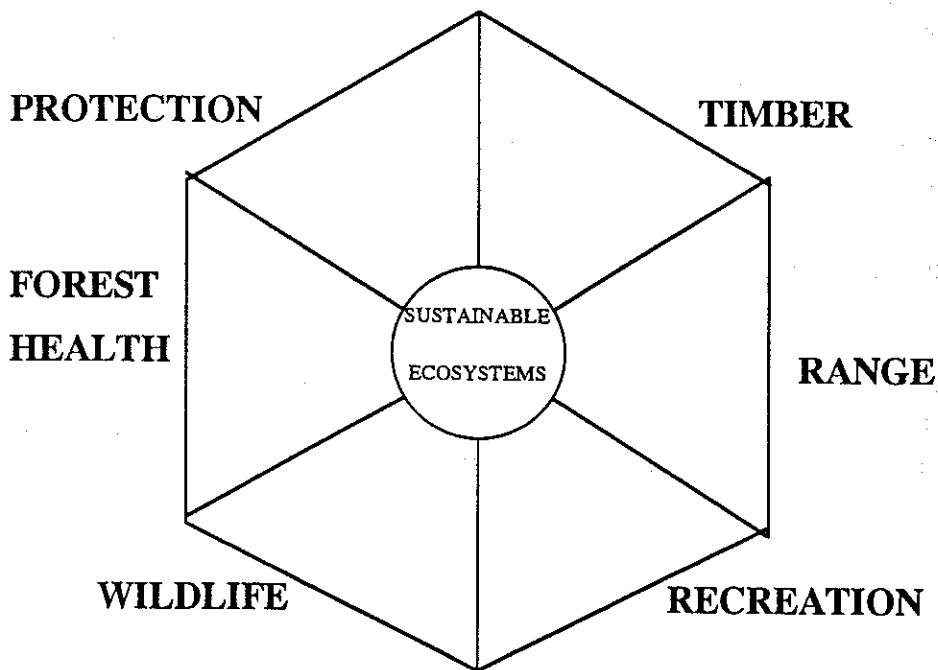
A total reversion to open forest and grassland would not serve the needs of wildlife: some patches of dense cover are required for ungulate thermal and hiding cover, as well as for those wildlife species that are dependent on dense forest habitat. The ideal for wildlife, as for many other sectors and concerns, is a continuously varying mosaic.

NATURAL RESOURCE IMPACTS: VEGETATION BIODIVERSITY

The grasslands of the Rocky Mountain Trench contain the highest concentration of rare and endangered plants in the Nelson Forest Region (Radcliffe and Porter, 1992). These species are further threatened by forest ingrowth. Local, unique subzones of PP in the Boundary District and IDF in the Arrow District are also at risk from ingrowth.

SUMMARY: NATURAL RESOURCE IMPACTS

Properly applied ecosystem maintenance burning is a true integrated resource management tool, since it provides benefits in a number of different program areas. To illustrate this in graphic terms, burning can be thought of as a six-sided polygon, with each facet representing a separate benefit stream:



A long-term benefit to ecosystem maintenance burning and the return to normal fire cycles will be an increase in the buffering capacity and sustainability of the subzones in question.

NATURAL RESOURCE IMPACT SUMMARY, BY SECTOR**TIMBER****BENEFITS**

1. Better stand structure, resulting in fewer stems/Ha, better individual tree growth rates and greater final dbh.
2. Reduced risk of stand-replacement fires and attendant timber losses.
3. Limbing action of ground-oriented prescribed burning produces clearer, straighter logs
4. Offers a cheaper alternative to mechanical thinning.
5. Recycles nutrients otherwise tied up in immature, decadent trees and slash.
6. Improves stand stability by increasing the diversity of tree species, age classes and canopy cover.

POTENTIAL NEGATIVE IMPACTS

1. Fire escapes may consume merchantable timber
2. Perceived impact of understory burning on AAC of forest license holder.

FOREST HEALTH**BENEFITS**

1. Better-spaced, more vigorous trees less prone to insect, fungus and/or mistletoe attack.
2. More open stand structure reduces rate of spread and final size of disease infestations.
3. Decreased incidence of root diseases due to reduction of food base, enhancement of competitive saprophyte populations, and reduced size of root networks.

POTENTIAL NEGATIVE IMPACTS

1. Individual trees that are weakened by fire, but not killed, may be more prone to insect or disease attack.

PROTECTION**BENEFITS**

1. Reduced fuel loading in low elevation forests close to settlements, reducing risk of interface fires.
2. Increased fireproofing of trees remaining after prescribed burn
3. Reduced risk and severity of wildfires
4. Shortening of fire season
5. Reduction over the long term of fire-fighting expenditures

POTENTIAL NEGATIVE IMPACTS

1. Possibility of escapes, with potential loss of merchantable timber and/or built infrastructure
2. Increased costs on the short term

RANGE

BENEFITS

1. Reverse current trend of accelerated forage loss due to uncontrolled ingrowth
2. Reduce conflicts with wildlife interests over use of scarce forage resources
3. Reduce grazing pressure on remaining grasslands
4. Improve distribution of livestock
5. Gradual improvement in ecological condition of grass/shrubland plant community
6. Possible rise in water table through reduction in proportion of deep-rooted tree and shrub species, leading to increased forage production and more available surface water.

POTENTIAL NEGATIVE IMPACTS

1. Possible short-term forage loss

WILDLIFE

BENEFITS

1. Reverse current trend of loss of open grass/shrub habitats due to uncontrolled ingrowth
2. Reduce conflicts with livestock interests over use of scarce forage resources
3. Reduce grazing/browsing pressure on remaining grasslands
4. Improve distribution, vigor, and reproductive performance of wild ungulates
5. Increased habitat diversity, leading to greater diversity of wildlife species (birds, small mammals etc.)

POTENTIAL NEGATIVE IMPACTS

1. Short-term forage and browse loss
2. Mortality of certain ground-nesting birds and small mammals
3. Short-term loss of snow interception and hiding cover.
4. Shift towards wildlife species that favor open forest and grass/shrub habitats over forest habitats.

RECREATION

BENEFITS

1. More attractive landscape for hiking, xc skiing, wildlife viewing
2. Enhanced wildlife viewing due to increased diversity of species.
3. Better distribution of recreational use of Crown land

POTENTIAL NEGATIVE IMPACTS

1. Short-term loss of visual esthetics
2. Short-term inconvenience to recreationalists due to smoke emissions.

4.0 PROBLEM ANALYSIS: SOCIOECONOMIC FACTORS

INTRODUCTION: SOCIOECONOMIC IMPACTS OF FIRE EXCLUSION

An in-depth discussion of all social and economic factors associated with fire exclusion in fire dependent areas is beyond the scope of this report. However, discussion of some obvious socioeconomic aspects is possible, and necessary, to understand understory burning for forest vegetation management. People want to know how any proposed actions might affect them. All people in the local area, and beyond, are socially affected by forest management decisions. These decisions affect their lifestyle, attitudes, beliefs and values. Community stability and cohesion can be affected positively when consensus develops, or negatively when people take opposing sides. People are also concerned about money and want to know that it is being spent wisely.

SOCIOECONOMIC IMPACTS: PROTECTION

Continued exclusion of fire in fire-maintained ecosystems will necessitate continued fire suppression with increasing risk of wildfires and direct fire suppression costs. Long term fire exclusion without associated activities to minimize its effects, such as harvesting, sanitation cutting or understory burning results in forest structures with high levels of wildfire hazard. These stands have increased the flammability and risk of wildfire to the entire landscape, and the longer this continues the more severe and damaging the reversion to a post fire condition will be.

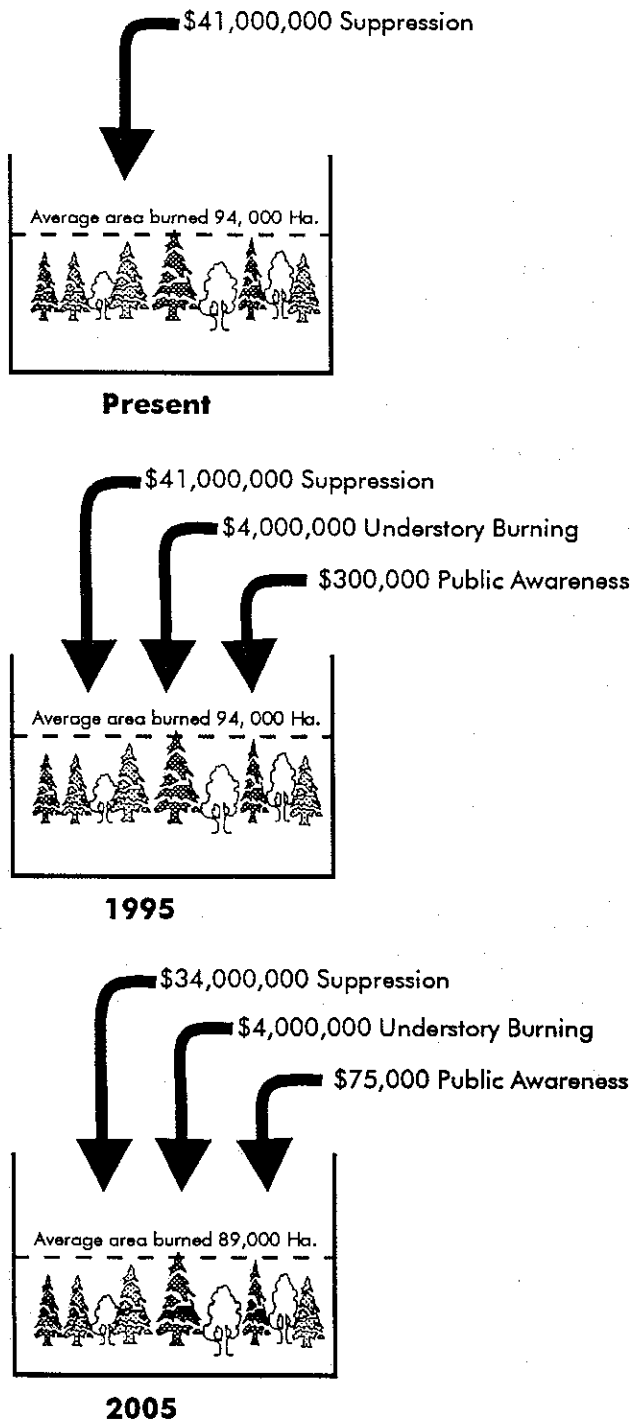
Several recent examples exist which demonstrate the eventual outcome of fire suppression without an ecosystem approach to vegetation management. The best known are the Yellowstone National Park fires in 1988. Over 50% of the park area was burned to varying degrees, despite the efforts of more than 10,000 fire fighters. Another less known example is the 128,500 Ha Foothills fire that threatened the city of Boise, Idaho in 1992. The only surviving large stand of timber in this fire was located at Tiger creek. This 1,100 Ha stand had been commercially thinned and understory burned. When the Foothills fire reached this stand it stopped and allowed fire fighters to gain control on that sector of the fire. Closer to home at Spokane, Washington, Firestorm 1991 destroyed over 70 homes and took the lives of several people.

These incidents are not unique to the United States. The town of Lytton B.C. has burned twice and been threatened several times. Mount Boucherie at Kelowna, B.C. was the site of a \$160,000 fire in 1992 which caused the evacuation of 109 people and threatened property values in excess of \$10,000,000. In the Invermere Forest District in 1985, fires caused the evacuation of Canal Flats, burned over 36,000 Ha and cost more than \$18,000,000 to suppress. One of these fires, the Spen fire, burned some 18,000 Ha, a good portion of which was in heavily ingrown forest. In 1994, two fires in the Penticton Forest District resulted in the evacuation of 3,500 people, the destruction of 18 homes, over six million dollars in direct suppression costs and resource impacts on 8,200 hectares of forest land.

Areas that have had previous understory burning would not be subject to wildfire and could provide much needed buffers to prevent the spread of wildfire if their size and distribution were sufficient. Could several millions of dollars in fire suppression costs be saved, along with many hectares of valuable timber? An active understory burning program of fire maintained ecosystems could theoretically result in the scenario shown in the accompanying graph.



Conceptual Costs of Understory Burning



The figures above represent the area and costs associated with fire suppression for the entire province. Delineating fire figures for areas suitable for understory burning in the southern and central interior of the province only, would show a much greater effect since the fire suppression costs of the northern and coastal areas, where understory burning is not feasible, would be removed. Of interest in the above graph is the reduction of total suppression costs after one decade of a sizable understory burning program.

This proactive approach to wildfire/ecosystem management will require substantial investment in training, reeducation, and public information. Recent public meetings in the Nelson Forest Region for presenting proposed understory burn plans in the local areas met with overwhelming interest and approval by locals. The cost for this extension work is a necessary component of a successful understory burning program as it gives the public an opportunity to be involved and share in the management decisions that affect their forest and quality of life. Because the Ministry's extension message of "preventing forest fires" has been so effective, a further extension effort will be necessary to explain the merits of ecosystem maintenance burning to the public, with the modified message of "preventing *wildfires*."

SOCIOECONOMIC IMPACTS: SMOKE MANAGEMENT

Not all aspects of an understory burning program are positive. Perhaps the most negative aspect is smoke, which can create a short term impact, with long term consequences. *This is primarily due to public opinion.* Failure to ensure community support will greatly increase complaint levels and perhaps jeopardize the ability to conduct a program at all. With the local community in full agreement and understanding of these programs, smoke related problems will be greatly minimized. Only after this support is achieved, should the technical specifics of smoke reduction be discussed. (Refer to the Nelson Forest Region Smoke Emission Reduction Standard Operating Procedures in Appendix 1 for technical details of smoke reduction.)

The largest cost in understory burning is full area mop-up to reduce smoke production as quickly as possible, as compared to perimeter mop-up that is done to minimize the chance of fire escape to areas outside of the burn. Mother nature can perform most of these mop up functions on the interior areas of burns at a much lower cost if we have the patience to accept light smoke for a few extra days. The same people who are concerned about smoke are also concerned about how their tax dollars are spent. The logic of accepting hangover smoke for a day or so and thereby saving many thousands of dollars in mop up costs may well be acceptable to the informed public.

Some air quality specialists are aware of the potential conflicts between controlling smoke emissions and the need for ecosystem maintenance burns, and have proposed the following caveat to air quality standards:

"In instances where this goal [of air quality] conflicts with the application of prescribed fire for the express purpose of precisely replicating the beneficial aspects of wildfire, the resulting emissions and visibility impairment should be considered to be natural, or part of the background" (Reid, 1993).

SOCIOECONOMIC IMPACTS: SILVICULTURE

Manual thinning will achieve the desired level of stocking in one pass, and allow the manager to achieve the composition of tree species he or she desires, if there are enough stems of the desired species to begin with, and if they are distributed homogeneously throughout the stand. However, this creates a serious fuel loading problem on the forest floor, which has the additional negative effect of suppressing grass, herb and shrub regeneration and growth. Furthermore, the use of commercial thinning in many fire-maintained or fire excluded stands will be prevented by the fact that the stems removed are those most desired to form the future crop. In these stands the use of fire to select thin barked species comprising the under story will produce immediate changes to the stand environment that will encourage faster growing tree species.

Burning is unlikely to create the desired level of stocking on the first try. Multiple passes will be needed to reduce initial fuel loads and eliminate the small diameter, shade tolerant stems. These burns will reduce the fuel hazard and promote regeneration of desired grasses, herbs, shrubs and tree species. The cautious introduction of fire in many heavily overstocked areas will be require as many as three times to gradually reduce stocking to the desired level and promote the establishment of desired species. These fires are known as **reduction burns** and are the most expensive form of burning, with costs as high as \$150.00/ha if pre burn slashing or other treatment is required.

Once the desired stand condition is reached, subsequent burning will be done to maintain conditions. This type of fire is a **maintenance burn** that is much cheaper. Burning costs under \$15.00/ha are possible if the area treated is of a size which permits good economy of scale, burning crews are experienced, units take advantage of natural terrain features to reduce the risk of escape, and burning is carried out under optimal weather conditions. Slashing or other pre treatment is not required and fire intensities are low if burning is done on a regular cycle of approximately 20 to 30 years.

Intensive silviculture is performed on established and "free growing" stands. This type of silviculture is expensive but will usually produce a more valuable crop at rotation. Typical treatments include thinning (spacing), fertilizing and pruning. Costs for conventional treatments range from \$200/ha for fertilizing and pruning, to \$800/ha for thinning. In overstocked fire based ecosystems, thinning treatments will be necessary for basic stocking control which does not happen in the absence of fire. Fire on the other hand is a natural stocking control agent that will favor removal of dense regeneration, the sick and diseased, and fire susceptible species. Natural pruning also occurs as low limbs are readily consumed and fuel ladders are eliminated.

When the spinoff benefits to other resources are calculated for prescribed burning and compared to conventional silviculture costs, many of the arguments against fire are eliminated.

5.0 EMBER OBJECTIVES

In response to the preceding Problem Identification and Analysis, we have created the Ecosystem Maintenance Burning Evaluation and Research (EMBER) Pilot Project, a three-year project that will:

1. Plan, assist in the execution, and evaluate pilot burns in the Cranbrook, Invermere, Arrow and Boundary Districts;
2. Coordinate with the Research Branch and the Canadian Forestry Service in conducting relevant fire research projects;
3. Document any technical and administrative obstacles to achieving successful ecosystem maintenance burns, and make recommendations for removing those obstacles;
4. Produce a problem analysis and working plans regarding the natural role of fire in the ecosystem and operational feasibility of reintroducing fire through prescribed burning.
5. Make final recommendations to the Regional Management Team at the end of the the pilot project.

Thus the objective of EMBER is to **investigate the feasibility of an expanded and integrated ecosystem maintenance burning program for those parts of the Nelson Region's PP, IDF ICH and MS zones that were traditionally exposed to high-frequency, low-intensity fires, with the intention of improving stand structure and ecosystem function for forest health, silviculture, protection, range, wildlife and recreation purposes.** The expected outcome of the project will be the development of a comprehensive Regional fire master plan and a greatly expanded understory burning program.

A key element of the EMBER Project is District initiative. Since the Districts take responsibility for the actual burns themselves, they are the proponents of the trial burns, and the Committee acts in a support role.

6.0 EMBER STRATEGIC PLAN

Executive authority and coordination of the project will be provided by the Working Committee, composed of:

- Rick Stewart, Forest Health Officer, Nelson Region MOF (Chair)
- Greg Anderson, Operations Manager, Invermere District MOF
- Al Bond, Fire Management Coordinator, Nelson Region MOF
- Tom Braumandl, Research Ecologist, Nelson Region MOF
- Don Gayton, Regional Range Ecologist, Nelson Region MOF
- Don Hendren, Operations Supervisor, Cranbrook District MOF
- Mike Hudock, RO Protection, Kootenay Lake District MOF
- Mike Malmberg, District Agriculturalist, Cranbrook MOAFF
- Gordon Keir, RO Protection, Boundary District MOF
- Gary Tipper, Habitat Biologist, Cranbrook MOELP
- Skip Walsh, RO Protection, Arrow District MOF

Committee Roles and Responsibilities

- Provide overall coordination for the Project
- Keep Regional Executive abreast of developments
- Facilitate inter-District and inter-agency resource sharing
- Develop and implement Prescribed Fire Tracking System
- Supervise production of extension bulletin
- Coordinate external review process

District Roles and Responsibilities:

- Determine suitable candidate areas
- develop operational burn plan
- implement public extension for specific burns
- implement normal burn monitoring systems (Form 117A)

Regional Office Roles and Responsibilities:

- Assist District Program development
- Establish and monitor research plots
- Evaluate impacts and make cost comparisons
- Liaise with other Ministries
- Assemble extension bulletin
- Coordinate Workshop
- Develop burn prescriptions and monitor burn impacts

PROJECT TIMELINE

The EMBER Project began in 1992, will include the burning seasons of 1993 and 1994 and 1995, with final report and recommendations to be submitted by January, 1996. Research projects will begin concurrently with the Project, but will be expected to carry on beyond 1996.

PROJECT DELIVERABLES

2. **6 Burn Plans** (one main, one alternate for each District), for prescribed understory burns to be done under the auspices of the Project.
3. **3 Prescribed Understory Burns** (minimum), ideally at least one in each District, by October of 1994.
4. **Research Project(s)** (see Section 7)
5. **Ecosystem Maintenance Burning Symposium** (spring, 1995)
6. **Ecosystem Maintenance Burning Extension Bulletin**, for consumption by the public, by January 1995. (Estimated Cost \$4000)
7. **Final Report and Recommendations** to Regional Management Team, by January, 1996.
8. **External Review of Project** by June, 1996.

7.0 RESEARCH STRATEGY

Research associated with the EMBER project tries to address two major topics.

1. What is the extent of the problems associated with fire exclusion in the Interior Douglas-fir (IDF) and Ponderosa Pine (PP) zones of the Nelson Forest Region?
2. What are the ecological effects of reintroducing fire?

Topic 1 approach. There is a perception that large portions of the IDF and PP zones have exhibited significant forest ingrowth in the last half of this century, in part due to fire suppression. Reconstructing conditions prior to significant non native intervention is difficult, given the lack of good historical records of logging and grazing before the second half of this century. Evidence from similar environments in the U.S. suggests that much of the IDF and PP were dominated by open ponderosa pine, maintained by periodic, light intensity fire (Gruell *et al.*⁶, Leiberg⁷). Changes in forest cover can be easily traced from the late 1940's to the present by comparing the oldest available aerial photographs with recent photos.

A project has been initiated to quantify, using aerial photography, the amount of forest ingrowth in three areas in the Rocky Mountain Trench (total area approximately 50 000 Ha). The areas range over most of north - south extent of the PP and IDF (the portion of the IDF that has significant extant grasslands). The photo typing was entered into a Geographic Information System (GIS) and derivative maps of areas undergoing different rates of forest ingrowth were generated. Selected areas experiencing rapid change and those showing little change were visited and site, soil, and site history information were gathered. The project should provide estimates of areas dramatically altered due to fire suppression and site and historical features of these areas. This should assist in identifying areas for treatment. The report and maps for the East Kootenay will be produced by December 1995. If the project proves useful it may be extended to the Boundary Forest District in the following year. (Work plan found in Appendix 1)

Topic 2 approach. A major thrust of the EMBER project is to develop operational expertise in burning the dense problem stands that have developed. Several demonstration burns are planned during the pilot project. The approach to investigating fire effects is to monitor these demonstration burns rather than installing small scale, replicated, research burns. Components being measured include: fuel loading, vegetation (trees (mortality, regeneration, growth), shrubs (cover, height, biomass, utilization), and herbs (cover, biomass), fire behaviour, and insect and disease occurrence. Forestry Canada and Protection Branch will be cooperating to develop smoke emissions models for these fuel and burn types as part of their Smoke Plume Evaluation and Modeling project (see Appendix 2). A sample methodology for the pre burn stand, site, shrub, and insect and disease assessment is found in Appendix 3. Post burn assessments will be carried out 1, 3 and 5 years post burn. The surface fuel, surface temperature, fire behaviour, and atmospheric condition methodology is presented in Appendix 4 (taken from Taylor *et al.*⁸).

⁶ Gruell, G.E., W.C. Schmidt, S.F. Arno, and W.J. Reich. 1982. Seventy years of vegetative change in a managed ponderosa pine forest in western Montana - implications for resource management. Gen. Tech. Rep. INT-130. Ogden, UT; U.S. Department of Agriculture, Forest Service, Intermountain Station

⁷ Leiberg, J.B. 1899. The Bitterroot Forest Reserve. Washington, D.C.: U.S. Geological Survey. 19th Annual Report (1897-1898), Part V: 253-282

⁸ Taylor, S., C. Ross, and B. Armitage. 1993. Ecosystem maintenance burning evaluation and research project: fire behaviour and impact research component. 1993/94 working plan and progress report, Skookumchuck and Picture Valley sites. Draft file report. Canadian Forest Service.

Appendix 1 Workplan for forest ingrowth study

TITLE: Estimating forest ingress due to fire suppression in the Ponderosa Pine (PP) and Interior Douglas-fir (IDF) biogeoclimatic zones of the Nelson Forest Region

1.0 INTRODUCTION Major problems have been encountered in areas of western North America where fire suppression has dramatically altered the natural fire cycle. These problems include the loss of forage production, increases in forest health problems, loss of merchantable volume in overstocked stands, and increased hazard of catastrophic wildfire (Dorey 1979; Arno 1988; Barrett 1988; Habeck 1990; Losensky 1992; McLean 1993).

Effective fire suppression has been undertaken for almost fifty years within the Nelson Forest Region. Normal fire return intervals in the PP and IDF zones range from five to twenty years. Most mesic forest stands within these two zones would have experienced between one to ten light intensity understory fires since the advent of effective fire suppression. The effects have been dramatic. Widespread forest ingrowth is apparent. A number of air photo mosaics of parts of the Boundary, Cranbrook, and Invermere Forest Districts have been assembled using early 1950's and recent photography illustrate this ingrowth.

There are various figures that indicate the magnitude of the problem. The PP and IDF zones in the region comprise about 530,000 Ha. About 400,000 Ha. of fire maintained ecosystems are found in these two zones, assuming that 25% of total area are ecosystems not dependent on periodic, understory fires, i.e., riparian or rocky sites. Using a fire return interval of 20 years, about 20,000 Ha. per year would be expected to burn without fire suppression. The Trench Integrated Renewable Resource Management Plan (known as the Trench Plan), a strategic plan identifying resource use priorities, covering a large portion of the East Kootenay portion of the PP and IDF zones, has identified close to 100,000 Ha. where fire is an acceptable treatment (primarily where forage was the primary use (T. Volkers, pers. comm. 1992). An estimate of overstocked stands within the Cranbrook portion of the Trench (due in large part presumably to the exclusion of fire) is 90,000 Ha. (J. MacLeod, pers. comm. 1992). Another concern with forest encroachment onto grasslands in the Rocky Mountain Trench is the loss of biological diversity. The greatest number of rare plant species within the Nelson Forest Region are found on grasslands in the Trench⁹. Regionally rare wildlife species, such as, the Sharp Tailed Grouse, Long Billed Curlew and badger require grassland habitat.

The forest/grassland ecotone vegetation changes due to climatic cycles, fire occurrence, and grazing. Logging can have a significant impact due to the relatively poor regeneration establishment and slow growth. The apparent trend of climatic warming should favour grasses over trees. In spite of the influence of climate and logging, a number of sources point to a large area of significant forest encroachment, with its attendant increase in stands of poor health, reduction of forage, and increase in the likelihood of catastrophic crown fires, there is no clear

⁹ *Biodiversity of the Nelson Forest Region* by G. Radcliffe and G. Porter. 1992. Contract report for B.C. Forest Service Nelson Forest Sciences Section.

quantification of the amount of forest encroachment. It is critical to have an appreciation of the size of the encroachment if we are to plan a program to deal with the problem. As well, certain sites have undergone rapid ingrowth while others have remained relatively unchanged in terms of canopy cover during the last 40 years. It would be useful in assessing sites for treatment to be able to identify site and treatment features that have led to these contrasting developments.

2.0 OBJECTIVES

1. Estimate area and degree of forest ingress, within the PP and IDF zones of the Nelson Forest Region, since the advent of effective fire suppression.
2. Characterize features (e.g., subzone, site series, soil and site features, management and disturbance history) of areas that have had little forest ingress and those that have had significant forest encroachment.

3.0 METHODS

The activities planned for 1993 are designed as a pilot study. If found useful the methods will be extended to the rest of the PP and IDF zones in the Region in 1994.

3.1 Study Area Selection

Locate an approximately 20000 Ha area of the trench that has not had extensive logging or fires over large portions from 1930 to the present. B.C. Forest Service records, both at the Cranbrook District Office and at the Provincial Archives, fire history maps at the B.C. Ministry of Environment office in Cranbrook, and historical accounts in local museums will be consulted,

3.2 Photo Interpretation

Obtain oldest aerial photos (circa 1950) and most recent, of similar scale, of portions of the Rocky Mountain Trench outside of heavy tie cutting areas (portions of the Trench were heavily logged during the early part of the century; these areas would inflate the area of grassland and low tree cover). Identify areas of different crown closure. A four class system will be used: open grassland (0 to 5 % cover of trees); treed grassland (6 to 15% cover of trees); open forest (16 to 40% cover of trees); closed forest (>40% tree cover). Digitize crown cover classes interpreted from air photos. Generate derivative maps of areas of rate of change classes:

- slow (same cover class);
- moderate (one cover class change); and
- rapid change (two or cover class change)

The effect of logging and fire, during the 1950 to 1990 period, on tree cover within the study area will be subjectively assessed.

3.3 Field sampling

A random sample of 10 polygons in the slow change class (initially in either the grassland or treed grassland cover class) and 30 polygons in the rapid change classes within both biogeoclimatic variants will be selected. Any sites that have had dramatic reductions in tree cover due to logging will be rejected. A transect will be laid out across the selected polygon and three randomly located plots will be placed along the transect. Site features sampled will include elevation, aspect, slope, soil moisture regime, soil texture, humus form and depth, soil classification, site series. A 0.02 Ha (7.98m radius) plot for all trees < 12.5 cm dbh and a prism sweep for larger trees will be carried out according to SIWG (1992) at each plot. Logging and grazing history will be determined from Forest Service records. Any evidence of pre 1950 harvest (rotten stumps) or the long term existence of forest (brunisol gray luvisol or eutric brunisol rather than melanic brunisol or chernozemic development) will be noted. The presence of fire scarred trees will be noted to allow for sampling if time and money permits at a later date.

3.4 Data Analysis

Summaries of crown cover classes by subzone 1950 and 1990, and amount of area in each rate of change class by subzone will be generated. Stocking by diameter class tables for those sites sampled will be produced. Age class distributions for rapid and slow change class sites will be graphically compared.

4.0 RESPONSIBILITIES

Project Leader: Tom Braumandl, Research Ecologist, Nelson

Technical Supervision:

Technical Review: John Parminter, Research Branch
Steve Arno, USDA Fire Ecologist, Missoula, MT
Phil Burton, Faculty of Forestry, U.B.C.

5.0 EXTENSION

Reports will be produced in November 1993 and April 1994. A presentation will be made at the planned Nelson Region ecosystem maintenance burning workshop in the spring of 1995. A poster display will be prepared using the digital maps and existing air photo mosaics,

Appendix 2 Smoke plume evaluation and modeling project summary

(not available at press time)

Appendix 3 Sample pre burn assessment methodology

Site description and treatment monitoring of the Findlay Creek 1994 ecosystem maintenance burn

A burn is scheduled for the last week in April 1994 in the Invermere Forest District. The burn is located about 17.5 km. west of Hwy. 93/95, on the Findlay - Doctor Forest Service road. The proposed burn area totals about 56 Ha.

The contractor shall:

Layout plots - Two strata will be sampled: a Fd, Py type within the proposed burn area and a similar type outside the proposed burn area (the control). Within each stratum, 30 plots will be established systematically (see attached map). Plots are to be placed no closer than 30 m to any road, severely disturbed area, area of a strongly contrasting site series, or stratum's boundary (minimum inter plot spacing 40 m). Plot centers will be marked with 1.5m high piece of electrical conduit or rebar (supplied by contractor) placed firmly in the ground. Plot locations will be established during a field visit with the contract coordinator.

Describe the strata - Two randomly chosen site description plots will be established in each of the strata: areas. Procedures for site description will follow *Site mapping, data collection and sensitivity evaluation for pre-harvest silvicultural prescriptions: Interior sites* by R. Mitchell, M. Curran, and R. Newman. October, 1992 draft land management handbook 25 (available on request). Features to be noted include those outlined in the *Data collection procedures* section up to and including point 37. Approximately 10 minor inspections per stratum (shallow check pits or observation of tree churns or road cuts) will be made to ensure site features have not changed significantly from the detailed sample plot. The sample plot locations will coincide with fuel, stand description, vegetation, and insect and disease plots. Data will be gathered on F.S. 711A-1 forms (sample attached).

Describe stands - Using procedures described in *Correlated Guidelines for Management of Drybelt Douglas-fir Stands in British Columbia - first approximation* (relevant sections attached). At each plot center conduct a pre-burn stand assessment for layers 2, 3 and 4. as described in procedures under *Pre-harvest cruise* will be followed with the following modifications.

Layer 2 will be subdivided into two classes, 7.5 to 9.9 cm dbh and 10 to 12.5 cm dbh.

Layer 3 will be subdivided into two classes, >1.29 m in ht and up to 3.9 cm dbh, and 4.0 to 7.4 cm dbh.

Age, live crown and periodic increment will not be assessed for sample trees.

Layer 4 will have basal diameter and height measured for a representative sample seedling.

Pre-stand tending (FS 748) forms may be used to gather the information for layers 2, 3 and 4.

Two trees in each of layers 2 and 3 will be tagged with a metal tag, at each plot in all areas, except the unburned control areas. For these trees, height to live crown will be measured (to the closest 50 cm.)

Every second plot will have Layer 1 (>12.5 cm dbh) assessed. This will be done using a prism sweep. The same prism will be used throughout the strata. One tree per plot will have height measured while other trees will have height estimated using measured height as calibration. Cruise Tally Sheets (FS 205) will be used to gather layer 1 information. Eight trees in each plot, representing a range of diameters, will be tagged with a metal tag and have the height to live crown (to nearest 50 cm.) measured. Diameters of tagged trees will be noted. Trees will be tagged in all areas except in those areas noted in the previous paragraph. Tree ages (DBH age) and heights will be taken on codominant trees of each species at 5 randomly chosen plots within each of the strata for a total of 5 trees per strata of each major species (Fd and Py for area 1 and area 1 control; and Pl for area 2 and area 2 control)

Data will be entered into Microsoft Excel spreadsheets. Data will be summarized by plot, stratum, diameter class, species, and location. Data summarization format will be finalized at a meeting with Chris Thompson. Variables to be summarized include tree basal area, number of stems/Ha., and tree volume.

Photograph the plot center, with crew person for scale, from a point 10m due south with a 35mm camera with 28mm lens and slide film.

Note insect and disease conditions - At each plot center, that are assessed for layer 1 trees, all trees (within all layers described in the stand description) within a 5.64m radius will be assessed for insect and disease using the attached forms. The damage codes will follow those of the *Silviculture Survey Damage and Condition Codes Reference F.S. 747* form (attached). In the comments section the following will be noted:

1. A codes will include estimate of damage age if within three years.
2. DM codes will use the Hawksworth six class rating system.
3. IB codes will include stage of attack as green, red, or gray.
4. N codes will include estimate of damage age if within three years.
5. V codes will include a brief written description of problem and may apply to any portion of the stand.

Tree # refers to those trees numbered during stand description. Layer are as in stand description.

Measure shrubs (see attached figure)-

Five plots in each stratum will be randomly chosen for shrub measurements. At each of the randomly chosen plots a randomly oriented 30m transect will be established. The end point and the 15 m point will have a 1.5m piece of rebar or electrical conduit hammered

firmly into the ground. The origin of the shrub transect will be the plot center previously established under the locate plots section. (For plots that may have been previously sampled for fuels the orientation of the shrub transect will be at 180 degrees from the fuel transect.)

The intercept of each species, along the 30 m transect, will be measured to the nearest decimeter.

At 5 randomly determined points along the 30 m transect (random numbers from 0 to 29, also each number must differ by at least two) a 1X2m plot will be established. The corners of each plot will be marked with depth of burn pins or wire markers (supplied by the Forest Service). Within these plots, all stems emerging from the ground will be tallied by species.

Heights for all species encountered on the line transect will be measured for height. The individuals chosen will be the closest ones to the origin of each stem count plot.

At each stem density plot, a 1X1m plot will be established for shrub biomass estimation. The corners will be also marked with depth of burn pins or wire markers. The plot will be inspected for any shrubs that may be found in the space above the 1X1 m base of the plot. An average sized individual, of each species, found in the plot, will be clipped in an area nearby, but not within, the plot or under the transect. The clipped individuals will then be visually compared to volume of that species within the plot and assessed as a percentage of the clipped individual. The clipped plants can be used for several of the plots. They are to tagged for identification and bagged for future drying and weighing.

The data will be recorded on forms provided by the Forest Service (example attached). Data will be entered into a Microsoft Excel spreadsheet and summaries will be provided by plot and strata for cover by species, species height, stem count by species.

Two meters perpendicular to the origin of the stem density plot a 0.56m radius plot will be clipped of all herbaceous plants and grasses, including last years dead attached leaves. The clipped material will be bagged in paper bags , sealed and marked with plot identification

Final products will include a 1:10 000 scale map showing transect line location, sample plot locations, tie points, and major terrain features, completed 711A-1, cruise, pre-stand tending, and insect and disease forms, labelled, clipped reference shrubs, labelled herb clip bags, labelled 35mm slides, and data summaries (both in hard copy and on 3.5 inch diskette).

Appendix 4 Canadian Forest Service Research Objectives and Methods for two EMBER burns (excerpted from draft 1993/94 Workplan and progress report by S. Taylor, C. Ross, and B. Armitage)

The major theme of CFS fire research in the Pacific & Yukon Region is the development of fire environment models. The EMBER Project provides an opportunity to develop and test models of fire behavior, smoke emissions, and ecological effects in Douglas fir / ponderosa pine forests to support integrated resource management. These models will assist fire and resource managers in developing prescriptions to achieve management objectives. The smoke, fire behavior, and tree mortality models are linked to the other ecosystem research being carried out in the project. Specific CFS research objectives in EMBER follow.

Objective 1. Fire Behavior Prediction

Develop rate of spread, and fuel consumption equations for prescribed burning in Douglas fir and ponderosa pine ecosystems.

The existing rate of spread (ROS) equations of the Canadian Forest Fire Behavior Prediction (FBP) System (Forestry Canada 1992) are for fires originating from a single point ignition with acceleration to equilibrium ROS, or from single line ignition. We need to test which model best fits the prescribed fire ignition pattern of multiple lines produced from either a hand held drip torch or aerial ignition device (AID), and develop a model that accounts for varying ROS and fire intensity due to ignition pattern. Similarly, the fuel consumption equations in the FBP System do not include fuel load because they are intended for real-time application in fire suppression. We will reformulate the equations to include variable fuel load and stand characteristics for prescribed burning applications.

Objective 2. Smoke Emissions, Energy Release, and Dispersion Models

Extend the SPEM Project smoke modelling system to prescribed burning of unmodified fuels (e.g., underburning or ecosystem maintenance burning). In addition to fuel consumption equations, develop energy release rate equations, examine smoke emissions composition, and test smoke column development and plume dispersion models for ecosystem maintenance burns.

A family of models is being developed in the Smoke Plume Evaluation Modelling Project in order to provide managers with tools to forecast emissions yield, column height and plume direction from prescribed broadcast burns in logging slash. In order to extend the system to ecosystem maintenance burning, specific fuel consumption, fire growth rate, and energy release rate equations need to be developed for this fuel type.

We also need to collect data to test the smoke plume and dispersion models for ecosystem maintenance burns, because their energy release rate is probably much less than from broadcast prescribed burns. Furthermore, sampling of the chemical composition of the smoke from

ecosystem maintenance burns should be fostered in order to provide emission factors for emissions modelling.

Objective 3. Crown Scorch and Tree Mortality Prediction

Test crown scorch and tree mortality equations and link to fire behavior equations in a predictive model.

Ryan and Reinhardt (1988) and Harrington (1993) have developed single-tree mortality equations for eight western conifers that relate scorch height and tree diameter to the probability of mortality in a fire. These equations could be used to predict the impact of fire on forest stand structure and composition if information is available on stand structure and crown scorch height. The mortality equations were developed from studies in the U.S. and should be tested under the range of fire and stand conditions that occur in Canada. Also, we need to link the mortality equations to crown scorch height predictions for particular burning conditions. Crown scorch can be predicted from fire intensities of the FBP System and intensity - crown scorch relationships.

METHODS

The methods that will be employed to sample fire behavior and smoke characteristics will be very similar to previous sampling of broadcast prescribed burns in the SPEM Project (Taylor 1992), except that stand characteristics and tree mortality will also be assessed. The sampling intensity and variables sampled will vary between burn units depending on the size and variability of the study sites, and on the time and funding available.

Site and plot location

Two sites where operational burns were proposed were sampled in 1993. Pre-burn sampling was much less intensive at the Skookumchuk site than the Picture Valley site, and smoke was not sampled directly. This was because funding only allowed for intensive sampling of one site, and the Picture Valley unit was thought to be more uniform. Also, it was originally planned to burn a large unit of rangeland adjacent to the forested portion of the Picture Valley site at the same time, and this would have compromised the smoke sampling objectives.

Forty sample plots were systematically located at the Picture Valley site, and nine were subjectively located at the Skookumchuck site.

Stand characteristics, crown scorch, and tree mortality

The stands were sampled to assess pre-burn structure, volume, biomass and crown fuel load. Trees were sampled in six size classes (>12.5 cm DBH, 10.0 - 12.5 cm, 7.5 - 9.9 cm, 4.0 - 7.4 cm, >1.3 m height - 3.9 cm DBH, and <1.29 m. height - 0.3 m.) The height and diameter of trees >12.5 cm DBH were measured in twenty variable area (prism) plots at Picture Valley, and in nine fixed area (400 m²)-plots-at Skookumchuck. The smaller trees (<12.5 cm DBH -0.3m ht.) were counted by size class in fixed area (100 or 200 m²) plots using dry-belt Douglas-fir pre-stand

tending survey procedures (BCMF 1992b). Trees <0.3 m height were tallied in the shrub layer, as described later in this section. Forty and nine small plots were assessed at the Picture Valley and Skookumchuck sites, respectively.

In addition, ten sample trees in each plot of a range of diameters (200 at Picture Valley and 90 at Skookumchuck) were marked with steel tags and the top height, height-to-live crown, and diameter were measured before burning. These data were used to determine height - diameter relationships for each species (Appendix B). Following burning, scorch height was assessed on the sample trees at Skookumchuck, and they will be revisited to assess mortality in future years.

Total stand volume was calculated using BCFS single tree volume equations (BCFS 1976); these data were needed to predict crown biomass. The crown fuel load (defined as foliage and <0.5 cm diam. branches) was calculated using equations of Standish *et al.* (1985) for > 12.5 cm DBH trees, and of Brown (1978) for < 12.5 cm DBH trees. Calculation of <12.5 DBH tree basal area, volume and biomass was based on the diameter class midpoints; mean heights of the diameter class midpoints were calculated using the height-diameter relationships. Brown's equations were used for the <12.5 cm DBH trees, because the Standish equations gave unreasonable values for small trees. The site mean values for the Skookumchuck site were derived from the individual plot totals of all layers. For the Picture Valley site, site means were derived as the total of the means of the small and large tree layers of all plots; in the latter procedure, the small and large tree layers were assumed to be independent (no covariance term) and the standard error of the sum was calculated as the square root of the sum of the variances of the mean for each layer.

Surface Fuels

Woody fuels on the forest floor surface were assessed using the line intersect technique; pieces were measured along randomly oriented lines using procedures in Trowbridge *et al.* (1986). Twenty and nine transects were sampled at the Picture Valley and Skookumchuck sites, respectively. Calculations of the pre-burn and post-burn fuel load were carried out using the FUELOADER computer program (deJong *et al.* 1989).

Ten t-shaped pins were placed along each transect (90 and 200/site) in order to measure forest floor depth-of-burn. Samples of forest floor material were collected by 2 cm depth class at each plot to determine relationships between relative density and cumulative mass with depth. Forest floor depth-of-burn and total depth measurements were made following burning at Skookumchuk. Forest floor mass and mass loss are were calculated as the product of relative density and total depth and depth-of-burn. An average relative density value was used for all depth classes because no meaningful depth - density relationships were found for the shallow forest floors on these sites.

The biomass of understory vegetation was determined using procedures of Brown (1982). In each large plot, the relative amount of grasses and herbs was visually rated in three 1.0 m² subplots with reference to a fourth plot. The latter was destructively sampled to determine the oven-dry biomass. A plot mean was determined from the measured value and the proportion estimates. The number of shrub stems were counted by species and diameter class in two 1.0 m²

subplots in each plot. Equations of Brown (1976) were used to calculate the biomass of each species from basal diameter class counts.

The tree, woody fuel, and vegetation sampling scheme is illustrated in Figure 3.

Surface temperatures

Time-temperature profiles at the forest floor surface during the fire were assessed using Forest Technology Systems (FTS) thermologgers. These data are used to estimate flaming and smoldering durations for energy release rate calculations, and can also be used to measure the rate of fire spread between points.

The FTS thermologger consists of three high temperature thermocouples and a datalogger. The datalogger is buried in the ground to prevent heat damage. Temperatures are recorded at 10 s and 1 min intervals from one and two of the thermocouples, respectively, when a surface threshold of 70 C is exceeded. Thermologgers were installed at twenty and nine locations at the Picture Valley and Skookumchuk sites, respectively. The thermocouples were located at +5, -1, and -2 cm relative to the forest floor surface at each site.

Fire Spread and Area Growth

Infra-red imagery will be used to measure fire area growth on EMBER burns, if circumstances permit; fire growth rate is one factor needed to estimate the energy release rate of the whole fire. A Barr & Stroud IR camera belonging to the CFS will be used for the imaging. The camera is mounted in a helicopter which is used to hover above the fire at varying heights (ranging from about 300 to 2000 m) depending on fire size. Images are recorded on video tape, and transferred to computer for determination of spread distances and area by digital analysis.

The IR camera was not used on the Skookumchuk burn because there was a conflict with use in Ontario, and because of relatively short lead time.

Fire weather, fuel moisture and fire behavior

Standard fire weather observations (temperature, relative humidity, 10 m windspeed and direction, and precipitation) were recorded hourly at weather stations adjacent to the Skookumchuk and Picture Valley sites, in order to calculate Canadian Forest Fire Weather Index System values.

The moisture content of the litter, forest floor, and tree foliage was sampled prior to burning at the Skookumchuk site, but the sample sizes were small because of time limitations.

Weather observations were also made using hand held instruments during the Skookumchuk burn, and flame height and rate of spread were observed. However, because an aerial ignition device was used in a strip head fire pattern to light the fire, these observations were limited to short intervals when the helicopter was refueling and were of initial spread from an ignition line.

Atmospheric Conditions and Smoke Plume Dispersion

Staff of the Fire Chemistry Project, U.S. Forest Service Intermountain Fire Sciences Laboratory, have sampled smoke emissions chemistry on two broadcast burns in the SPEM project to date, with the financial support of the B.C. Ministry of Forests Protection Branch. Protection Branch are also supporting atmospheric and smoke dispersion sampling and modeling in the SPEM project. Both of these agencies are interested in continuing this sampling on the EMBER burns. However, no direct smoke sampling was carried out on the Skookumchuk burn.

The methods that will be used where smoke sampling is carried out include:

1. Measurement of the height and rate of rise of the smoke column, and the movement of the smoke plume using a fixed wing aircraft. These data will be used to test smoke column models (eg Latham 1991) and a wind/smoke dispersion model (Danard and Galbraith 1990).
2. Atmospheric soundings (temperature, RH, pressure, wind speed and direction with height) are needed to drive the smoke column/plume models. The soundings will be carried out by BCFS or CFS staff using a ZEEMET W-9000 Meteorological Processing System owned by the BCFS Protection Branch. The system tracks and processes data from a radio-sonde (carried aloft with a standard weather balloon) which measures and transmits the atmospheric data to a surface receiver. A similar suite of atmospheric and smoke plume assessments have been carried out on six broadcast burns in the SPEM project during 1989-92.

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