Prescribed burning considerations for western Montana

Gardner Walton Ferry

The University of Montana

Follow this and additional works at: https://scholarworks.umt.edu/etd

Let us know how access to this document benefits you.

Recommended Citation
https://scholarworks.umt.edu/etd/3292

This Thesis is brought to you for free and open access by the Graduate School at ScholarWorks at University of Montana. It has been accepted for inclusion in Graduate Student Theses, Dissertations, & Professional Papers by an authorized administrator of ScholarWorks at University of Montana. For more information, please contact scholarworks@mso.umt.edu.
PRESCRIBED BURNING CONSIDERATIONS
FOR WESTERN MONTANA

By

Gardner W. Ferry

B.S.F., University of Montana 1965

Presented in partial fulfillment of the requirements for the degree of

Master of Forestry

1970

Approved by:

[Signatures and dates]
### TABLE OF CONTENTS

**ACKNOWLEDGMENTS** ........................................ ii

**LIST OF FIGURES** .......................................... iii

**CHAPTER I  INTRODUCTION** ................................. 1
  Historical Review .......................................... 1
  Goal of Paper ............................................... 7

**CHAPTER II  REVIEW OF PRESCRIBED BURNING**
  APPLICATIONS .................................................. 11
  Broadcast burning of slash in clearcuts .................. 11
  Pile burning .................................................. 14
  Slash reduction under standing timber .................. 15
  Natural fuel reduction under standing timber .......... 18
  Other burning ............................................... 23

**CHAPTER III  DOCUMENTED BURNING UNDER**
  STANDING TIMBER OPERATIONS ............................... 27
  Camas Prairie Burn .......................................... 27
    Site description .......................................... 27
    Stand history ............................................. 29
    Pre-inventory ............................................. 29
    Site selection ............................................ 31
    Determining when to burn ................................ 32
    Post burn sampling ...................................... 36
    Discussion ................................................ 37
    Prescription guidelines .................................. 37
    Survival classes ......................................... 39
    Insect attack .............................................. 41
    Future use of fire on the Camas Prairie burn area ... 49
  Ferry Basin Burn ........................................... 50

**CHAPTER IV  AIR QUALITY CONSIDERATIONS** ............. 53
  The case for air quality ................................... 54
  Smoke management .......................................... 57

**CHAPTER V  FIRE MANAGEMENT CONSIDERATIONS** ......... 60
  Burning plans ............................................... 60
  Workload involved ......................................... 61
  Factors involved in a cost benefit analysis ........... 62
ACKNOWLEDGMENTS

Since there is very little literature on prescribed burning for the Northern Rocky Mountain region, it was necessary to gather much information through personal experience and communication. I am particularly grateful to the Bureau of Indian Affairs, Flathead Agency's forestry staff for their assistance and willingness to experiment with fire use. Special thanks are also due to Allan Hartong, of the Northern Forest Fire Laboratory, for the many hours he spent assisting me in the field and in the office.

The members of my graduate committee have been understanding and have offered much helpful advice. Their thoughtfulness has been especially important because of the unusual nature of this paper. R. W. Steele (fire science) of the Forestry School has been my thesis committee chairman, and Dr. R. W. Wambach (associate dean) of the Forestry School and Dr. R. E. Shannon (economics) Department of Economics and A. L. Hartong of the Northern Forest Fire Laboratory have been members of this committee.
### LIST OF FIGURES

| FIGURE 1 | DUFF LEVELS AS AFFECTED BY BUST TREE STOCKING AS AFFECTED BY BUST | 22 |
| FIGURE 2 | COMPARISON OF SCHIMKE'S INDICES WITH CAMAS PRAIRIE DATA | 38 |
| FIGURE 3 | GRAPH OF PERCENT OF TREES IN DAMAGE CLASS I | 42 |
| FIGURE 4 | GRAPH OF PERCENT OF TREES IN DAMAGE CLASS II | 43 |
| FIGURE 5 | GRAPH OF PERCENT OF TREES IN DAMAGE CLASS III | 44 |
| FIGURE 6 | THEORETICAL COST PER ACRE CURVE FOR BUST OPERATIONS IN THE NORTHERN ROCKY MOUNTAINS | 65 |
CHAPTER I

INTRODUCTION

Historical Review

Progress is the substitution of one nuisance for another. Much to the chagrin of many foresters, the policy of forest fire exclusion aptly applies to this maxim.

How the exclusion policy became incorporated into the forest management practice and became accepted by the public can be attributed to good advertising and man's basic fear of fire. The old forestry rule that you can't practice forestry if you can't protect the forest from fire, and the Smokey Bear implication that all fires are bad, greatly attributed to an intensification of the fire exclusion campaign.

For years, advocating the use of fire was as much heresy as being soft on Communism was during the McCarthy era. Forestry professors who solicited the use of fire, or advocated a flexible wildfire control policy have either been considered pyromaniacs, or the most humorous men on the staff (Vogl, 1967). Fire laboratories were subject to criticism if their projects strayed from fire control research, and foresters who toyed with controlled fire frequently established reputations that were not to be envied.
What has happened to change all of this is an interesting story involving fire research programs, man's sociological behavior, and time. The full story would be a book in itself and, because the information is only needed as contributory material, a summary must suffice.

Man has been concerned with ecology in a practical sense throughout his existence. In primitive societies, the survival of man was dependent on definite knowledge of his environment (Odum, 1959). Ironically, civilization is considered to have started when man learned to use fire to modify his environment. But it was not until 1900 that ecology was recognized as a distinct field of botany. It was not until 1935 that Tansley introduced the ecosystem concept (Tansley, 1935). Thus it has only been in the last thirty-five years that man has learned enough about his environment to know what questions to ask.

In this relatively short period, forest, range, and wildlife ecologists have been investigating the complex role of fire. Samples of fire scars on trees and countings of charcoal layers

---

1 An ecosystem, as defined by E. P. Odum, is where the living community and the non-living environment function together as an ecological system.
in peat beds has yielded information on the frequency of past fires. Inventories made before and after the fire exclusion policy have provided ecologists with sufficient data to make predictions about the effect of the policy on the environment (Vogl, 1967). The ecologists have shown that fire is an important factor in molding the environment and maintaining plant and animal communities.

As the store of ecological knowledge accumulates, the beneficial aspects of fire in the forest have become increasingly recognizable. But, being cognizant of past benefits derived from fire is of little value to the northern Rocky Mountain region land manager of today. His management problems cannot be resolved by reverting to a policy in which fire is permitted to run its course. Present land use pressures dictate that the gross indiscriminate action of wildfires are unacceptable.

Specific reference is made to the northern Rocky Mountain region because most wildfires in this area were not light ground fires typical of open stands of other regions. Frequently, fire-use advocates in the northern Rocky Mountain region have commented, "look all about you, the history of fire is written all over the mountains." A quick observation will confirm this statement, but the type of fires that wrote this history were major
conflagrations, not creeping ground fires, as inferred. Even the open pine areas in the northern Rocky Mountain region, which were perpetuated by ground fires, might now be in jeopardy if the exclusion policy was reversed. The duff accretion that has occurred since the initiation of the fire exclusion policy could now foster a devastating fire.\footnote{The definition of duff as is used throughout this paper encompasses the three organic layers; the upper one composed of fine undecomposed and generally loose material, a mid-layer which is partially compacted and decomposed, and a lower layer that is heavily compacted and almost completely decomposed.} The option of prescribed burning is one alternative a forester may use to alleviate the unacceptable consequence of continuing the fire exclusion policy, or the unacceptable results of wildfires.

Only recently has the stalemate of conflicting management theories, of fire use and fire exclusion, been brought closer to resolution. As the knowledge in the field of fire science expanded and researchers began to quantify the interactions of fire, it became possible to predetermine the conditions at which a fire would be controllable. The obtainment of this information was a prerequisite for the use of prescribed fire.

Fire, as a tool in forest management, has had greater acceptance since its use in the disposal of logging slash. Many

\begin{itemize}
\item \textbf{conflagrations, not creeping ground fires, as inferred.}
\item \textbf{ven the open pine areas in the northern Rocky Mountain region, which were perpetuated by ground fires, might now be in jeopardy if the exclusion policy was reversed. The duff accretion that has occurred since the initiation of the fire exclusion policy could now foster a devastating fire. The option of prescribed burning is one alternative a forester may use to alleviate the unacceptable consequence of continuing the fire exclusion policy, or the unacceptable results of wildfires.}
\item \textbf{Only recently has the stalemate of conflicting management theories, of fire use and fire exclusion, been brought closer to resolution. As the knowledge in the field of fire science expanded and researchers began to quantify the interactions of fire, it became possible to predetermine the conditions at which a fire would be controllable. The obtainment of this information was a prerequisite for the use of prescribed fire.}
\item \textbf{Fire, as a tool in forest management, has had greater acceptance since its use in the disposal of logging slash. Many}
\end{itemize}
large forest fires have received their initial impetus in untreated logging slash (Lyman, 1947; Barrows, 1951; Anderson, 1968). This was observed in the 1920’s and it rapidly became apparent that logging slash had to be treated. Because treating the slash did not generate any direct realizable savings for the logger and apparent savings to the land manager, the quickest and cheapest method of treatment, that of burning, was utilized.

Initially, it was thought that slash had to be piled in order to be disposed of in a safe manner. As the clearcutting practice became more prevalent and timber sales occurred on steeper slopes, over 30 percent, it became increasingly difficult to continue to pile and burn slash. Gradually, broadcast burning on clearcuts became the accepted method of treatment. The broadcast burning of clearcuts has probably done more to reduce a forester’s uncertain feeling about fire than any other factor. It has afforded forest managers a chance to train their fire control crews in front of live, but safe, fire conditions. It has demonstrated that fire can be contained and that man can control its actions. And most importantly, it opened the way for prescribed burning to become a part of the forest management program. Working with broadcast burning is making foresters aware that fire is not something that just happens; its application should be scientific
and its results can be predicted.

As the psychological barrier against using fire slowly ebbs and fire researchers learn more about fuel, meteorology and combustion, the art of prescribed burning is becoming more of a science. With the new knowledge, there is less need for personal trial and error experience and a greater need for an understanding of the new processes. If guidelines are followed and principles are not violated, the chance of a mishap on a clearcut burning operation will be slim. The scientific approach negates some of the original hesitancy of using fire and enhances the chance of a broader effective program.

The problems involved in expanding the research scale to a management operation scale, the development of cost benefit figures and overcoming man's fear of fire, are only some of the problems encountered when implementing a controlled burning program. The acceptance of fire use programs by local forest management districts will also depend a lot on the respect fire control officers engender. Administratively, the fire control position may be hindering the development of fire use programs by the type of personnel that are assigned to that position. Too frequently the fire control position has been occupied by the personality type who would not take the initiative to expand the fire control
program, to one of fire management. Thus, the motivation for new programs must frequently come from other positions in the management staff, or from research extension services. Part of the problem may also stem from the administrative position of the fire control officer. A district fire control officer's primary purpose is protection and if he is subject to direction by a ranger that is well-indoctrinated with the Smokey Bear syndrome, there is little he can do to experiment with fire use. In either case, the fire manager will be involved with the sociological problem of having to win the confidence of the new management staff.

**Goal of Paper**

The goal of this paper is to highlight some of the problems that will confront forest management personnel if they embark on a fire management program. Some of the problem areas can and are being solved in the laboratory; most of the problems are managerial and can only be resolved through experience. If management is to realize the benefits of fire use, they are now faced with the problem of developing a practical application of an economically favorable prescribed burning program. The job is not easy and though it is overlooked
by many prescribed fire advocates, it will require a great deal of time and effort.

Several examples cited in this paper come from personal experience gained while working as a fire management consultant for the Confederated Salish and Kootenai Indian tribes on the Flathead Indian Reservation. This reservation, in size, timber harvested, topography and vegetation, typifies many National forests in regions one and four.

In this paper the term fire management program is defined as the planned, beneficial and multiple use of fire in accordance with the forest management objectives. The program must be flexible and vary with the objectives of the forest management unit, and the technical level of competence of the personnel. In contrast to this definition, prescribed burning is used to indicate the use of fire in that part of a fire management program not concerned with fire control.

Though this paper only discusses that part of a fire management program relating to prescribed burning, the reader should recognize the fact that this term encompasses other fire uses including

---

1 Personal communication with fire scientists in Alberta and British Columbia indicates that the problem of implementing a fire management program is not restricted by international boundaries.
those used in fire control activities. In this paper, the use of prescribed burning under standing timber will be the main topic. The author has chosen this course of action for the following reasons:

1. If negative public reaction against clearcutting continues, there will probably be a shift towards over wood-cutting systems. As this occurs, there will be an increased demand for the perfection of burning slash under standing timber.

2. If a rigid policy of wildfire protection persists, there will be a greater need for man-manipulated fire hazard reduction.

3. Virtually all reference to prescribed burning in the northern Rocky Mountain region relates to burning of slash on clearcuts.

4. The problems confronted with burning under standing timber in this region have been masked by the relative ease of application and success in dissimilar areas.

5. If, in the future, intensive forest management practices only occur on sites of high timber productivity, vast timbered acreages in this region will no longer be subjected to the minimal fuel alterations now resulting from logging.
6. The author has had personal experience with the problems of planning and operating large prescribed burns under standing timber in western Montana.

Throughout this paper, the phrase burning under standing timber will be referred to as BUST. Presently, when reference is made to broadcast, prescribed or controlled burning, there is no way of conceiving what type of burning the speaker is referring to. Generally, when reference is made to broadcast, prescribed, or controlled burning, burning slash on clearcuts is implied. A wealth of literature has been published on prescribed burning but a close examination of this topic title will reveal that there is virtually no works concerning BUST operations. Thus, this lack of a title has masked the fact that very little information is available and may be one reason why so very few people have become involved with BUST operations.
Broadcast burning of slash in clearcuts

The most prevalent application of the prescribed burning in the northern Rocky Mountain region is broadcast burning of slash in clearcut blocks. The broadcast system originated with the early loggers, who indiscriminately burned off the slash after logging (Wilson, 1970). Though the origination of broadcast burning may be attributed to the early loggers, there is little in common with the method now employed by foresters. With the implementation of the fire exclusion policy, uncontrolled slash burning has become a thing of the past.

Studies by Lyman (1947) and Barrows (1951) illustrated with empirical data that slash does contribute to wildfire generation. Lyman circumstantiated that during a nine-year period, the ratio of burned areas in untreated and treated slash areas was 7:1. Davis (1959) mentioned that the situation is worse than the statistical data indicates. Many small, easily controllable fires have become major fires after rapidly expanding
in untreated slash areas.

The techniques of broadcast burning slash in clearcuts have mostly evolved from trial and error experience. Recently the mechanism of broadcast burning has developed into a very precise and intricate treatment. Of all the types of burning that will be mentioned in this paper, broadcast burning on clearcuts is by far the most advanced. It has been a part of forest management since 1910 and its application is not considered to be a major problem (LeBarron, 1957; DeSilvia, 1965).

For years, the advocates of clearcutting and burning were criticized for sterilizing the soil and contributing to accelerated erosion (Ahlgren, 1963). More recent studies have disproved these claims (Vlamis, 1955; Biswell, 1957). Still, the fear of overburning lingers, with the result that many burns are accomplished when the conditions are too wet. Though a few old timers, with a lot of experience, do not need fuel and meteorological measurements to determine when to burn, most burners do. Since adequate measurements are frequently not available and sound resource management precludes slop-overs, along with the fear of ridicule if slop-overs occur, most burners wait until there is
no doubt that the fuel is wet.\footnote{A slop-over is said to occur when a prescribed fire burns a small area adjacent to, but outside, the designated area.} This results in higher cost, marginal site preparation, and lowered air quality.

Wet blocks require an intensification of ignition and generate hot-spots that may smolder for weeks in the damp large fuel. Unless there is very little chance of a late fall dry spell, these spots must be isolated and extinguished. Conversely, studies have shown that with increased duff reduction, resulting from more intensive burning, there is a better chance for successful seeding (Boyd, 1969). Schmidt (1969) has also stated that larch trees up to 13 years old will grow one-third faster on well-burned sites than on sites that have received less than intense preparation.

Burning slash on clearcuts when they are too wet adds greatly to the smoke problem (Fritschen, et. al., 1968). The most deleterious effect resulting from decreased fire intensity is the lack of development of a central convection column for smoke dispersal.

With an increase of public awareness of air quality, and a greater public intolerance towards the smallest slop-over fires, fire managers must set new standards and demand the use of more
precise indices. With some alterations, the new national fire danger rating system, to be field-tested in 1970, may provide some assistance. Presently, the new danger rating system does not account for the effects of large diameter fuels; fuels over three inches in diameter (Anon., 1970). Though the larger fuels do not contribute to a fire's rate of spread and ignition probability, they do greatly affect the overall intensity of a slash fire.

Pile burning

An alternative method to broadcast treatment is that of machine or hand-piling slash and burning. This treatment is commonly utilized, and so easily accomplished, like that of burning leaves, it may not seem necessary to mention it. Recent ramifications of air quality legislation have changed this. ¹

Theoretically, slash piles could be burned early in the fall when the forest moisture conditions are still relatively dry; slash piles, if correctly constructed, will burn hotly in place without undue risk of spreading. If this were accomplished the slash would burn much hotter, produce less smoke, and the smoke produced would be better dispersed due to the prevalence of

¹Montana Clean Air Act, 1967 Legislature, Chapter 313, Section 90000 - 90190
unstable air layers during late summer and early fall. Because piles are easy to ignite and will burn when there is a couple of feet of snow on the ground, they are usually left until the fall workload slackens. When piles are wet and stable atmospheric conditions exist, they will smolder for days and produce voluminous quantities of drift smoke. The persistence of this smoke is very annoying and has disturbed many rural residents. One possible corrective measure is to determine the earliest possible safe burning time and schedule the treatment accordingly. If more consideration is not given to the scheduling of slash pile burning, all fire uses may be in jeopardy. To the public, smoke is smoke and there is no difference if it is coming from smoldering piles, or from broadcast burning operations.

Slash reduction under standing timber

Recent unfavorable publicity, exerted by conservationists, about the use of clearcutting practices may create a trend towards greater use of the partial cutting systems. In the past, slash on sanitation, selection and overwood cuttings has been piled and burned. This method is expensive and is

mechanically limited to slopes less than 30 percent. With the present demand for wood, it is not uncommon to harvest timber on slopes in excess of this percentage. In many areas of western Montana, it is uncommon to find any harvesting operations on slopes less than 30 percent.

During 1969, a pilot project was established on the Flathead Indian Reservation to test the feasibility of burning slash under standing timber. The project site was limited to a manageable area of 200 acres of selectively logged ponderosa pine and Douglas fir, on the Ferry Basin logging unit. On this acreage, the slash pre-treatment consisted of the following operations:

1. Limbing large branches that significantly extended above the average plane of the fuel-bed.

2. Breaking up large concentrations of slash, with special attention given to heavy fuel concentrations about the crop trees and subsequent seed source.

3. Construction of fire lines to sectionize the area into approximately 40-acre blocks.

It was also found that the BUST slash preparation required one-half the time for treatment than similar acreages being prepared for
piling and burning. On the remaining area of the logging unit, the slash was piled and burned.

The understory, predominantly Douglas fir, was heavily infested with dwarfmistletoe and some stand improvement was necessary. By using the broadcast burning method, more than one objective was accomplished. The objectives of the operation were:

1. Reduce the slash.
2. Reduce the natural fuel loading.
3. Prepare a mineral seed bed for ponderosa pine regeneration.
4. Thin the infrequent patches of dense understory.
5. Kill the Douglas fir understory that was contaminated by dwarfmistletoe.

The project was considered a success by the contractor and the forest management personnel, and demonstrated the feasibility of future large scale applications.

The key to success of slash burning under standing timber is to find the delicate balance between not too hot (dry) and not too

---

1 Personal communications with Ed Nelson, woods foreman for Rossignol Logging, indicated that, with his D-7 Cat, he was able to treat twice as many acres on the BUST system as he was when he piled the slash.
cool (wet). A hot fire, though it may do an excellent job of slash reduction and duff reduction, may result in damage to the residual crop. Burning when it is too wet will require intensive ignition to facilitate the spread of the fire and will result in excessively high cost relative to the poor quality of the operation.

The main advantage of burning slash under standing timber is its multiple accomplishments with very little need for site preparation. The main disadvantage is the limited frequency of ideal burning conditions. Stated in other terms, the main disadvantage is having to rely on the ability of the burner to distinguish what are ideal conditions and when do they occur.

To the neophyte fire user, the need for precise fuel moisture determinations and special slash pretreatment may seem to be a lot of extra work that was not required when the slash was piled and burned. The pretreatment process for BUST slash operations is easier, faster, and less expensive than machine piling.

Natural fuel reduction under standing timber

Controlled burning, also known as broadcast and prescribed burning, for hazard reduction, is the use of fire in areas planned for the reduction of small and large dead fuels
and the thinning of surplus live stems in seedling and sapling stands. It does not include the burning of piled or lopped and scattered slash or slash in clearcuts.

The periodic use of fire to maintain a low duff level is presently used extensively in the southeast and southwest regions of the United States. In the past ten years, 230,000 acres of ponderosa pine has been treated with fire on the Fort Apache Indian Reservation (Strum, 1966). Two and one-fourth million acres are annually intentionally burned in the southeast's loblolly, longleaf, shortleaf, and slash pine regions (Copper, 1965; Bateman and Roark, 1967; McNab and Ech, 1967). While other regions are also extensively using fire, the northern Rocky Mountain region has virtually never used fire on a management scale for hazard reduction. Though there are those that advocate the use of fire in this region, problems with the rugged terrain and variations in the vegetation has restricted the use.

An 80-acre demonstrational hazard reduction burn, on the Flathead Indian Reservation, was carried out on July 17, 1

---

1 R.C. Henderson partially dealt with duff reduction on his test for thinning by fire in a 30-50 year old stand of ponderosa pine on the Lubrecht Experimental Forest in 1966. Stems per acre ranged from 2,475 to 7,400; three fire intensities were applied by the manner of use of backing or head fires. The author concluded that under the conditions studied, thinning by fire was feasible and that fire intensity can be manipulated.
1969. Initially, 600 acres was to be treated, but because of the inexperience of the crews and the staff, a more manageable acreage was chosen. Details of this project will be discussed at a later point, but the mentioning of this project serves notice that some work is being done in this field. The project did illustrate the need for more planning and training of ignition and suppression crews, if hazard reduction programs are to be implemented in this region.

The success of natural fuel reduction burning cannot always be determined after a single treatment, but is usually based upon a series of burns. The frequency of application, necessary to obtain a desired stand condition, depends on the initial fuel loading, the stocking of the stand and the intensity of the individual burns. Theoretically, a stand might require three burns in a ten-year period to achieve a desired fuel loading and stocking. Once this level is obtained, one burn every eight or ten years may be sufficient to maintain that level (Weaver, 1967).

When it is stated that a desired stocking and duff level has been reached, and from that time forward periodic fires will maintain those levels, this may be slightly misleading. The duff level will fluctuate, but the stand density will probably continually decrease at a diminishing rate for many years.
Figure 1 is a theoretical model of expected rates of stand density and duff level reduction. In Figure 1, the unequal rate of fuel build-up during a ten-year burning cycle may be attributed to at least two factors. One, the heavy initial needle drop caused by scorching and, secondly, the accretion of cull and snags that fell as a result of the fire. Subsequent duff build-ups will have lower maximum duff depths, due to a decrease in stocking and less vegetation available for scorching.

Weaver's study on the Colville Reservation has demonstrated that rotational burning does not continuously thin the reproduction out of existence. Unless each fire is devastatingly intense, some reproduction will escape each fire's effects. The genetically superior regeneration will grow rapidly between treatments and should thereby be more fire resistant by being bigger and taller. Thus, a natural equilibrium is created between the decaying old growth and the establishment of the reproduction. In the thinning process, the stand's genetic qualities will be enhanced.

If a hazard reduction operation is only considered complete when the desired fuel loading is obtained, then it is incorrect to consider the cost of any one burn as the total cost. This may seem rather moot, but in a cost-benefit analysis, the total
FIGURE 1

EXPECTED DUFF LEVELS AS EFFECTED BY BUST

TREE STOCKING AS EFFECTED BY BUST
cost figures must be utilized. What will the cost be for subsequent
reburns is subject to question. Most likely, the cost will be
slightly less than the original operation.

Other burning

Other benefits, such as wildlife habitat improvement, vegetational type maintenance, forest range improvement and aesthetic improvement, may be categorized into this group and may be coincidentally obtained with natural hazard reduction burns. The utilization of fire in this sphere would represent the ultimate in sophisticated fire management programs. Most likely, this variety of use will generally be utilized by special use agencies and in special management units, such as by the National Park Service and in wildernesses.

Type maintenance through prescribed burning is the natural preservation of seral communities by intentional burning. One of the best illustrations of this technique is on a recent study being executed on the Sequoia Kings Canyon National Park. Hartesveldt and Harvey (1967) reported on this project that plant successional changes began to manifest themselves in the growing season following burning. A total of 2,013 sequoia seedlings were discovered in the manipulated area and none were
found on the control. It was also found that hotter fires
seemed to have produced conditions that were more ideal
for seedling survival than light fires.

Daubenmire's vegetational climax studies have also il-
lustrated the role that fire plays in determining what cover type
will occupy an area. For example, western hemlock is a climax
species that displaces all other trees in its narrow range of
environmental conditions, whereas western larch is a fire
follower that invades burned areas and will rapidly dominate the
area and remain as long as fire is prevalent (Daubenmire, 1968).
On areas that are not subjected to clearcutting practices, which
simulates the patchwork of burns, tree cover-type transformation
will occur. For economical and possibly sociological reasons,
this transformation may not be desirable.

The type of treatment necessary to sustain seral
communities would generally have to be a harsh, tree killing
fire; though not all type maintenance would have to be so
devastating. On ponderosa pine cover types, frequent ground
fires that keep the stand open and the forest floor relatively
clean, is sufficient disturbance to prevent the establishment of
another habitat type.

Prescribed burning for wildlife habitat improvement and
for forest range improvement are frequently listed as benefits by fire use advocates. In the process of covering every possible benefit that a BUST operation may encompass, a long list of objectives may be constructed. Though this may bolster a program's justification, the accuracy of such claims may be questionable.

In a recent conversation with Jack Lyon, a research associate with the Forestry Sciences Laboratory in Missoula, Montana, a statement was made, "that all the burning in the world would not improve game habitat unless the desirable species were once present." Fire will not introduce new palatable species, though it may stimulate seed sources and species that are no longer visually present (Lyon, 1966). Fire will also favor species that are prolific sprouters. If the change in species composition is favorable for wildlife, only then should the fire treatment be listed as habitat improvement.

Presently, most of the literature available on burning for habitat improvement in this region relates to revegetation of clearcuts, or wildfires. Though the changes in vegetational composition occurring on burns under standing timber may prove to be limited, the benefits derived from this component do merit consideration.
Burning to improve the aesthetic quality of the land is a new concept in the field of forest management. Most of the support for this technique comes from wilderness and park land managers (Murphy, 1967; Dasman, 1968; Adelblue, 1970). Burns for aesthetic improvement would include the perpetuation of meadows, curtailing tree encroachment on open slopes, the creation of natural vista-points and maintaining open park-like stands. The techniques involved in achieving these objectives are now only speculative.
CHAPTER III

DOCUMENTED BURNING UNDER STANDING TIMBER OPERATIONS

Camas Prairie Burn

The problems inherent with BUST operations may best be illustrated by examining, in detail, the two pilot projects previously mentioned. The objectives, and the techniques involved in achieving these objectives, differ greatly from operations of slash burning on clearcuts. The total benefits of a fire management system will only be realized when BUST operations become an integral part of the system.

The Camas Prairie Burn was an administrative operation designed to demonstrate the feasibility of burning for hazard reduction under standing timber. A pre- and post-burn inventory of the fuels and timber was superimposed on the project to objectively evaluate the effectiveness of the burn. Only tools and techniques that would normally be available to the forest management staff were utilized.

Site description

Camas Prairie is approximately six miles north on
Highway 382 from the town of Perma, on the Flathead River. The Camas Prairie runs north and south for approximately ten miles and is roughly six miles wide. According to the Geodetic Survey maps, the Camas Prairie is 3,000 feet in elevation. The mountains to the west of the Prairie create a rain shadow effect, making this area one of the driest in the state. A mean annual precipitation of eight inches has been calculated from local ranchers' rain gauges.

The burn area is on the west slope of the prairie. The timber-grass line closely approximates the 3,100 foot contour line. The burn site is at 3,200 and, therefore, typifies a dry pine-grass site.

The slope averages 10 percent and ranges from 3 percent on the east side to 15 percent on the west side.

Small patches of surface rock are found on the southwest side of the area. This results in a slight decrease in stocking of grasses, forbs, and trees. On this area, we noted a habitat type change from Pinus ponderosa - Symphoricarpus albus (ponderosa pine - snowberry) to Pinus ponderosa - Purshia tridentata (ponderosa pine - bitterbrush).
Stand history

In the early Thirties, the area was selectively logged by Pitts Lumber Co., which at that time had its mill on the Camas Prairie. The area is now covered with a medium stocked saw-timber size stand. There is an average of 80 commercial stems to the acre.

An understory of stagnated 30-year old saplings predominates throughout the area, indicating that heavy natural regeneration occurred shortly after logging. Approximately half of the 80-acre block selected to burn was thinned in 1963. The chain saw thinning occurred during the winter of 1963-64. The slash was piled and burned in the spring and fall of 1964.

During the pre-burn inventory, it was noted that the thinned stand had closed its canopy and is now in need of a second thinning. The stock on the thinned area now averages 3.0 inches in diameter at breast height and 25 feet tall.

Pre-Inventory

After the site was chosen and its boundary demarcated, a strip prism cruise was made. Four strips with plots every two chains were recorded. This was not a permanent inventory and correspondingly no trees were marked. Only an estimate of
commercial volume and reproduction intensity was desired to fully describe the stand.

Duff depths were taken at points one pace away from each plot center, in the direction of travel. This was done to eliminate bias and to negate possible sampling error which would have resulted by sampling the disturbed plot center.

Duff depths were measured to the nearest quarter-inch. Accurate readings were fairly easy to obtain, owing to the nature of the organic mantel. An average duff depth of 1.9 inches was determined. Percent of fuel size classes occurring on the total area were ocularly estimated. Percent fuels in the size classes were: light--0 to $\frac{1}{2}$ inch, 90 percent; medium--$\frac{1}{2}$ to 2 inches, 8 percent; large--2 inches plus, 2 percent.

Though a two-inch and greater diameter class may be considered quite small, when compared to the relatively large fuels on slash burns, it should be remembered that the constituents of a hazard reduction burn are entirely different.

Maximum consideration must be given to the protection of the residual crop on hazard reduction burns. Therefore,

---

1A hundred point line transect was established before the Camas Prairie burn. Eighty-three of the points were recorded as duff and 12 of the points were recorded as moss. After burning, all of the points were recorded as soil.
the removal of large fuels can only be accomplished in
elements by periodic burning. The residence time of a
fire and the dryness of large fuel required for complete
consumption during one treatment would present unacceptable
burning conditions when regarding the safety of the stand. ¹
Weaver (1967), on the Coyote Creek test area, has pictorially
illustrated the effect of continuous large fuel reduction on the
1942, 1958, and 1964 burns.

Site selection

One step in planning a hazard reduction program is to
identify areas of high priority where the investment will yield
a maximum return. This may be done by making map overlays
showing burned areas, areas of high investments. A twenty-year
period of fire history should be of sufficient length to delineate the
fire patterns. Unburned areas within the general burn pattern
should be considered high hazard areas. Once these areas have
been identified, special categorization for priority treatment should
be given to areas that have had previous investments.

¹ Frequently early fall rains will wet a site throughout the
entire mantel but will be insufficient to affect the moisture
content of the large fuels. If the preponderance of large fuels
is not concentrated about the boles of the crop trees, it may be
safe to burn.
Initially, the Camas Prairie burn was planned to encompass 600 acres. This area was completely enclosed by a good road system and contained a fairly uniform slope, aspect, and timber type. Because the size was not commensurate with the capabilities of the organization, a smaller unit of 80 acres within the larger area was chosen. A cursory inventory, to determine stand vigor, fuel loading and stand uniformity was made before final acceptance of the area. To facilitate the ease of burning, a uniform stand was desired. Therefore, uniformity of plant species, density and fuel loading was the prime requisite for choosing the site.

Determining when to burn

After the objective has been chosen and the site has been identified, the decision of when to ignite becomes the next concern. On the Camas Prairie project, a high intensity burn was desired because it was felt it could best demonstrate benefits of BUST. Therefore, fuel moisture conditions approaching the extreme limits for a safe BUST treatment were selected.

The ability to predetermine the occurrence of a high intensity fire or a low intensity fire must partially come from
experience and partially from being familiar with the literature. At the risk of sounding facetious, it should be recognized that virtually no one in this region has any experience with BUST operations and there is very little applicable literature. For the forest managers starting a hazard reduction program, this gap in knowledge and experience is critical. It may partially be rectified by acquiring information from other regions. Though papers by Biswell, Weaver, Schimke and Kalander are for BUST hazard reductions on dissimilar areas, enough congruence exists to justify borrowing their prescriptions.

The actual determination of when to burn depends on the weather and the conditions of the fuel. Though every forest management agency has fire control weather stations, the information they give is insufficient for prescribed burning. The knowledge of diurnal wind, temperature, and relative humidity trends is far more important to a burner than what the weather is at a single point in time. Furthermore, the standard valley bottom fire weather station only typifies forest conditions that exist on similar topographical locations.

Many forest management operations occur in the thermal belt zone, and are subject to low nighttime relative humidity
recovery. Valley bottom weather stations, even with 24-hour recording instruments such as the hygrothermograph, will not detect this phenomenon. Therefore, the fuels in this zone are frequently drier than other areas. Since many prescribed burns occur in the evening, to take advantage of the cooler and moister conditions, it is imperative that a burner be aware of a site's nighttime weather. Though this means additional meteorological sampling and the placement of instruments in the field, the use of hygrothermographs precludes the necessity of daily monitoring. Foresters must be impressed with the fact that meteorological sampling is one area that cannot be overdone.

On the Camas Prairie burn, continuous on-site recordings of temperature, relative humidity and wind were not available. Spot hand readings of wind, temperature, and relative humidity were made on the site throughout the week of the projected ignition time.

Though the burn occurred on July 17, well into the summer, an extremely heavy rain during the last week of

---

1 The thermal belt occurs on the middle third on the sides of valley slopes. Frequently in this zone, there is very little nighttime relative humidity recovery and nighttime temperatures are generally higher than surrounding areas. Frequently, these conditions are accompanied by slight air turbulence.
June simulated spring-like moisture regimes.

A buildup index from the local fire-weather station was used to represent the site's local condition. It was later found that this station did not accurately represent the burn site. Due to river-induced microclimatological effects, the fire-weather station indicated wetter conditions than actually existed on the project site. The buildup index for July 17 was 55 and the spread index for fine fuels was 12.

Fuel sticks were used on this project to describe the fuel moisture content because of a lack of a better index. It was also felt that being a spring burn, where only small fuels were involved, the sticks, along with the relative humidity, would be sufficient to monitor the fuels' moisture condition. Particular reference is made to "spring burn" because, during this period, a drying trend predominates. The duff profile is drying from the surface down and the larger fuels are drying from the outside in. This condition will prevent the occurrence of a deep hot burn (Henderson and Muraro, 1968).

A strong humidity rising trend and very little air movement were necessary to compensate for the occurrence of the low fuel moisture contents of 5 and 6 percent. Winds less than 5 miles per hour and a relative humidity of 35 percent, or more,
were established as minimum conditions. Direct solar radiation greatly increases the surface temperatures of fuels, and will affect the resultant fire intensity (Gates, 1962). An evening burn was planned to take advantage of the rising relative humidity, reduced air velocity, and lack of solar radiant heating.

**Post burn sampling**

A post burn inventory was made 40 days after the burn. It was decided for future reinventory purposes to use permanent plots and code each sample tree.

Three prism cruise strips were laid out perpendicular to the contours. Fifteen sample plots were established four chains apart from each other. On each plot, the plot center was marked with flagging.

All trees, with sufficient height for measuring DBH\(^1\) were marked with yellow paint. Each tree was marked with a symbol code to distinguish survival classes. Every recorded tree was painted on the bole facing plot center.

On each plot the DBH, in two-inch classes, was recorded. A description of brush cover, before burning was

---

\(^1\) DBH indicates diameter at breast height which is 4.5 feet above the tree's base, on the uphill side of the tree.
estimated as either low, moderate, or high. Reproduction density was ocularly estimated to be within an imaginary circle whose radius was the line from plot center to the farthest tree. The reproduction was recorded as low, moderate, or high density. Fire intensity was classed and recorded as low, moderate high, and extreme. Three survival classes were established and recorded. Survival class one, will survive, was painted with one dot. Class two, may or may not survive, was painted twice. Class three, will not survive, was painted three times.

DISCUSSION

Prescription guidelines

To help breach the gap in knowledge on guidelines for BUST operations, Schimke's indices, derived from experimental works in California, were utilized. These indices consisted of five elements. The elements were relative humidity, fuel sticks, wind, temperature, and timber burning index. Figure 2 compares Schimke's indices with the meteorological measurements taken at

1 The tables were obtained by personal communication with Harry E. Schimke, Forest Research Technician, Fuel Break Project, Pacific Southwest Forest Range & Experiment Station.
FIGURE 2

COMPARISON OF SCHIMKE'S INDICES WITH THE CAMAS PRAIRIE DATA

<table>
<thead>
<tr>
<th>Schimke's Parameter for Safe Burning</th>
<th>Camas Prairie Conditions on July 17, 1969</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative humidity</td>
<td>26 - 64</td>
</tr>
<tr>
<td>Fuel stick weight</td>
<td>6 - 20</td>
</tr>
<tr>
<td>Wind, m.p.h.</td>
<td>0 - 12</td>
</tr>
<tr>
<td>Temperature, °F</td>
<td>20 - 80</td>
</tr>
<tr>
<td>Timber burning index</td>
<td>2 - 6</td>
</tr>
</tbody>
</table>

Buildup Index 55

Schimke's timber burning index was derived by:

Table 1 (of Timber Burning Index series in Wildland Fire Danger rating U.S. Forest Service, PSW 1962)
Fuel stick moisture content of 6 percent and relative humidity of 38 percent equals fine fuel moisture of 6.

Table 2.
Fine fuel moisture of 6 and wind speed of 2 m.p.h. equals spread index of 7.

Table 3.
Fuel stick moisture content of 6 percent and Buildup of 55 (from National Fire Danger Rating System) equals Intensity index of 69.

Table 4.
Intensity index of 69 and Spread index of 7 equals Timber Burning Index of 6.
the burning site of July 17, 1969.

Multiple indices, such as Schimke's, may be more valuable to the fire planner than the present National Fire Danger Rating system. Direct indices, such as temperature and wind, are values that every fire man is familiar with and can relate to without the benefit of years of experience. Indirect indices, such as the Buildup and Spread Index, though they are derived from the same elements, are much more difficult for the neophyte fire planner to correlate with. A person can feel temperature, wind, and dryness, but unless one has had a lot of experience he cannot feel, or sense, buildup and rate of spread.

Survival classes

At the time of the post inventory, 40 days after the burn, a litter layer of needles already covered the ground. In a few places, some forbs were regenerating. By late October, a complete organic mat covered the entire area. Thus the burn area, which had approximately 100 percent duff reduction on 80 percent of the area, was well-protected from surface erosion within a few weeks after burning.

Survival class decisions were made entirely upon the effect the fire had on the tree. The possibility that a weakened
tree might be attacked by insects was not considered. Percent live crown scorch, fire scar damage, tree size, and vigor were used to classify the trees.

Trees that had large proportions of crown scorching were only placed into a lower survival class if they did not look healthy. Salmon (1934) mentioned that vigorous trees that had received up to 90 percent crown scorching lived, but unhealthy trees that only received 50 percent crown scorch died. Wagener (1955), regarding ponderosa pine, stated bud kill is much more important than foliage kill in predicting a tree's survival probability. He also stated that no one percentage of crown damage can be used as a guide for determining whether an injured tree will survive.

The survival probability classes were graphed by percent of the total recorded, for each two-inch DBH class. The graphs were found to correspond with the following expected pattern. In the smaller diameter classes, the greatest percent of trees fell in the "will probably die" class. The medium diameters were generally centered about the second class and the large diameters were in the first survival class (See Figures 3, 4, and 5).
Insect attack

At the time of the post burn inventory, bark beetles were observed in the stand. The beetles involved, Dendroctonus brevicomis and Ips pini were observed attacking survival class three trees on areas where the fire had engulfed the trees. No insect-attacked trees were observed in the pre-burn inventory nor had been observed in the immediate vicinity. A large, indigenous population is known to exist on the west side of the reservation. At the time of the burn, an insect epidemic affecting 590 acres of ponderosa pine had been identified approximately 30 air miles from the burn site.

The approximate time of the start of the insect attack can be deduced to within a two-week period. Throughout the week following the burn, the entire area was closely examined and no insects were found. The extent of the attack at the time of the reinventory, 40 days later, indicated that the insects had been present for at least one week. Therefore, the time of the initial attack must have occurred during the last week of July and the first week in August.

A subsequent inventory on April 10, 1970, indicated that the infected area covered 4 acres. On May 23, 1970, the insect area was again examined but no major changes in the
Figure 3

Percent Trees in Damage Class #1
(WILL NOT DIE)

Percent of Total vs DBH in Inches
Figure 4

Percent Trees in Damage Class #2
(May or May Not Survive)

Percent of Total vs. DBH in Inches

- Percent of Total
- DBH in Inches
PERCENT TREES IN DAMAGE CLASS #3
(WILL PROBABLY DIE)

OCCURRED ON A EXTREME BURN SITE
extent of the attack were observed. Samples of the insects were taken for positive laboratory identification. The western pine beetle (Dendroctonus brevicomis), the mountain pine beetle (Dendroctonus ponderosae), red terpentine beetle (Dendroctonus valens), the flathead borer (Buprestidae), the roundheaded borer (Cerambycidae) and Ips pini were identified. ¹ Along with these primary and secondary attackers, three predator insects were found: Ostomidae, Staphylinidae and Tenebrionidae.

To what extent the attack will continue is not known. No immediate salvage action seems justified. However, the general area will be subjected to a selection harvest during 1971. At this time, the high risk trees can be economically removed. If the insect attack does not increase, the present extent of the attack may be considered partially beneficial because the stocking in these areas, after burning, is still above the desired level.

In retrospect, the key to success and the way to prevent overburning on most high intensity burns is through quality ignition. Ignition is the only manipulatory tool available to

¹ Species identification was made by Jerry Bringuel, doctoral candidate, Forest Entomology, University of Montana, School of Forestry, Missoula, Montana.
the fire manager once the project starts. A fire can be
manipulated by varying the type of ignition (Lotti, 1960).

Henderson (1967), in Thinning Ponderosa pine in Western Montana
with Prescribed Fire, makes frequent reference to the effect
ignition techniques have on varying a fire's intensity. Henderson
further stated that high intensity fires at 6 percent fuel moisture
content, engulfed trees when the fire was manipulated by increasing
the width of firing strips. Experience with unsupervised ignition
manipulation on the Camas Prairie burn substantiates Henderson's
observations.

Reference to unsupervised ignition manipulation on the
Camas project brings to bear the issues of crew training and
multiple authority, and has led to the following discussion for
achieving desired ignition patterns.

Immediately before the ignition time, on the Camas
burn, all of the personnel involved were assembled for an
instructional meeting. Work assignments were made and the
ignition crews, six men, were instructed about their functions.
No questions were raised following the lecture so the operation
began.

Educators frequently find that no response to a lecture
on new material indicates that the students did not fully grasp
the topic. As one student phrased it, "You can't ask a question if you don't know enough to know what to ask." Within minutes after the ignition process started, it became apparent that the information session was too short. In many operations, when a similar situation is recognized by the management, the action can be stopped and corrective procedures can be taken. Once the ignition process starts on a controlled burn, the alternative of stopping is no longer available. To drop the ignition devices before the operation is completed will allow the fire to become its own master.

As simple as the work may seem, new ignition crews invariably become disorganized in the face of fire. Spacing between igniters and the speed at which each man moves in relation to the group are the major problems. Poor ignition coordination will create unmanageable firing patterns and could prove fatal to some of the ignition crew. Possibly, if the gravity of the situation was more fully acknowledged by administrators, greater time would be allocated for training. Any crew that has never held a drip-torch, the common ignition device in the northwest, should not be expected to perfunctorily perform on its first fire.

Another factor that partially contributed to unplanned intensity
manipulation was multi-authority. Only one person should have authority on a fire. This is an administrative decision that should not be left for the field personnel to decide at the time of the operation. Crews operating the ignition devices are not in a position to distinguish authority. They should not be subjected to two sets of instructions.

As a result of some shortcomings, the Camas fire was more intense than desired. Instead of a planned initial single backing fire, ignited parallel with the contours, six strips of varying widths were used. Luckily very little, if any, direct damage occurred. Subsequent poor ignition procedures did result in crowing on several small quarter-acre areas. It was on the largest of these areas that the insects made their initial attack.

With the ever-present bark beetle threat, fire managers in the northern Rocky Mountain region cannot tolerate small errors. Because of the climatological differences of this region as compared to the southwest, burning must occur during the active season of the insects. Exactly what are the attractants that bring bark beetles to burned areas where trees have been damaged is subject to question. Whatever the attractant, odor or infrared heat emitted by the tree, burning in the late
fall after the insects have wintered seems to decrease the probability of attack during the following spring. The option of late fall burning is not always available to the fire manager in this region. Thus, as it has been previously emphasized, the art and science of BUST in the northern Rocky Mountain region is not similar to any other region.

Future use of fire on the Camas Prairie burn area

Burns such as the Camas Prairie fire may also be used in conjunction with pre-burning logging operations. In this proposed technique, a BUST hazard reduction treatment would be made on an area before harvesting. By doing so, the natural fuel bed would be reduced. With less natural fuel, it will be easier to burn the slash created by the following harvest. The reduction of the natural fuel, before cutting, also facilitates the harvest operation by opening the stand, creating easier maneuverability. With less brush, it will also be easier to find the logs, speeding up the skidding process.

According to Davis, Folliott and Clary (1968), two years after a BUST operation in ponderosa pine poles in northern Arizona, the litter layer will rebuild to preburn levels. Therefore, it can be expected that, in one year's time, only enough fine
fuels should accumulate to facilitate the spread of a prescribed burn. The duff level during this period should not be sufficient to foster anything more than a low ground fire. In order to assure a sufficient supply of fine fuels for the slash burn, the initial fire would have to be intense enough to create a sizeable needle drop similar to that which was observed on the Camas Prairie burn.

Ferry Basin burn

The Ferry Basin slash reduction pilot project was an attempt by the Flathead Reservation forest management staff to combine the benefits of burning for stand improvement with those of broadcast burning of slash. All communications from the fire management consultant were handled through the timber sale officer. In every way possible, this project was operated as a usual timber sale. By doing so, the feasibility of using the BUST technique in standard forest management operations could be objectively examined.

Arrangements were made with the logging contractor to prepare 200 acres of slash in a special manner. Two chain sawyers went ahead of a D-7 Cat to limb heavy vertical branches on the ponderosa pine crowns. The tractor followed, crushing
the slash to decrease the fuel porosity. Fire breaks were constructed at 100-yard intervals. These breaks were constructed by creating perpendicular trails connecting the contouring haul roads. The Cat operator was instructed to reduce heavy slash concentrations about the leave trees. This was accomplished by the tractor's churning about the base of the leave trees. On extreme concentrations, a brush blade was used to push back the slash. Care was taken not to create piles during the fuel alteration process.

Optimum conditions for ignition occur when fuels are dry enough for the fire to spread by itself, but not so dry as to require protection equipment. Because of the extremely high fire buildup index in August and September of 1969, more than cool nights with heavy dew was necessary to condition the fuels for safe burning. As is frequently the problem with fall burning, the extremely dry conditions rapidly changed to extremely wet conditions. This tenor remained throughout the burning season.

Burnings on Ferry Basin, that occurred on the west and south aspects at periods of maximum radiation, responded desirably. With multiple strip ignition, heading fires, burning up-hill, were able to sustain the fire's movement. Occasional crowning occurred in the Douglas fir sapling thickets,
which were infected with dwarfmistletoe. In these thickets, the abnormally dense branching, created by the dwarfmistletoe, facilitated the fire's vertical movement.

Time estimates were kept by the contractor. It was found that twice as many acres could be mechanically pre-treated for BUST operations as could be treated by piling during the same period of time. Ignition, when ideal conditions for BUST treatment existed, required only one-fourth the time needed to ignite the piles on similar acreages. On the north and east slopes, where the fuel was found to be quite moist, the ignition required intensive manipulation. The effectiveness of the treatment under these adverse conditions was questionable. The cost of BUST ignition, where it was too moist, was higher than for similar areas that were piled and burned. Very little natural fuel reduction occurred on the sites that were too moist. Generally, on the wet sites, the fire intensity was insufficient to generate heat that could kill saplings. In summary, it may be said that the advantages of slash burning under standing timber may only be realized when the narrow range of optimum fuel conditions occurs.
CHAPTER IV

AIR QUALITY CONSIDERATIONS

Smoke management is an integral part of any prescribed burning program. Ironically, the demand for cleaner burning, though it may be viewed as a death measure by some forest managers, will enhance a prescribed burning program. Smoke management requires a burner to have a good knowledge of the fuels, their conditions, and the weather. The gathering of this knowledge will force managers into a more scientific approach to the problem. Burners that delay burning until late fall when the fuel is wet and inversions persist, causing smoke detainment, will have to curtail operations.

Probably for every prescribed fire that was too hot, there have been a dozen that merely filled the sky with smoke and blackened a few logs and stumps. The benefits from these fires are purely psychological, but the costs are very real. If forest management agencies are to realize the benefits of a fire management program, they must recognize the necessity to invest in the tools and personnel that can bring about these benefits.
The Case for Air Quality

There is an interesting corollary between the present defensive tactics used by foresters in defending prescribed burning and the old tactic used by industry in defending their efforts at air quality control. All across the U.S. travelers can see monuments to industry's futile effort to rid itself of industrial waste. The famous smoke stack is everywhere. The more noxious the effluent matter, the taller the smoke stack. What can a convection column be called if it is not a super smoke stack? Hopefully, pollution control specialists and the public will not assume this corollary.

Another interesting corollary can be drawn between the old implied adage of industry's "the solution to pollution is dilution" and the new witty adage of foresters, "the solution to pollution is dilution."

One explanation for such seemingly naivete is that foresters are convinced that smoke is not toxic. So far, all tests also substantiate the non-toxicity of forest fire smoke (Darley, et. al., 1966 and Anon., 1969-a).

---

1 A convection column exists when a parcel of air is lifted to the level of free convection by the energy of the fire. Above the level of free convection the parcel of air will be warmer than the environment and there will be an upward acceleration.
If the amount of the various gaseous components of every fire can be predicted, it is still difficult to assess this in terms of the world's air supply. Undoubtedly smoke sensitive areas, especially in our megalopolises, have an overburdened atmosphere. Presently, the natural particulate cleansing agent of the atmosphere, rain, has been able to cope with even the worst fire seasons in forest regions. Therefore, the question arises, is the smoke from forest fires really contributing to the world's air pollution? If the local climate can cope with the smoke, then it is not a contributor. If urban pollution invades the forest zones and disrupts this gigantic cleansing reservoir balance, then forest smoke is a contributing factor.

The correctness of such logic is questionable when considering the gaseous components of a fire. Particulates will be precipitated out in time, but the planetary wind system will continue to carry the CO₂, CO and C (Hydrocarbons) about the earth.

There is one common viewpoint that most fire-oriented people have taken that gets their view across a little too plainly. "What are they going to do, outlaw wildfire?"

This view originates from the fact that fire is an integral part of the ecological system. Most foresters, familiar with fire fighting, realize that there is little man can do to stop a
forest conflagration when the fuels and weather are just right (Wilson, 1970).

This now brings us to the problem. How can a tremendous burning job be accomplished without causing serious deterioration of air quality?

Fortunately, smoke from prescribed burning has certain distinct differences from the usual sources of pollution (Cramer, 1968).

1. It can originate in large, high energy convective columns.
2. It is mostly remote from populated areas.
3. Its source is usually at a high elevation.
4. The smoke can only last a few hours.
5. It has some scheduling flexibility.

Air pollution aspects of slash burning can be minimized by establishing a high energy fire with a strong convective column under conditions favorable for rapid atmospheric dispersion.

Warm air rises and the hotter the air, the faster and higher it rises. When slash is burned under ideal moisture conditions, a high energy fire is produced; assuming it is not a BUST slash reduction operation. This fire will create a hot convective column which usually transports smoke several thousand feet above the fire. The height to which this column
will ascend depends upon the temperature and the wind profiles of the atmosphere. Hot air, smoke, will rise until it reaches an altitude where its temperature and the ambient air temperature are the same.

The temperature structure, or stability, of the air can change greatly with elevation. In stable air, the temperature decreases with altitude at a rate less than 5.5 degrees Fahrenheit per 1000 feet. Smoke rising in a stable condition will reach the same temperature as the surrounding air at a low altitude.

Smoke Management

Some of the more salient features of smoke management have been discussed by Beaufait and Cramer (1969). Their emphasis was upon burning when the driest possible, but safe conditions existed. This would minimize the smoke and produce fewer water droplets, thereby increasing visibility downwind of the fire. Great emphasis was also placed on burning in the unstable atmosphere, or in thin stable layers where the heat of the fire will penetrate the stable layer.

Burning under the driest conditions requires intensive meteorological sampling. The instruments involved are rain gauges, anemometers and hygrothermographs, continuous recording
devices of temperature and relative humidity. Fuel moisture sticks may also be desirable. All of these instruments, with the exception of fuel moisture sticks, are presently used at standard fire weather stations. Proper placement and maintenance of these instruments is vital for obtaining meaningful data.

All of the present literature on smoke management pertains to burning slash on clearcuts. Convection column development in BUST operations would be disastrous. Burning with the driest possible conditions may well be too hot for many BUST objectives. To take advantage of dry fuel conditions, and favorable meteorological conditions, many BUST operations will have to occur in the evening. It is during this period that the most pronounced stable atmospheric layers start to develop. Still one should not conclude that BUST treatments are in conflict with air quality programs.

Extremely dry conditions are not needed to prepare fine fuels for burning. If BUST operations occur during periods when heavy fuels contain a lot of moisture, very little prolonged smoke will transpire. Generally, a BUST operation consumes fine fuels and resembles a grass fire in respect to the short residence of the fire. The most ideal time for BUST hazard reduction occurs when the surface litter and duff are dry but the medium and large
fuels are too wet to burn. This condition rarely occurs in the fall. The drying trend of the spring and early summer, when inversions are short-lived, corresponds with the desired moisture regime. Stable conditions, that occur in the valley bottoms during evenings, rarely linger beyond the early morning (Beaufait and Cramer, 1969). Also, most BUST operations will occur above the valley floor where a relatively buoyant atmosphere will persist for a couple of hours after sundown. Any drift smoke that flows into a valley will be dissipated in the morning.

Though many of the conditions that generate air quality problems are not present in BUST operations, special agency smoke regulatory controls are still needed. If standards have to be met, then operations will not likely be "spur of the moment" affairs. Smoke management restrictions may be the only way to stimulate forest management agencies into developing a full-time prescribed burning program.
CHAPTER V

FIRE MANAGEMENT CONSIDERATIONS

Burning plans

Weather conditions limit the period of prescribed burning. During the short favorable periods, thousands of acres of clearcuts and BUST should be treated. Sometimes the only planning that corresponds with this massive treatment program is for escapes. If only plans for controlling escapes are made, the probability of having to implement this plan is great.

Local timber sale officers are required to prepare hazard abatement plans for all government timber sales. Many times, these plans consist of colored maps that merely indicate on which clearcut block, or on what end of a selection cut, the treatment should start. Occasionally, an ironclad ignition pattern is also prescribed. Rigidity should not be written into a burning plan. There are too many variations which may occur at the time of burning that cannot be accounted for in the office.

With one set of topographic, fuel, and weather conditions, a backing fire should be used. Under another set of conditions, possibly a heading fire should be used. When dry conditions
prevail, low hazard areas should have priority; when wet conditions occur, high hazard areas should have priority.

A burning plan must be flexible enough to accommodate the conditions at the time of burning. Ideally, the part of a burning plan that pertains to the when and how of the burning should be left open and decided upon at the time of the operation. Possibly, a checklist approach to this section of the burning plan would be most favorable. This would provide flexibility and remind burners what options are available. It would also provide a more accurate record for the future of what actually transpired.

Work load involved

A synopsis of the magnitude of work involved with a fire management program is astonishing. It is not uncommon for an agency to harvest 80 million board feet of timber a year. Using a very conservative estimate of 10 thousand board feet per acre, approximately 8 thousand acres a year would be in need of slash treatment. This acreage, coupled with hazard reduction programs and the vast backlog of slash in need of treatment, becomes enormous.

As previously mentioned, there is a great necessity for
preburn planning. Time has to be expended to establish a fuel monitoring system. Areas should be selected for treatment with some order of priority. Timber sale plans should also incorporate designs that will facilitate the slash treatment process. Operation sites should be continually checked for compliance with the specifications. Training programs should be organized and equipment procured. Ideally, this work would be handled by a special fire management staff. More realistically, this work load would be handled by a fire manager in a staff position working through the district personnel. In either case, there is a necessity for an all-season program with full-time fire manager as a coordinator.

Factors involved in a cost benefit analysis

The case for economic justification of a fire management program is a difficult one to make and must receive greater future consideration. Cost figures for BUST projects throughout the United States range from 25 cents per acre to 70 dollars per acre. What a reasonable cost figure would be for this region is presently undetermined. Most likely, the cost would be higher than in other regions.

General cost figures are fairly easy to obtain for BUST
The major costs are site preparation, firing, and mop-up. Placing a dollar value on the benefits is not as easy. By considering only hazard reduction benefits resulting from a single burn, only part of the total benefits of the system can be realized. The cost on any one fire can be determined, but the benefits from the initial burn are not so discernible. To limit a cost benefit analysis to hazard reduction considerations and exclude the many incidental and intangible benefits would restrict the realization of the total economic asset.

When using cost figures in an analysis, a decision has to be made as to which fire's cost estimates will be used. Dr. William Beaufait from the Northern Forest Fire Laboratory has stated that there is as much a difference within treatments as there is between different types of treatments.

Before further discussing the cost benefit analysis and the ambiguities involved, some of the variables that affect a project's cost should be reviewed.
CHAPTER VI

COST FACTORS IN BUST ANALYSIS

Size aspects

In the southwestern regions of the United States, the size of the burn has not yet been demonstrated as an economically limiting factor. It is generally accepted that the cost per acre of a burn is inversely related to the size. In the rugged northern Rocky Mountain region, the nonuniformity of the topography and vegetation will limit the normal inverse cost per acre relationship. A cost per acre curve for BUST operations in this region would probably resemble a U-shaped curve (See Figure 6).

The quality of the burn must be considered as one of the components in determining the cost. If quality were not included, the adage "the operation was a success but the patient died" would have to apply. Cost could continue to drop with an increase in size, but during the process the forest might be destroyed. Therefore, as the size increases and the management becomes less intense, the quality will decrease.

Though the derivation of these cost-size trends is pure conjecture, the following section on administration coordination
Theoretical Cost Per Acre for BUST Operations in the Northern Rocky Mountain Region
and communication may serve to illustrate why this assertion was made.

Administration Coordination and Communication

On clearcut burning, visibility is not restrictive and communications and coordination are fairly simple. On sizeable BUST operations, it is easy for the ignitors to lose sight of each other. Without some visible reference point, ignitors, working alone, may become disoriented. Disorientation could affect the ignition and the resultant control of the fire's intensity.

Fires are usually started by lighting along the contours, on the top line of a burn. If the fuel moisture content is slightly higher than desired, several ignited strips, run parallel to the contours, may be necessary to sustain a fire. When high fuel moisture contents exist, 14 - 16 percent, it may be necessary to ignite with the wind, or from the bottom of the slope. On small burns of 100 acres or less, it is not difficult to follow the fire's progress throughout the stand and treat each condition individually. If there is a slight change in aspect or vegetation, an ignitor is able to temporarily change the fire's intensity. Where dense sapling thickets occur, wider strips may be used to produce a more intense fire; assuming that the particular objective
is to intensify the thinning. This type of intensive fire herding would not be feasible on larger areas.

On the Fort Apache Indian Reservation in Arizona, stands of 3 to 5 acres have been destroyed by extensive fire management operations. The loss of a few 5-acre patches has been justified by the extensive size, 28,000 acres or more, of the operation. These patches are usually destroyed when the fire front becomes uneven, and envelopes the stand. Due to microclimatic variances, some areas of the fire front will reach a low elevation long before another section of the fire. When this occurs, the lower fire may reverse its direction and become a heading fire. If the fuel is dry enough, a heading fire may be too intense for the vegetation. When the two fire fronts meet, an extremely intense fire will result, usually engulfing the vegetation with flames. Similar extensive fire operations in the northern Rocky Mountain region would most likely result in large acreages being adversely treated. Several of the following factors

---

1 Lindenmuth, in a Survey of Effects of Intentional Burning on Fuels and Timber Stands of Ponderosa Pine in Arizona, 1960, mentions that fire is an imperfect tool and that burning on such a large scale appears to have a low ratio of benefits to damages. More favorable results should be possible by intensive application. He further states that adjusting fire intensity to tree size has good possibilities for controlling killing of trees.
contribute to this phenomenon:

1. In the northern Rocky Mountain region pronounced vegetational changes occur between north and south, and east and west aspects. Similar differences do not occur north and south of this latitudinal range. These microclimatic differences can be attributed to geometric effects of solar radiation in the 35 to 55 degree latitude. On latitudes less than 35 degrees, the insolation is direct and opposing aspects receive equal amounts of radiation. At the higher latitudes, the radiation is diffused because of the steep angle of the insolation. This neutralizes the radiational effect because all of the aspects receive equal amounts of the diffuse radiation.

2. The fuel buildup and the density of the stands in this region are generally excessive, when compared to the southwestern forest. If a small 5-acre patch of saplings were to be engulfed by fire in this region, the possibility of it becoming a wildfire is quite high. The fuel accretion effect of the wildfire exclusion policy has been minimized in parts of the southwest by the liberal use of controlled burning. In this region, a rigid fire exclusion policy has prevailed for approximately 50 years, and has facilitated the development of dense stands and deep duff layers.
3. Prescribed burns in the southwestern region of the United States generally occur in the late fall. During this season, the temperatures frequently drop below freezing, the days are short, and there is a high nighttime recovery of moisture. But the daytime fuel moisture conditions are similar to those that occur during the summer. When freezing temperatures, short days, and high nighttime moisture recovery occurs in this region, the burning site is usually under a couple of feet of snow.

Prospectively, extensive fire operations will be feasible in this region only after massive areas have received prior intensive treatment. Until large areas can be treated in this region, the fire manager must work with fractionally higher cost per acre figures.

Review of cost figures for BUST operations

Chrosciewicz (1959) has found that burning in evenings is less costly than afternoon fires. His cost figures ranged from 4 to 20 dollars per acre in jack pine stands. Biswell (1967) has submitted that initial BUST burns will cost many times more than successive burns. His initial burn cost figures, run from 5 to 10 dollars per acre for BUST operations.
in ponderosa pine stands. Costs of successive treatments are suggested to be as low as 25 cents per acre. Gordon's (1967) figures are among the highest recorded. Special costs for pre-burn treatment were included in the first of his two sets of figures. These figures showed 52 dollars per acre, of which 34 dollars was used for pruning and fuel alteration. On the second set, the extremely high cost of 70 dollars per acre was recorded. Fifty-eight dollars per acre was accounted for by patrolling and mop-up action. In contrast to these costs, the Camas Prairie burn was 8 dollars per acre. Since the Camas Prairie operation was a pilot project, liberal protection measures were taken which increased the cost. It must be remembered that the Camas Prairie burn was chosen for its access and ideal uniformity. It, therefore, does not represent normal forest conditions and should not be considered as a reference point for all other BUST operations in that area.
In light of the tremendous variance in cost, it may be more enlightening to examine the economics of a fire management program from the benefit aspect. Weaver, in Effects of Prescribed Burning in Ponderosa Pine (1957), discusses the benefits in relation to occurrence and cost per acre of wildfire on treated and untreated lands. It was found by accumulating data over a ten-year period that the cost of controlling fire on treated lands was 55 percent less than that for untreated lands. There was also 87 percent less damage to the residual stock on the treated lands. Similar results were obtained on the Fort Apache Reservation where 65,000 acres were burned. Harry Kallander, retired forest supervisor on the Fort Apache Reservation, stated that the real pay-off in hazard reduction is the easier job of controlling wildfire. This statement was supported by a study where a six-year comparison, before and after burning, demonstrated that prescribed burning may be credited with an 82 percent reduction in number of fires, and a 94 percent reduction in size of the average fire (Kallander, Weaver and Gaines, 1955).
In this study, it was also stated that BUST can be justified only if the total benefits exceed damage, plus cost of operation.

Other benefits, such as wildlife habitat improvement, are not measurable. The question of what is the value of wildlife seems to be unanswerable and, therefore, curtails any further development of an economic model. Jack Lyon, wildlife habitat specialist at the Forestry Sciences Laboratory in Missoula, stated that the field of wildlife management is far from being able to assign any value to game animals, and has not even considered the cost of management practices that improve the habitat.

Thinning with fire is frequently listed as a secondary objective of hazard reduction burns. Weaver (1959), Henderson (1967), and Lindenmuth (1960), in various studies, have discussed this aspect. Weaver (1967) found that, after three successive prescribed burns in young ponderosa pine, over the past 23-year period, crop trees have continued faster growth in diameter and height, in comparison to growth occurring in crop trees of an unburned control.

Lindenmuth (1960), on a study of the effects of hazard reduction burning on the Fort Apache Reservation, concluded that for every potential crop tree released, an average of 5.5
potential crop trees were damaged or killed. His findings were moderated by the comment that under more intensive fire management, the indiscriminate thinning would probably produce more favorable results.

Growth increment can be measured and converted to dollars, but the variance within thinning operations makes it exceedingly difficult to assign any predictable economic return. Therefore, the entire economic evaluation of prescribed burning operations is presently limited. It is impossible to tell a forest manager what return he will receive if he invests in a thinning with fire program. It may be concluded that realistic applications of economic principles to prescribed fire activities requires a greater knowledge of short and long-term effects of fire on all parts of the ecosystem and the results of these effects on a variety of land uses (Muraro, 1968).
CHAPTER VIII

GUIDE FOR ESTABLISHING A FIRE MANAGEMENT PROGRAM

Administrative Position of the Fire Manager

Where on an administrative flow chart should a fire management specialist be placed? Most management applications of fire, other than the parochial clearcut burning of slash, has occurred where fire enthusiasts have taken it upon themselves to try and use fire. Personnel in regional administrative positions have not been very successful in furthering fire use. Nor have fire control officers at the field operations level.

A fire specialist needs to be in a position where the field staff and the contractor have sufficient access to each other to be on a first-name basis. This type of relationship is valuable because the success of instilling a fire management program partially relies upon the confidence of the staff in the manager. The fire specialist should also be in a position where he can assist in planning the harvest operations. Ideally, this position would be at the management unit's headquarters.
Demonstrations and Workshops

A picture is said to be worth a thousand words, a demonstration is worth a book. Experience has shown that many fire use advocates have no conception of how a prescribed fire functions. Often foresters become panicky and want to start suppression action immediately, if a single tree is engulfed by fire. Ironically, these same people sometimes express the desire of having the treatment kill the understory and the diseased trees. This type of contradiction transpires when inexperience prevails and can be resolved through demonstrational burns.

A demonstrational burn should be of sufficient size to incorporate the usual variation in topography and vegetation that would occur on a management scale operation. Realism should be one of the main goals of the demonstration. The problems involved when the research scale is expanded to the management scale are what forest managers must confront. A research-size burn, a couple of acres, with every piece of fire fighting equipment in the district present, cannot simulate an economical management scale operation. A demonstration should at least approach one hundred acres and only the protection equipment necessary for patrolling should be present.

Observers should be given every chance to participate and
to identify with the fire as their fire. One of the best ways to develop confidence in fire is to start one and observe the predicted reactions resulting from your actions. The personal feeling of control over what has been sometimes called the arch enemy of foresters will probably do more to further fire use than any other propaganda measure.

The observers should be requested to move along with the fire front and a running commentary informing them of what they are seeing and why something occurred, should be made.

The attention of the observers should also be directed toward the burned area. Boles of trees should be inspected and surface soil temperatures and duff reduction should be examined.

More than one demonstration will likely be needed before controlled burning will be accepted. Succeeding fire use demonstrations should be for different objectives to illustrate the multiplicity of fire use. Repetition of demonstrations also serves to enforce the fact that the first burn's success was not luck.

**Budgeting**

Before a fire management program becomes functional, provisions for budgeting and procuring must be made.

The initial budget request should be conservative.
When the value of a program is still in question, a large budget request might mask the initial benefits. For the first years of operation, the equipment expenditure could be kept low by cooperatively buying with other divisions. Most of the equipment needed for prescribed burning can also be used by the fire control division. The meteorological equipment may also be valuable to the forest development division in its reforestation program.

Timber sale slash reduction funds and fire control funds will pay for the labor on most of the treatment operation. Therefore, the budget allocation for the treatment process should be very low.

Guideline development

Guidelines may be considered the instruction sheet for the prescribed burning kit. The success of the burns and the magnitude of the program depends upon the district staff's understanding of the basic principles. Biswell titled these principles the WHY, WHERE, and HOW of prescribed burning (Biswell, 1967).

Guideline topics must encompass more than moisture, wind, and temperatures that prevail during an operation. There are so many factors and so many combinations of these factors
that it is presently impossible to set precise numerical guidelines for all fires. Until a basic feeling is established for fire behavior, guidelines should be basic and should include some of the following items:

I. Site preparation and block layout
   A. Aspect
   B. Slope
   C. Instrumentation
      1. Fuel moisture stick readings
      2. Relative humidity
      3. Wind
      4. Estimating flammability
         a. National Fire-Danger Rating System
      5. Ignition

II. Manning

III. Timing the burn
   A. Maintaining a clean atmosphere
   B. Spot forecast
   C. Mop-up

1 Guideline outline obtained from Allan Hartong of the Northern Forest Fire Laboratory, Missoula, Montana.
Forms and Records

Most prescribed burning will be of a cyclic nature. As the prescribed burning program expands, records will have to be kept to maintain order in the system. Information pertaining to the conditions that prevailed at the time of the burn, correlated with the results, will assist in planning future burns. Forms and records also act as a method of administrative control. They tend to check spur-of-the-moment operations and formalize legal responsibilities.

Training

The Camas Prairie Burn illustrated the need for comprehensive training. The adage, "a chain is as strong as its weakest link", aptly applies to the importance of the fire crew's role. The best equipment, the best site preparation, and the best meteorological data available cannot alone guarantee the success of an operation.
CHAPTER IX

SUMMARY

The forests of the northern Rocky Mountain region have been influenced by wildfire ever since the last ice age. Numerous plant species have adapted physiological characteristics that have ensured their perpetuance in this fire climate. Many habitat types have evolved that are dependent upon periodic fire occurrence. But, the society of man and his demands for greater land utilization became incompatible with the natural management scheme. In time, a wildfire exclusion policy was instituted and became accepted as a national goal.

While the campaign against wildfire became more intense, programs on fire use expanded. During the period that methods for burning logging residue were developed, the understanding of how to use fire as a tool of forest management also grew. But, this use has been restricted to slash treatments on clearcuts in this region.

Ecologists, of all disciplines, are continuously emphasizing the role fire has played in this region. Ecological studies on the effects of fire exclusion substantiate the claims that habitat types
are evolving towards the climax. Forest fuel scientists are forewarning foresters that sufficient fuel accretion and stand stocking has occurred since the implementation of the fire exclusion policy to foster major conflagrations. One method of alleviating this natural hazard buildup is through the use of fire.

To use fire as an integral part of the fire control, timber harvest, and forest development programs, more than seasonal token acknowledgment must be given to fire problems. Successful burning operations will only come as the result of intensive environmental sampling and intra-agency planning.

If prescribed burning is to be of any major benefit in the forest management practice, the technique of burning under standing timber will have to be perfected.

Recent pilot projects on the Flathead Indian Reservation have demonstrated that burning under standing timber for slash reduction and natural fuel reduction are feasible. The projects also illustrated the need for more management scale operations, to identify the constraints of burning in areas of disparate vegetation and topography.

To guide and coordinate a fire management program, a fire use specialist in a staff position would be practicable. The
fire use specialist, or fire manager, should be involved with demonstrational burns, developing guidelines and fire plans, program finances, and equipment procurement.

The use of fire will remain an art until management-oriented fire projects translate scientific principles into functional management techniques. It has been stated that "all things are difficult before they are easy" - Fuller. This perspicuous phrase aptly sums the predicament foresters are now facing in regard to fire management implementation.
CHAPTER X

RECOMMENDATIONS AND CONCLUSIONS

Controlled burning is not the cure-all for the ills of forest management practices. Like clearcutting, controlled burning can be overused and misused. Presently, the benefits of prescribed fire use in the northern Rocky Mountain region is virtually unassayed. If the total benefits are to be realized, burning under standing timber will have to become a major activity in a fire management program.

Throughout this paper, problems inherent with BUST treatments have been mentioned. No single problem poses an insurmountable situation. It is entirely possible that a combination of problems may present such a restrictive situation as to make BUST treatments economically infeasible. Though there are numerous areas of fire application that need examining, and may prove to be a greater problem than expected, it is the author's opinion that many of the problems are managerial and, as experience is gained, may prove to be insignificant.

The problem areas encountered in BUST operations can be classified into the three following groups: physical, technical, and managerial. The physical problems, those of smoke manage-
merit and insect attacks, may be the most limiting and should receive research priority. The technical and managerial problems will probably vary in degree of limitation, depending on the type of operation. The technical problems will most likely occur when repeated burns are required. The technical grouping includes such considerations as: what burning conditions are necessary to achieve the objective, when should reburns occur and, what, if any, pretreatment is necessary. The managerial problems pertain to logistics, personnel expertise, economics, and planning.

The following recommendations for future studies have been made in light of a nearly complete dearth of knowledge and use of BUST activities in this region.

1. The public involvement with air quality control programs is not just a fad. Programs must be started now, to educate the public about the ecological role of fire, so that they will understand why it is necessary to burn.

The standard parochial means of dispersing information must be expanded and modernized. The primary target in the education process should be the concerned conservationist. Pressure groups such as the Sierra Club, Trout Unlimited, Wilderness Society, and the National Parks Society could be
extremely effective proponents of fire use.

Concurrent with this effort, studies must be made to find out how to minimize the smoke nuisance in BUST operations. Information is also needed about the particulate and gaseous components of natural fuel reduction burns as compared to clearcut slash burns.

2. Because of limited burning periods during the spring and fall, summer burning will become a necessity. It is during this period that bark beetles are most active and will rapidly invade fire-damaged trees.

Information is needed on the relationships of indigenous bark beetle populations and attacks on various intensities of burn. Possibly BUST operations should not be considered in areas where the insect population is above a certain level. The Camas Prairie operation demonstrated the rapid response insects will make on pockets of damaged trees. Would these insects have attacked this area if the fire intensity had been better controlled?

3. Hazard reduction burning, in order to be effective, will have to be cyclic. If, after the initial treatment, fuel loading will return to its previous level within two years, the period between the first and second treatment will be shortlived if
hazard reduction benefits are to be maintained. Should the fire intensity of the reburn be low, so as not to create any new kill and needle scorch, or should it be a high intensity burn and attempt to consume the previously-killed vegetation? Will the previously-killed vegetation that is still standing act as a torch to foster a crown fire? Should one wait for the killed trees to fall over before reburning?

4. The possible use of burning before selective logging, followed by a BUST slash reduction operation, has not been investigated. It is through integrated operations such as this that the benefits of prescribed burning would most likely be maximized.

Pilot projects should be established to examine the feasibility of such operations. Timing of the burns, in relation to the logging, and the necessary fire intensities needed to optimumly prepare the site must be determined.

5. There is a great need for management-oriented fire-use research. Quarter-acre experimental plots do not simulate the conditions that occur on management operations. Variations in topography, vegetation, and the effects of fire generating its own meteorological conditions cannot be duplicated on small test plots.

6. A fire management position should be established to guide
and coordinate fire use activities. This position would be part of the fire management division and should include fire control activities as well as all other fire uses.

This change is not meant merely as an administrative shift, but represents an entirely new philosophy of total fire use. If fire is to be placed in its proper perspective, the following questions should be asked:

1. What is the resource situation?
2. What are the resource management objectives?
3. What are the management tools available for accomplishing the objectives?
4. If fire is one of the available tools, how can it best be applied?

7. Cost benefit analyses are nearly impossible to make at the present time because of insufficient regional data. Cost will ultimately regulate the use of fire. It is entirely possible that the cost of summer operations will exceed the benefits. Fire researchers and managers must be more conscious of the variables that affect cost. Presently, cost and benefits are based too much on conjecture and could be misleading.

8. Fire scientists must make a greater attempt to emphasize the importance of the man factor. The success of an operation
depends almost entirely on the ability of the field staff to interpret situations and administer the appropriate technique. Publications should not minimize, or completely gloss-over, mistakes that were man-caused. This should not be done to pass off the failures of the system but emphasize the man factor and the need for planning and training.
BIBLIOGRAPHY


Daubenmire, Rexford. 1968. Structure and ecology of coniferous forest of the Northern Rocky Mountains. Proc. of the 1968 Symposium, Coniferous Forest of the Northern Rocky Mountains. Univ. of Montana Foundation 1969.


