THE BALMORAL FOREST FIRE

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INTRODUCTION

At 2135 hours on Friday 25 November 1955 a small industrial fire broke out in an old mill building situated within Balmoral Forest, Canterbury. Although at first brought under control with negligible damage to the forest, winds of gale and hurricane force on the morning of 26 November carried sparks from burning roots into the main block of the forest, where the fire eventually covered 7,790 acres* —the most disastrous exotic forest fire ever to occur within a New Zealand State Forest.

The purpose of this paper is to record observations and facts, to analyse the fire behaviour, and to suggest how the lessons learnt could lead to improved fire protection of other exotic forests, both established and planned. Particular emphasis is placed on the silvicultural and management aspects of better fire protection.

THE FOREST AND THE FUEL

General Description

The forest is located on the flat or gently sloping plains of the Culverden basin some 54 miles north of Christchurch. Altitude varies from 500 ft. in the east to 1,100 ft. in the west of the forest. A total of 18,415 acres of exotic State forest together with 557 acres of privately owned exotic forest are situated immediately north of the Hurunui River. A further 1,757 acres of State forest are located one mile south of the river; this latter area was not at any time seriously threatened by the fire.

The light gravelly river-terrace soils make Balmoral almost sub-marginal for production forestry. The shallow rooting propensity of these soils, the low average annual rainfall of 27.09 inches, the exposed site, the harsh winters, and the normal periods of summer drought, have combined to make this a problem forest. The greater part of the forest was established between 1917 and 1931, the major species being *P. radiata* (11,800 acres), *P. laricio* (3,000 acres), and *P. ponderosa* (2,400 acres). No less than 70% of the area was planted in the short period 1923 to 1931.

SUBDIVISION

The forest is sub-divided into rectangular 150-to-300-acre compartments, each of which (in the area covered by the fire) is bordered by a road or a firebreak negotiable by vehicles. Originally the firebreaks

*The area actually destroyed was just over 6,000 acres. On the remaining 1,700 acres the trees were scorched but not killed.

were from one to two and a half chains wide, but in 1936 the margins were planted with *P. radiata,* reducing the effective width to a half to one and a half chains. These firebreaks are mostly in a north-south or east-west direction.

There are in addition three major firebreaks based on lines of communication in existence at the time of planting. The Balmoral Road firebreak, four and a half chains wide, runs N.N.W. from the Hurunui River and divides the main block of the forest into two. To the west a railway line runs S.S.W. through the forest; the railway firebreak is five chains wide and separates Balmoral Forest from a 557-acre *P. radiata* plantation established in 1927. To the east another four and a half chain firebreak (Main North Road) runs through the forest in a northeasterly direction.

The locations of these firebreaks and the general subdivision of the forest are illustrated in Plate No. 1.

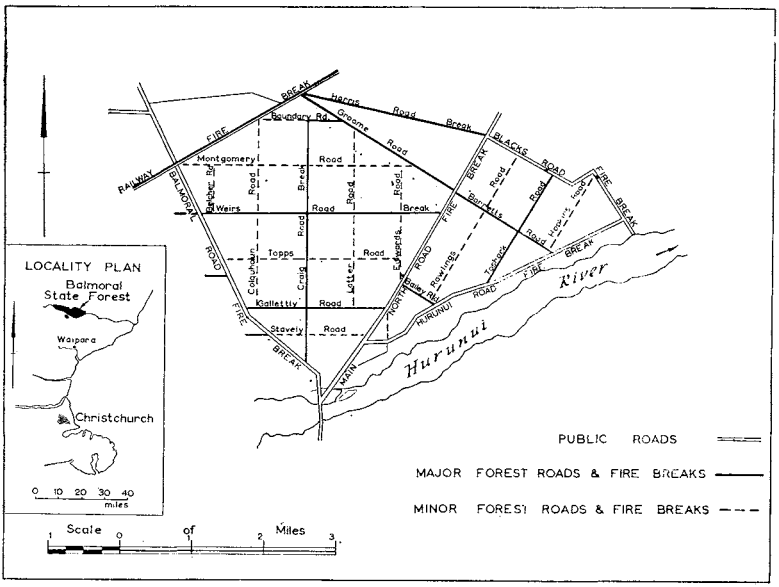

Plate 1. Locality plan.

THE FUEL

At the time of the fire most of the *P. radiata* was from 65 ft. to 80 ft. high. It had been low pruned, but not high pruned or thinned. Except on marginal trees and in lightly stocked stands the green crowns did not extend for more than half the height of the trees; on most trees there was thus a dead-branch zone of some 20 ft. to 30 ft. The *P. laricio* and *P. ponderosa* stands were shorter (mean top heights of 50 ft. and 45 ft. respectively) but they too were characterised by

relatively high canopy levels and hence by many persistent and inflammable dead branches.

In 1945, approximately 3,500 acres, mostly *P. radiata,* were severely damaged by wind (70% or more by number of stems blown over). Most of this area was subsequently salvaged but because of the necessarily low utilisation standards applied to the operation, the slash was exceedingly heavy. This slash, and the dry stumps and roots remaining, were still in a highly inflamable condition at the time of the fire.

In 1952 an epidemic of the looper type larva of *Selidosema suavis* partially defoliated and killed a high percentage of 24-year-old *P. radiata* on approximately 750 acres. The epidemic thus substantially increased the quantity of dry fuel that was present throughout the affected stands.

Between 1949 and 1954, 1,650 acres of *P. laricio* were heavily thinned to waste, and, like the salvaged and looper-killed areas, these treated *P. laricio* stands were highly inflammable.

Furthermore, in a number of *P. laricio* and *P. ponderosa* stands, a moribund and inflammable understorey of the native shrub *Leptospermum ericoides* persisted.

The growth on the firebreaks was sparse and consisted of herbs and grasses still green at the time of the fire. The vegetation on the pastoral land surrounding the forest was similarly quite green.

These fuel types are illustrated diagrammatically in Plate No. 2.

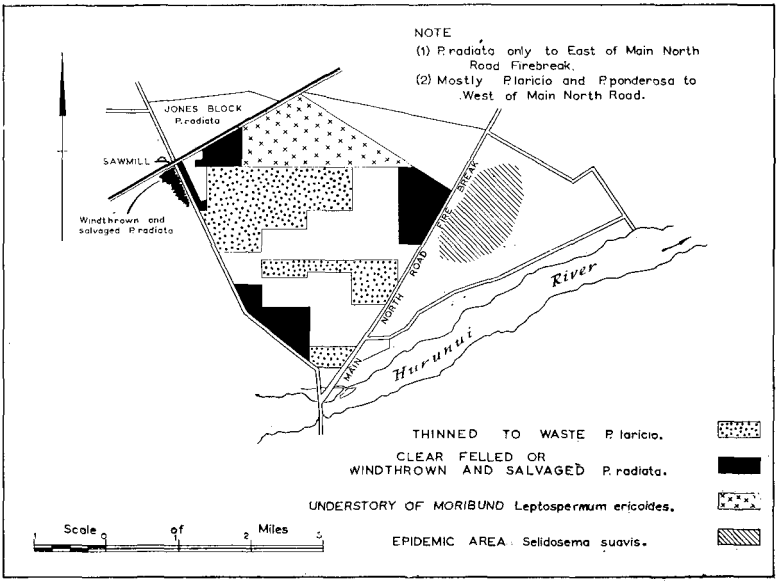

Plate 2. Plan of burnt stands showing position of mill, the distribution of inflammable material, and firebreaks and fire lines.

WEATHER CONDITIONS

In the four weeks prior to the fire, only 0.07 inch of rain was recorded at Balmoral Forest headquarters. Such dry spells in the spring are not uncommon and do not normally cause alarm.

On the day of the fire, the fire hazard readings at headquarters were as follows:

	9 a.m.	1 p.m.
Humidity	53%	33%
Temperature	61°F	70°F
½″ x ½″ stick	18% M.C.	14% M.C.
2″ x 2″ stick	17% M.C.	10% M.C.
Wind	E.2*	N.W.4*

The 1 p.m. humidity was low, but not unusually so. Both the fuel stick readings and the green state of the vegetation indicated that the fuel was far from being in a tinder-dry condition. Although not recorded at headquarters, it is known that local northwest showers fell during the day, and conditions continued to be moist throughout the night of the industrial fire, i.e. 25–26 November. Further northwest showers fell in the vicinity of the mill building between 5 a.m. and 9 a.m. on 26 November. As will be seen from the account of the fire itself, weather conditions deteriorated rapidly during the day of 26 November, mainly under the influence of a northwest wind of exceptional gale force.

THE FIRE

Phase 1 (The industrial fire and the associated spot fires. From 2135 hours on 25th to 0940 hours on 26th.)

At 2135 hours on Friday 25 November 1955 a fire started in an old mill building located several chains north of the railway firebreak and two chains to the west of the Balmoral Road firebreak. The cause of the fire is not known. At the time a force 3 wind from the N.N.W. was blowing, sufficient to carry burning material across the railway firebreak and into an area of wind thrown and salvaged *P. radiata*. Four small spot fires were started; they were quickly brought under control as were the many sawdust fires in the mill yard. (Plate 3, Fig. 1).

By 0300 hours on 26th the mill was completely burnt out. Forest staff continued to patrol the slash and sawdust fires, now black and showing no signs of smoke or sparks. Patrols were maintained throughout the night. The wind continued to blow with moderate strength from N.N.E. and N.N.W., and as previously stated, some light showers of rain fell in the early daylight hours. Heavy rain was falling in the mountains to the west, and there appeared to be every indication of strong northwest showers developing.

At about 0800 hours the wind increased in strength, and swung round to the northwest, the 9 a.m. reading at headquarters being

* All wind strengths expressed in Beaufort scale.

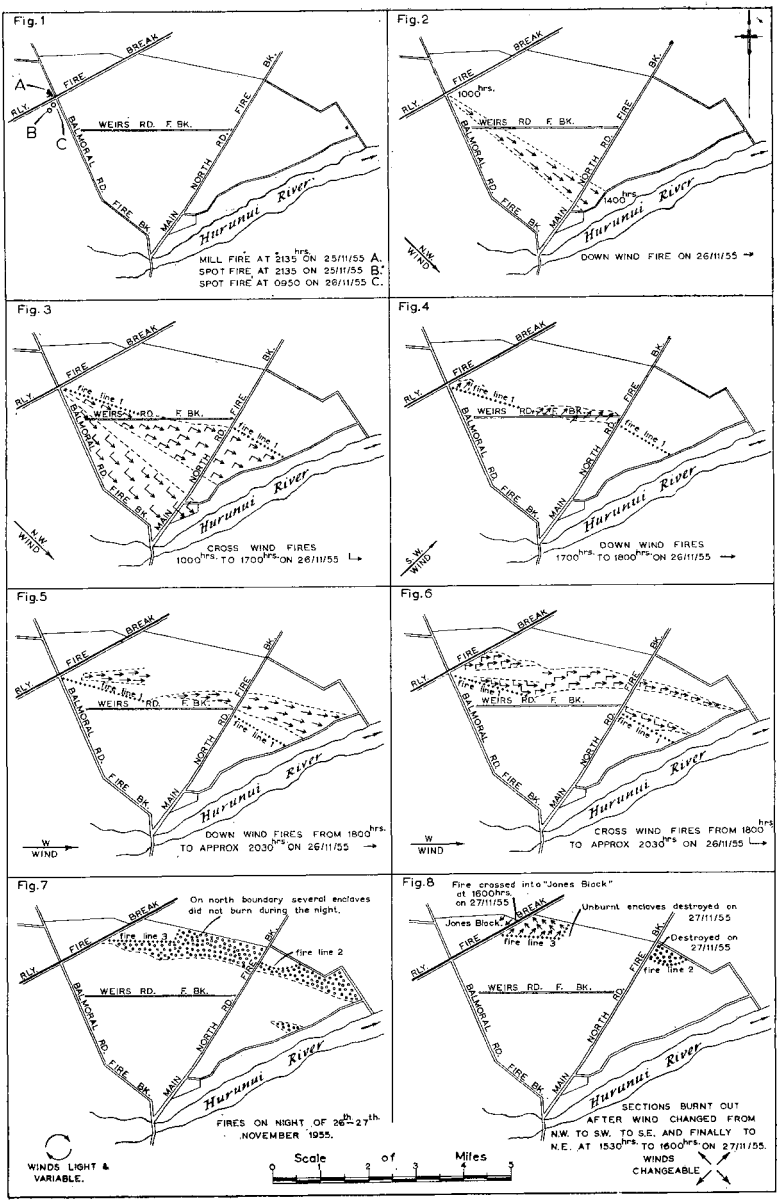

Plate 3. Progress plans of fire.

N.W.7. More dangerous fire conditions developed quickly, the same readings showing a relative humidity of 39% and a ½" stick weight of 11 grammes, both low for the time of the day. By 0930 hours the wind had reached hurricane force.

Except for one stump which flared up at 7.15 a.m. and was quickly dealt with, there was no sign of smoke in the area covered by spot fires during the whole period from midnight to 0930 hours. However at 0940 hours flames burst out suddenly, and at a point which had been inspected by patrols only a few minutes earlier. The evidence suggests that the fire started from a root that had been burning underground. When the soil caved in there were sufficient embers to be fanned into flame by the strong winds then blowing.

Despite all efforts to control it, this fire spread quickly into adjacent slash and kept jumping ahead chains at a time. It covered some ten acres, all to the west of the Balmoral Road firebreak. At about 1040 hours a particularly strong gust carried sparks across the firebreak and into slash from a two-chain marginal strip of windthrown and salvaged *P. radiata*. Three spot fires were started in this slash; they crowned almost immediately, and an uncontrollable crown fire then developed.

Phase 2 (The main northwest fire from 1040 hours to the first wind change at 1700 hours.)

Once the fire had started in the crowns of *P. radiata* there was little that could be done to stop its progress southeast. Attempts were made to back burn from two of the compartment firebreaks (Craig and Galletly Roads), but they were doomed to failure, and the fire raced ahead on a widening front to the Main North Road. (Plate 3, Fig. 2.) A further attempt to back burn from the Main North Road firebreak was also unsuccessful. The fire crossed this 4½-chain break at several points and continued unchecked towards the eastern margin of the forest.

All efforts were therefore directed towards containing the fire to the area east of the Balmoral Road firebreak, and, if possible, towards holding it in its northern flanks. During the morning and early afternoon some 1½ miles of fire line (No. 1) was formed from the rear of the fire and along the entire northern flank. (Plate 4 and Plate 3, Fig. 3.) This fire line linked up with the Weirs Road firebreak, still at this stage north of the fire, and there appeared to be every prospect of holding the fire along its flank. With the Main North Road breached, it became necessary to form a further 80 chains of fire line through to the eastern margin. This extension also held up to the end of Phase 2.

Of the total of 2½ miles of fire line that were formed during the day, approximately one hundred chains passed through thinned to waste *P. laricio* stands and one hundred chains through lightly wind-damaged *P. radiata* stands.

The wind continued to blow consistently from the northwest during the day, but at about 1700 hours it dropped slightly, changed to the southwest, and blew up to gale force again.

Phase 3 (The southwesterly wind change. From 1700 hours to 1800 hours on the 26th.)

This first disastrous wind change undid much of the good work which had been done during the afternoon. Both the formed fire line and Weirs Road firebreak were breached at several points. (Plate 3, Fig. 4.) The strong wind carried sparks well ahead of the fire lines and the new fires started created a situation of extreme danger. Men and equipment had to be evacuated hurriedly, and although some equipment had to be abandoned there were fortunately no casualties. The wind change also pushed the fire north from the actively burning section ahead of the fire line. An attempt was made to hold it from one of the compartment firebreaks, but to no avail. At about 1800 hours the wind changed to the west.

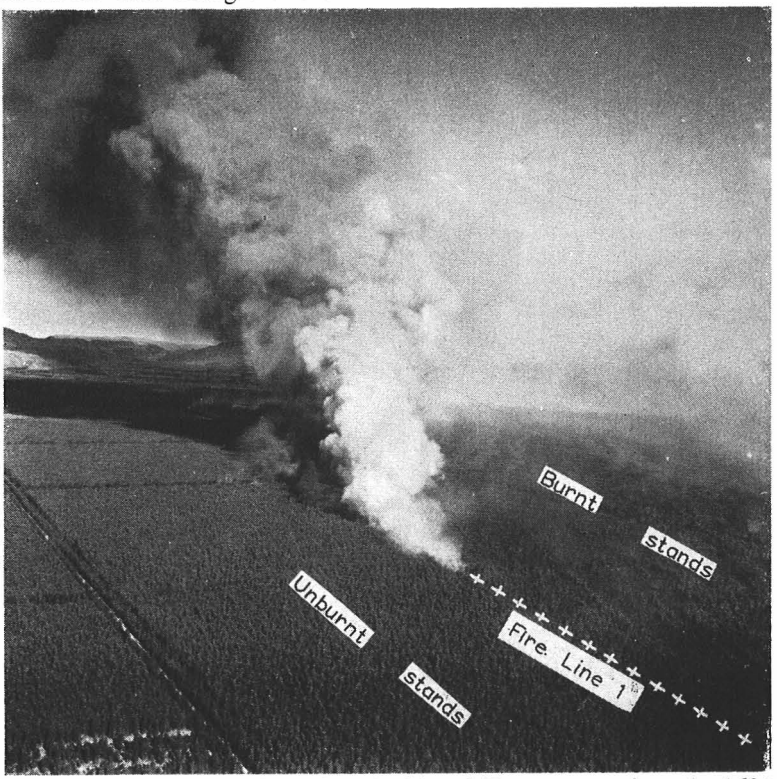

Plate 4. The N.E. flank of fire, looking S.E., at approximately 1600 hours on 26 November 1955. The position of the fireline at this time is shown.

Phase 4 (The second northwest wind. From 1800 hours on the 26th until 1530 hours on the 27th.)

The temporary wind change made the task of containing the fire immeasurably more difficult. With the fire pushed well to the north and with northwesterly winds blowing again there was a much larger area of inflammable forest down wind. The crown fires swept forward again on two relatively wide fronts. (Plate 3, Figs. 5 and 6.) The defence now had to be completely reorganised. As previously, the main efforts were concentrated on the Balmoral Road firebreak, where there was a continued danger of the fire crossing into the stands to the south and west and hence to the forest headquarters. By 1800 hours the fire had burnt back to most points along the eastern side of this firebreak, but at no stage did it cross. Men and equipment were used lavishly on this sector; they were helped by the fact that the firebreak ran more or less down wind, the only major break to do so.

During the night of the 26th and 27th an attempt was made to save two relatively small pockets of timber to the east of the railway firebreak. Two fire lines were constructed. Fireline No. 2 ran in east to west direction and cut-off 450 acres of *P. laricio*. Fireline No. 3 surrounded 120 acres of *P. radiata*. (Plate 3, Fig. 7.) The winds during the night were light and variable and only slow-moving ground fires occurred.

During the early hours of the morning the fire was considered to be well under control and operations consisted mainly of mopping up. The weather forecast was for a wind change to the northeast. The concentration of effort on the still vulnerable Balmoral Road frontage therefore continued.

High fire-danger conditions developed again during the morning and afternoon of the 27th, with the wind continuing from the northwest, and by midday reaching force 7. There were numerous small flare-ups, but all were held, as were fire lines 2 and 3. Phase 4 ended with the fire well under control for northwest conditions, but with the fire hazard remaining high and with a further wind change still prophesied.

Phase 5 (The northeast winds. From 1530 hours on 27th to 1700 hours on 28th.)

Durng the afternoon of the 27th the wind dropped and for a few minutes it was actually calm. At 1530 hours the wind sprang up again, first from the southwest and then quickly from the east and northeast. The two existing fire lines were breached and once again men and equipment had to be hurriedly evacuated. They were deployed along the railway-line firebreak in case this was crossed and fires started in Jones Block. A wind change to the south east did carry sparks across the five-chain break and two small crown fires developed. (Plate 3, Fig. 8.) They were quickly extinguished, most fortunately as a further 11,000 acres of unburnt forest was now down wind and was gravely threatened.

After this crisis was surmounted the fire was never anything but

well under control and no further crossings of the railway or Balmoral Forest firebreaks looked likely. Nevertheless, the situation was potentially dangerous and there was no relaxation of effort all through the night of the 27th and the day of the 28th. At 1750 hours on the 28th rain commenced to fall, and by 1900 hours it was raining heavily. Though not extinguished, the fire was well damped down; for the first time in three days it was safe.

Phase 6 (Final patrols 28 November to 7 December.)

Over an inch of rain fell during the night of 28 November but in the morning hot spots could still be found. A period of day and night patrols then commenced. The day patrol ceased on 3 December and on 7 December, two days after the last burning root had been located, the night patrol was finally abandoned.

FIRE BEHAVIOUR

Down wind

From the point of origin of the crown fire at the intersection of the Balmoral Road and railway firebreaks the fire travelled 310 chains to the southeast edge of the forest at an average rate of 70 chains an hour. The aerial photographs show that originally the fire travelled on several narrow fronts each of which traversed adjacent tongue-like strips of forest. Over the final 160 chains the leading front widened and at the southeast edge of the forest was approximately 45 chains across. As each front of the fire advanced down wind it assumed (in plan view) a more or less rounded front.

Observations revealed that during the periods of strong winds the crown fire was as much as 120 feet ahead of the ground fire in areas where there was little undergrowth or slash, but that in heavy slash and stands with an undergrowth of *Leptospermum ericoides* it was difficult to distinguish crown from ground fire. It appeared as if the heat in front of crown fires was often sufficient to ignite the *Leptospermum* scrub and heavy slash and this in turn developed into crown fires.

Although some spot fires were started well ahead of the crown fires by wind-borne material, it appeared that, in the absence of abundant slash, the running crown fires generally moved well ahead of the associated ground fires. During periods of reduced wind speed the fire moved as a ground fire, or as a ground-to-crown fire when the fuel at ground level was sufficient to ignite the crowns.

Narrow firebreaks were crossed in almost every instance by crown fires and only rarely by a surface fire. The crossings were instantaneous and there was no delay in the forward progress of the running crown fires. On the other hand the strength of the wind was usually inadequate to carry the fire into the crowns on the down-wind side of the 4½-chain Main North Road firebreak. The breaching of this firebreak was effected by spot fires, which in turn spread to the crowns. Along the down-wind side of this and some other firebreaks, the foliage on a marginal strip up to one chain wide continued to remain green after the passage of the fire.

The changes in wind direction which occurred throughout the fire transformed the slow-moving flank fires into rapidly moving, wide-fronted fires. The southwest wind change at 1700 hours on the 26th caused deep penetrations into the northeast flank. Following the westerly change an hour later large areas were destroyed within one hour. The southwest wind change at 1530 hours on the 27th resulted in a further rapid spread of fire as did the following northeast change.

At no time did the fire spread for more than a few feet from the forest into the adjoining pastoral land; in many cases the spread beyond the needle litter was measurable in inches rather than in feet. Small pieces of scorched *P. laricio* bark were picked up some 20 miles to the southeast of the forest. There must therefore have been considerable quantities of burning material deposited closer to the forest; in no known case was a spot fire started.

Across wind

On the northeast and southwest flanks the fire spread slowly across wind. Where the slash was heavy, and during periods of strong wind the marginal slash fires were observed to catch in the crowns and move down wind. Under the influence of the strongest winds the fires rose to the crowns simultaneously over long sections on the flanks. During periods of reduced wind speeds the lateral spread was by ground fires only. The aerial photographs indicate that parallel north-west to southeast strips of completely burnt areas alternate with strips of green or partially burnt areas. (See Fig. 5.) These parallel strips reflect the many changes in wind speed and illustrate the behaviour of fire under such circumstances.

On the flanks, in spite of heavy slash, it was possible to approach within a few feet of the ground fires and fire lines could be formed wherever required. As would be expected, wind strengths near the ground were less in the interior of the forest than they were in the open. It was noted that winds were stronger inside the lightly crowned and more open *P. laricio* stands than in stands of *P. radiata;* as a consequence ground fires were more violent.

Description of Fire-damaged Stands

In the stands subjected to running crown fires the foliage was completely destroyed and the stands were left in a blackened condition. Ground-to-crown fires killed the trees, but the needles were scorched only, and not consumed by fire. In areas traversed by ground fires only the butts were scorched but the crowns remained green. It was thus possible to recognise three distinct categories of damage. The extent of each was:

	Destroyed by running crown fires	Destroyed by ground-to-crown fires	Traversed by ground fires only
	%	%	%
P. radiata	41	20	39
P. laricio	59	10	31
P. ponderosa	55	10	35

Plate 5. Aerial photograph showing where across-wind fires spread in the N.E. flank on 26 November 1955. That strips of defoliated stems alternate with green-topped or "brown-topped" stems is a reflection of the effects of changes in wind force.

Apart from wind strength and wind changes, there were several factors influencing the intensity of the fire. They were the amount of slash, the nature of the vegetation, the stocking, and the time of day.

Bark scorching was severe in the thinned-to-waste 5 ft. × 5 ft. *P. laricio* stands and in untreated stands carrying a heavy undergrowth of *Leptospermum* scrub.

The areas attacked by *Selidosema suavis* caterpillars in 1952 were the most severely scorched of the first-crop *P. radiata* stands.

Unthinned and overstocked 5 ft. × 5 ft. spaced stands, with a big percentage of dead and moribund branches, were in all cases severely scorched. Understocked pockets often continued to remain green in marked contrast to the adjoining, more fully stocked and severely scorched stands.

Within the area covered by the fire, some 50 acres of clear-felling slash had been burnt in the autumn of 1955 and the area replanted. In the absence of fuel this was the only stand through which the fire could not pass; although adjacent areas were burnt out, the young trees in this area entirely escaped damage.

Stems felled or killed within the last six years rarely had more than the branches consumed by the fire. Stems which had been killed many years before the fire (possibly by *Sirex noctilio*), and which subsequently had fallen, continued to smoulder for long periods, and in some cases were completely consumed.

In view of the serious consequences of burning roots during the early phases of the fire, it is of importance to note that the roots of stems that were felled or killed less than six years before do not appear to have been burnt to any extent. However, the bark surrounding the stumps did smoulder and perhaps burn for a few inches into the soil. On the other hand, the roots of stems which had been felled or killed more than six years before the fire continued burning for some considerable time. Burning roots were found on 5 December some nine days after the fire had been through the area and after more than an inch of rain had fallen. The stumps were consumed, as were the radiating roots for a distance up to 8 ft. from the stumps. (See Plate 6.) The roots of old *Sirex*-killed stems readily burnt and thus, even in stands in which felling had not taken place, burning roots were abundant.

The slow-moving night fires consumed only the upper layers of the needle litter. In all other burnt stands the needle litter and the shallow humus layer was completely consumed by fire.

Details of Injuries to Individual Stems

Where a fire moved down wind, stems were more severely scorched on the down-wind side. With the fire moving across wind on the flanks, the scorching appears to have been more severe at a point midway between the down-wind side and the side which faced the approaching fire.

Plate 6. Bared soil typical of most areas traversed by day-time fires at Balmoral Forest. Also shown is the position of a burnt-out root of a wind-thrown and salvaged *Pinus radiata*.

The extent of scorching varied from the bottom few feet to the full length of the tree. Only on isolated occasions was the bark completely burnt at any point on a living stem. Where this occurred it was invariably just above ground level at the points of contact with thinning slash or uprooted stems.

The degree of injury to the cambium varied with the species, the thickness of the bark, and of the intensity of the burn. The distribution of cambium damage was closely related to the normal furrowed condition of the bark. The cambiums of *P. laricio, P. ponderosa,* and *P. pinaster* were only lightly damaged. The damage was confined largely to strips located under bark furrows and to small areas surrounding the branches, or, on trees which had been pruned, to the branch stubs. As a result of the injury adjacent to branches there were instances, always at the level of a whorl, where a complete surround of cambium was killed. The cambiums of *P. muricata* and *P. radiata* were much more severely injured than those of the above-mentioned species. The cambiums of the thin-barked *P. contorta* were severely injured in even the most lightly scorched stands.

The degree of cambium injury was of considerable importance in connection with subsequent salvage operations. By 1 September 1956, some nine months after the fire, a large proportion of burnt *P. radiata* stems was badly sapstained. At this time sapstain caused no real problem in most burnt *P. laricio* stands. Clean *P. laricio* logs could still be cut from selected areas as late as April 1957, some 16 months after the fire.

CONCLUSIONS

As has been stated earlier, Balmoral Forest was established on land sub-marginal for forestry. By 1955 the stage was set for a disastrous fire. With the previous wind damage, the delayed thinning operations over the last six years, the wind of gale force, and the wind changes during the fire, it was inevitable that once the original fire breached the Balmoral Road firebreak the whole forest to the east was doomed. The primary reasons are the maldistribution of age classes, and the initial layout of the forest.

The Balmoral fire and the events leading up to the fire demonstrate how serious the consequences can be if the need for an approximately normal distribution of age classes in exotic forests is ignored. For all practical purposes there was but one age class for each of the three main species present. Although wind damage is inevitable on Balmoral sites it is clear that had there been a reasonable distribution of age classes, and thus a distribution of windthrow hazards, a much smaller area would have been destroyed by wind. Similarly, with an approximately normal distribution of age classes, the need for belated thinning-to-waste operations over extensive areas would never have arisen. It was the inflammable material in the wind-thrown and thinned-to-waste areas which made it possible for such a holocaust to develop.

As far as layout is concerned, the fire proved that, except for

access, the existing system of firebreaks was quite useless. A system of firebreaks orientated with the direction of the prevailing wind, and breaking up the forest into small narrow compartments, would have been infinitely more effective. This is undoubtedly one of the most important lessons learnt from the Balmoral Fire—drastically reduce compartment size and run the firebreaks into the prevailing wind. In Canterbury, where the pattern of wind change is usually from N.W. through S.W. to N.E., cross firebreaks should be orientated S.W. to N.E.

Admittedly, there is a limit to what area can be allocated to firebreaks under contemporary practice, but fire protection should be planned for the *worst* conditions which can be expected. The conditions from the 25–28 November 1955 were *not* the worst. This is borne out by the remarkable fact that, although the fire covered 7,790 acres of forest, it did not at any stage damage surrounding farm land. Had it occurred in January and February 1956, when temperatures were consistently over 90°F, relative humidities down to 9%, $\frac{1}{2}$" fire-stick readings down to 2, and the countryside as well as the forest tinder-dry, then not only the forest itself but tens of thousands of acres of surrounding farm land would ineviably have been burnt.

In districts of extreme fire hazard there must be some radical departure from contemporary practice to make exotic forests safe from total destruction. This can be done only by adopting the principle that some percentage of the forest land must be used for farming purposes and not for growing trees. The percentage of land set aside for farming will depend upon the locality, but at Balmoral it would appear that it should not be less than 50%.

In any one locality the layout adopted must take cognisance of the agricultural and forest potentials of the different soils which may be represented. Ideally, however, bands of forest no more than two miles deep and farming land no less than one mile deep should alternate down wind. (In Canterbury burning debris has been known to start fires 70 chains down wind; the one-mile belt of farm land is thus not excessive.) The forest blocks should be separated by strips of land twenty chains wide running into the prevailing wind so that any forest block is no larger than 2,000 acres.

Compartments within the forest block should be no larger than approximately 60 acres, and be four chains wide. Flank strips, sufficiently narrow to suppress weed growth (say a third of a chain wide) should separate the compartments, with a two-chain firebreak, kept weed free, every five compartments. Within the adjacent stands and immediately adjoining the firebreaks, strips one chain wide should at all times be kept free of slash. Cross-wind vehicle access tracks should be made during thinning operations every twenty chains down a compartment. The flank strips would not only give access, but would become potential fire lines, making it possible to contain a surface fire to one compartment or to five compartments at the most. A crown fire, in the worst conditions, could be held to one block.

The experience of the fire has led the author to the conclusion that slash burning is a practice which should no longer be avoided, although its scale may be limited. Slash burning has not been encouraged in the past, and, with little experience behind them, most officers are reluctant to start—understandably so, for New Zealand is a country of high winds, and in Canterbury at least, norwesters can create high fire-hazard conditions in any month of the year. In other parts (although not at Balmoral) the dense weed growth following slash fires is a problem. Nevertheless some slash burning can and should be done.

At Balmoral slash from thinnings cannot be burnt on a large scale. Because of the windthrow risk only one thinning per rotation can safely be made—an early and heavy thinning at a mean top height of about 25 ft. At this age, the burning of slash would entail severe injury to the young steps. There is, however, a good case for clearing thinning slash from one-chain marginal belts alongside all major roads and firebreaks and burning it in the open.

Likewise the burning of all clear-felling slash cannot as yet be recommended. Even in mid-winter, conditions can be too dangerous, particularly for officers with little previous experience.

However, the fire risk created by slash located adjacent to camps, housing sites, main roads, and railway lines, far outweighs any small risk that careful slash burning on these areas would entail. The policy of slash burning on selected areas must therefore be adopted, and in fact is now adopted at Balmoral Forest. As experience is gained it is probable that slash burning will be more widely used, particularly if there is a partial change over to farm land. The utmost precautions must be taken; they include, particularly, careful consideration of both the condition of the fuel, and of long-range weather forecasts. As previously mentioned, slash was burnt at Balmoral in the autumn of 1955; on this occasion burning rabbits spread the fire into adjoining slash. Steps must be taken to deal with problems of this nature.

The mill fire forcibly demonstrated that wherever reasonable alternatives exist no housing or industrial project should be located within an exotic forest.

Many of the recommendations made in this paper do no more than emphasise the need for adopting sound silvicultural and forest-management techniques. To practice sound silviculture it is essential that a relatively high standard of utilisation be attained, and that markets be found for all the material that is available. Until a building-board or pulpwood industry is available in North Canterbury to utilise small-diameter timber it is doubtful if much progress can be made. Meanwhile all efforts should be directed to making timely rather than belated thinnings, to judicious slash burning, to redistributing age classes, and to reorientating firebreaks and to creating wide cross-wind barriers of farmed land.