PART II
THE ENVIRONMENT

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TOPOGRAPHY

The topography of the catchment may be conveniently subdivided into a number of landscapes, and these have been used as a basis for the land systems. They are included in the land-system description so only a broad outline is presented here.

The Benalla Plain is the central figure of the catchment. It is a riverine plain of low relief at an elevation of about 150 m at Benalla, and grading back to the foothills and tributary valleys at about 230 m. The Plain is separated from the general Goulburn Plain by low hills between Baddaginnie and the Goorambat-Chesney area. It is continuous with the more extensive Goulburn surface through gaps in these hills, with the course of the Broken River through Goomalibee forming the major link.

The surface of the Benalla Plain is relatively smooth, although the scars of old stream courses are evident over most of the area adjacent to the larger streams, and prior stream levees and alluvial trails form sinuous low rises. The major streams have meandering courses. Because of the low gradients on the Plain surface drainage is slow and there are several swamps. The largest and deepest of these was the Mokoan Swamp (Plate 3), north of Winton, which, even prior to its enlargement as an irrigation storage, contained an extensive area of free water in most years. The Molyullah Swamp on Ryan's Creek, to the southeast of Benalla, has been drained, as has a small swampy depression at the head of Blind Creek east of Mt Pleasant, in the centre of the area. To some extent the drainage of the Plain has been man-made, but most of the effective removal of surface water is via streams and drainage depressions which have been cleared and become incised as a result of the clearing and poor management of the land.

Judging from the explorers' and early settlers' descriptions the alteration in appearance of the Plain has been drastic. An early name for the Broken River -" Winding Swamp "- suggests that there was no clearly defined stream channel at that time.

The Broken River also drains the fringe of the extensive Mansfield Plain at the extreme southern end of the catchment. That part of this Plain which is drained by the upper Broken River is slightly dissected, and the divide to the Lake Eildon catchment to the south-west takes the form of low rolling hills. The Plain surface becomes steeper to the east as it extends as a narrowing valley bottom up the Broken River to within about ten kilometres of the source. It also extends several kilometres up the valley of Bridge Creek, a major tributary.

Much of the catchment consists of broken foothill country, either remnant outliers in the Plain, for example the Reef Hills south-east of Benalla, or larger maturely dissected masses such as the Lurg Hills to the east of Benalla. The steeper hills in the southern half of the area are the dissected rises to the plateaux.

Plate 3. Mokoan Swamp on the Benalla Plain before construction of the retaining wall and the creation of the larger Lake Mokoan.

There are several plateaux surfaces in the catchment, the most obvious of which is the Strathbogie Plateau at about 700 m elevation on a granite massif in the south-western corner of the area. Only the plateau rim and the dissected northern edge of the massif drain to the Broken River; most is drained by the Seven Creeks system.

In the south-eastern corner of the catchment, in the Tolmie-Archerton area, there are several plateaux up to about 1100 m. The levels of the lower plateaux may be followed along the ridge top to the north where they eventually grade down into the long south-north divides between the deeply incised streams.

There is also an extensive plateau south and east of Mount Samaria, at about 800 m elevation. The eastern and northern sides of this plateau form an elevated rim, the Blue Range, the accordant flat summits of which are a little in excess of 910 m and include Mt. Samaria.

The Warby Range (Plate 4), a granite block which forms the north-eastern boundary of the catchment, also has a series of residual plateaux at about 500 m elevation, but these are mostly on the eastern side of the watershed in the Ovens catchment.

There are three major gaps, other than that where the river passes between the hills at Goomalibee. One contains the Broken River at Barjarg and another is a dry gap in the Warby Range at Glenrowan. Both of these are deep, comparatively restricted breaks in much higher country and form prominent landmarks. The third is a wide, low break between the Chesney hills and the Warby Range in the north. The lesser gaps, chiefly along the northern half of the eastern catchment boundary, are more easily lost to sight in the generally hilly terrain.

The drainage pattern is formed around the massif blocks of the plateaux, and generally trends to the north, though the Broken River runs east-west in its upper course at the southern end of the catchment, and the drainage swings to the north-west at the northern end of the catchment. Almost all streams seem to follow some local trend and there is no large area having the simple mature stream dissection which characterizes so much of the mountainous tract of eastern Victoria.

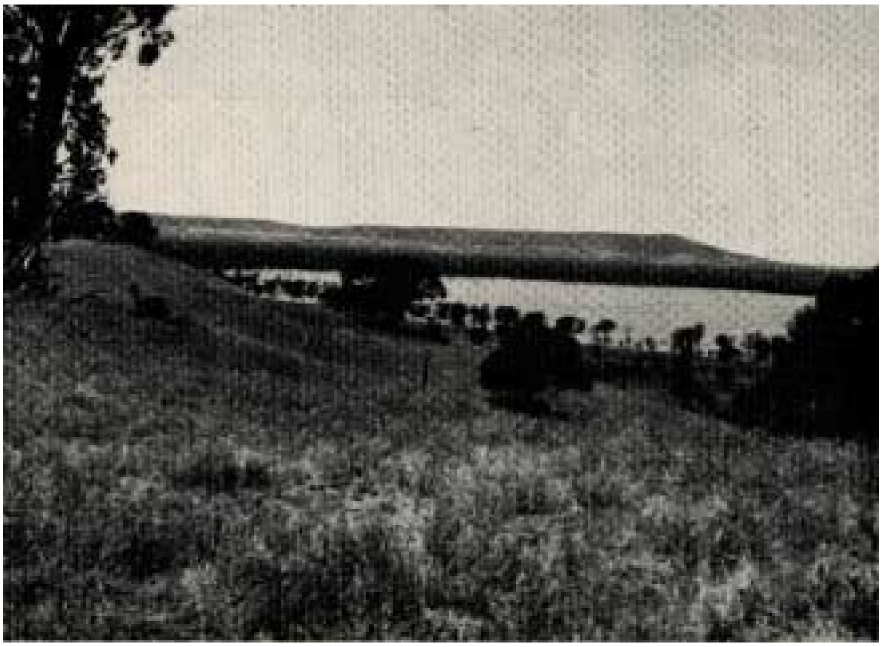

Plate 4. The Warby Range as seen from the Chesney hills across Lake Mokoan. This granite range forms the north-eastern boundary of the catchment.

The tributary streams follow irregular courses, similar to the major zig zag of the Broken River. Ryan's Creek, which, together with the shorter Sam's Creek, drains the northerly slopes leading from the Tolmie-Archerton Plateau, passes through the Molyullah Swamp area and joins Holland's Creek to become the Curlewis branch, which ultimately joins the river immediately upstream of Benalla. Holland's Creek, which also has a number of abrupt changes in course, drains from the Tolmie-Archerton area and is the largest single tributary.

The only large tributary on the western side of the Broken River is Moonee-Moonee Creek which drains a deeply dissected area to the north-east of the Strathbogie Plateau. (The name is also variously rendered as Monee, Money, Mooney, &c.).

Various smaller creeks drain to the Mokoan Swamp area rather than directly to the River. The largest of these is Wattle Creek which drains the Lurg Hills.

The Five Mile Creek, draining the Warrenbayne area, divides at Baddaginnie and a system of effluent channels leads around the low outlying hills. Thus part of the water drains west across the Goulburn Plain while part continues north to enter the Broken River, the actual proportions depending largely on local channel conditions. The real western boundary of the catchment may therefore vary somewhat.

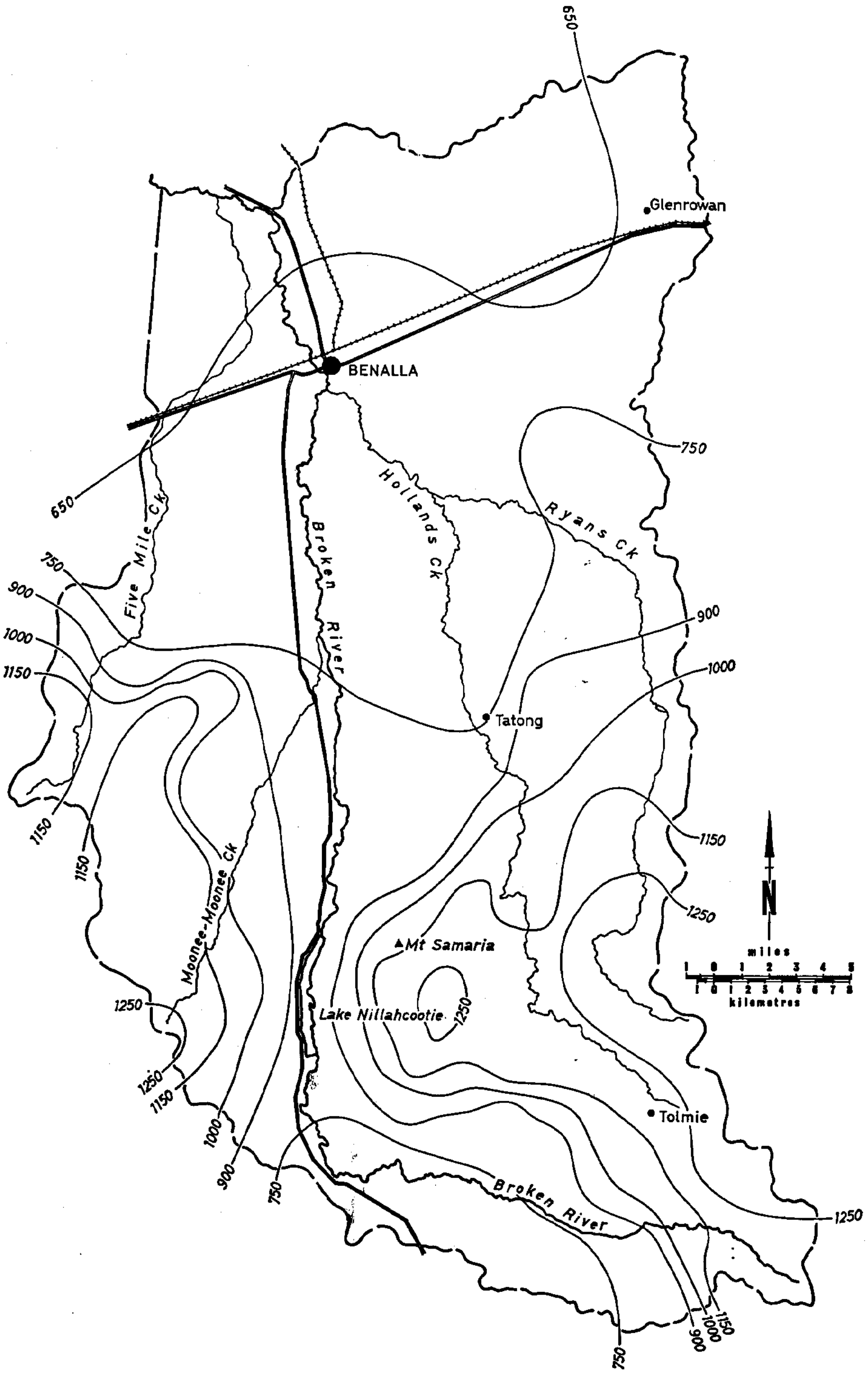

Fig. 2 - Average annual rainfall distribution (mm)

CLIMATE

RAINFALL

Most of the effective precipitation in the catchment occurs as rain, although the higher areas of the Strathbogie and Tolmie Plateaux receive occasional light snowfalls. Average annual rainfall figures are available for a number of stations in the area, although they are mainly scattered through the cleared country. Using these to place limits on the isohyets, together with a map of the dominant vegetation to provide the patterns, a fairly detailed estimate of rainfall distribution has been mapped (Fig. 2). Average annual rainfall ranges from 635 mm p.a. in the north of the area, to over 1250 mm on the higher plateaux. The station with the highest average is Archerton, 1359 mm p.a., although Whitlands, just east of the catchment, receives 1453 mm.

Most of the Benalla Plain has an average annual rainfall of between 635 mm to 750 mm but it becomes wetter towards the foothills. A rainshadow extends the 750 mm zone up the valley from Swanpool to Barjarg, and thence to the Mansfield Plain. Rainfall gradients are steep in the foothills, particularly on the western and southern side of the catchment, but the pattern is less variable over the plateaux, most of which receive in excess of 1150 mm p.a.

Histograms of average monthly rainfall for Baddaginnie, Benalla, Warrenbayne, Barjarg, Strathbogie and Strathbogie North are presented in Fig. 3, and those for Mansfield, Merrijig, Langley, Lima East, Tolmie and Archerton are presented in Fig. 4. Mansfield and Merrijig are just outside the catchment to the south.

The seasonal patterns show a marked winter incidence, with June the wettest month at most stations. The driest month is usually February and only the highest and wettest plateau areas receive more than 50 mm, per month in the summer. At most stations rainfall increases fairly sharply in the autumn particularly at sites where orographic effects might be expected to be strong. Strathbogie and Strathbogie North stations provide a good comparison. Although only a few kilometres nearer the edge of the plateau Strathbogie North receives 100 mm more rain per annum. The summer falls at the two stations are virtually identical but the winter peak is apparently boosted by orographic uplift. The effect is particularly striking in June. Similar effects on the winter rainfall peak can be seen in many station records, the most striking being Whitlands, situated on the plateau above the valley of Boggy Creek in the King River catchment. This station receives well over 180 mm in each of June, July and August, although in no other month does it receive more than 125 mm.

Stations in different situations are subject to different orographic effects. For example Merrijig in a basin sheltered by higher country to the east, north and south, has a very variable monthly pattern, with the maximum rainfall much later than at most sites in August. The winter peak is also less pronounced.

Mansfield, further west but similarly sheltered, also lacks the winter peak and the monthly falls from June to October are remarkably uniform. Although Mansfield has only 25 mm more annual rainfall than Benalla the rain is much more evenly distributed and the length of the growing season reflects this.

No pluviometer records are available in the catchment so that no direct measure of intensity is available. Prolonged heavy falls are typical of the scarp areas and plateaux in winter, but the heaviest precipitation probably occurs in thunderstorms which are most common in late summer.

Occasionally very severe falls, including disastrous hail, are reported. These are presumably likely to be worst in the rising foothills but no information is available on their distribution.

The reliability of the rainfall varies over the area. It is greatest in the higher and wetter areas and least on the plains. However in common with many Australian climates the annual fluctuations are fairly large. The drastic effects of this fluctuation are best illustrated in the histogram of annual flows of the Broken River at Goorambat (Casey's Weir) (See Fig. 1).

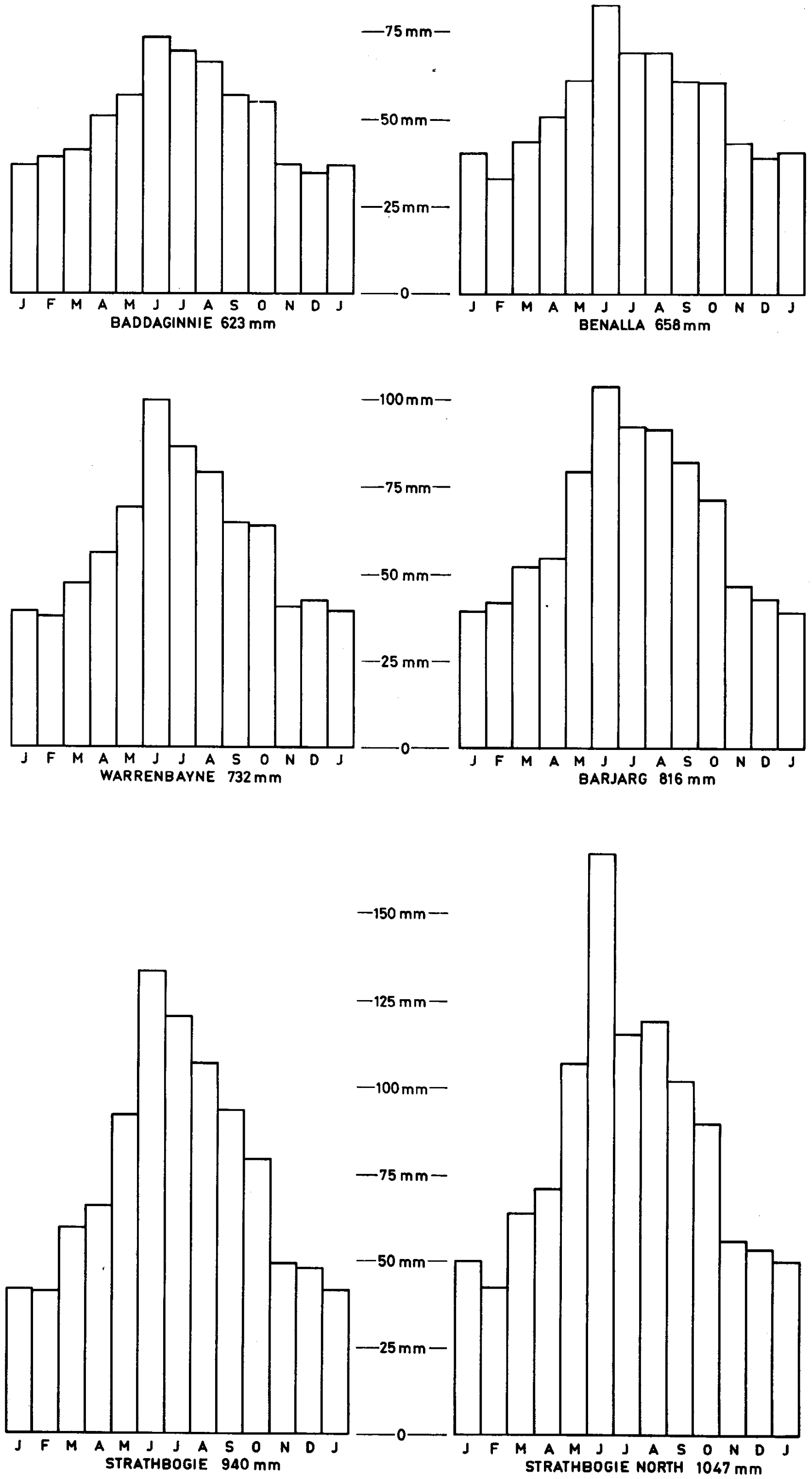

Fig. 3 - Average Monthly Rainfall

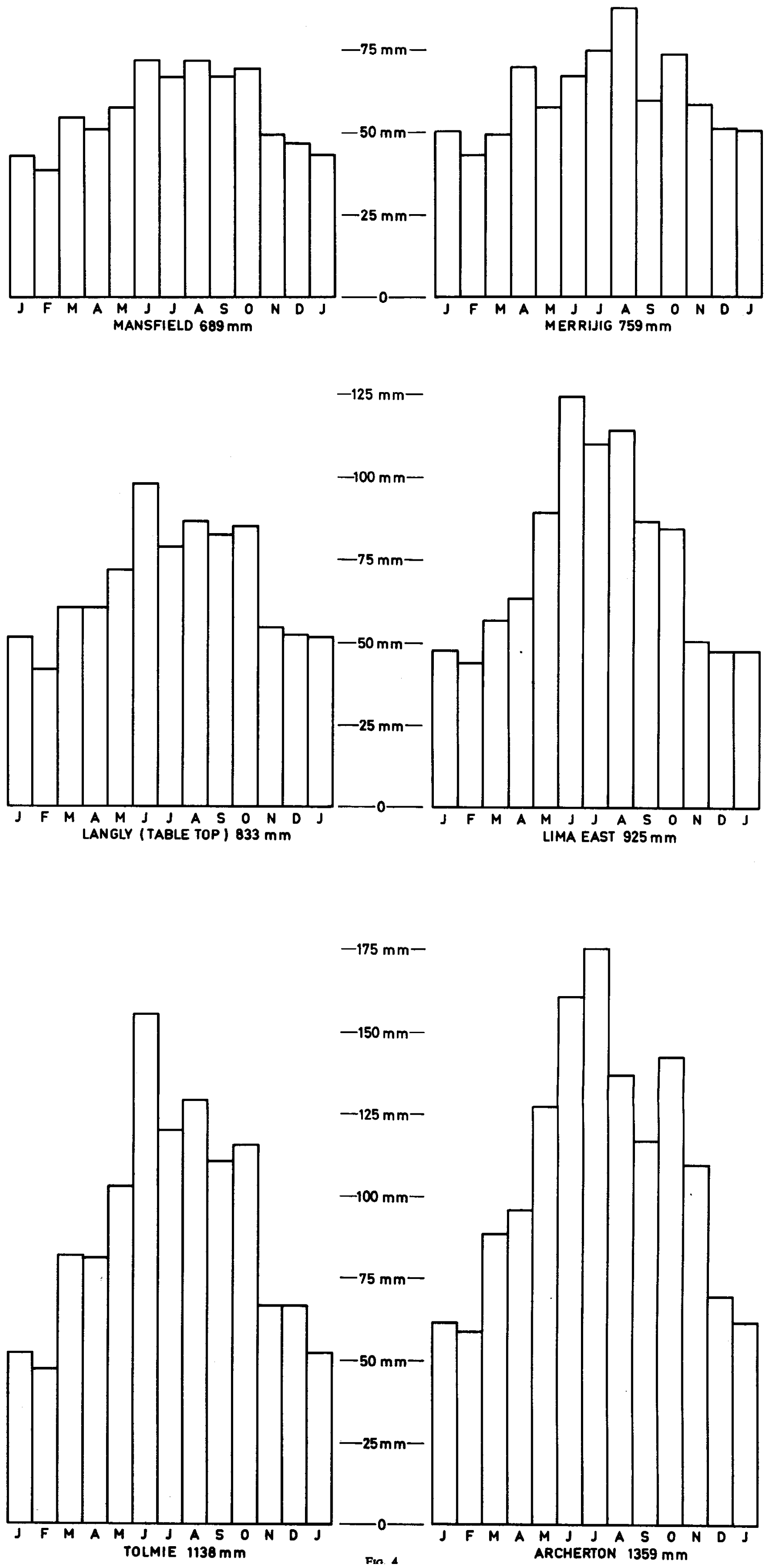

Fig. 4 - Average Monthly Rainfall

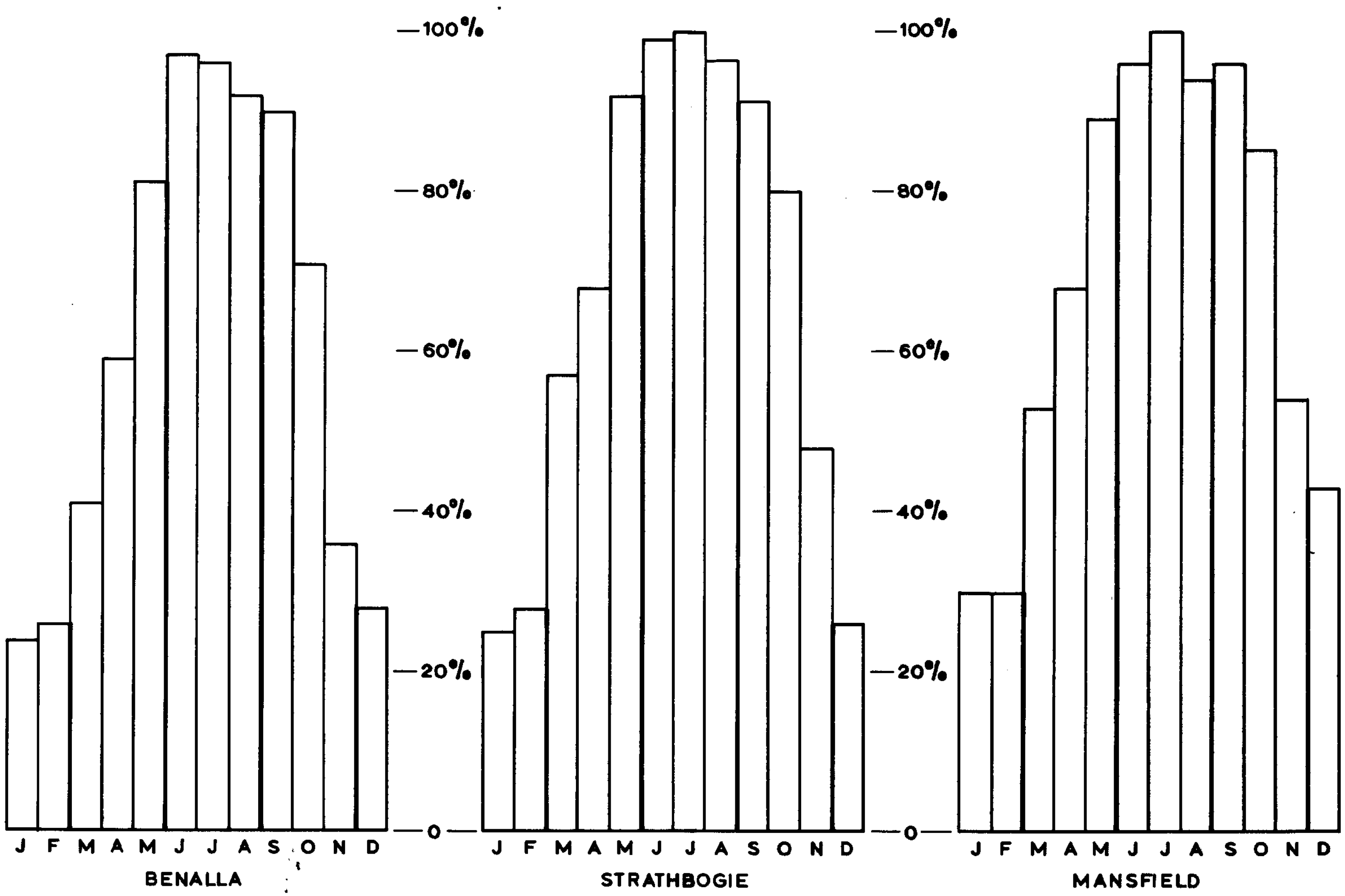

Fig. 5 - Percentage frequency of occurrence of "Effective Rainfall"

Assessment of reliability in terms of "effective" rainfall probabilities - the chances of receiving a quantity of rain assumed sufficient to cause germination and sustain growth at Benalla, Strathbogie and Mansfield are presented in the Regional Report (Central Planning Authority 1951), and histograms plotted from that data are presented in Fig. 5. Strathbogie has a better chance of receiving effective rain in spring and autumn than has Benalla, but the summer conditions are similar except that the dry period is a few weeks shorter at Strathbogie. Mansfield, in spite of its lower annual rainfall, receives effective rain more often in spring and summer than does Strathbogie. The chances of receiving effective rain are markedly greater at Mansfield than at Benalla throughout the year.

TEMPERATURE

The only station keeping temperature records within the area is at Benalla. In view of the importance of temperature on growth rates and evapotranspiration an attempt has been made to extrapolate the temperature data for other stations. Elevation is the most important variable in this area and a set of regression lines relating mean monthly temperatures to elevation for a number of stations throughout north-eastern Victoria (Rowe 1967) has provided the basis for Table 1.

Using lapse-rates applicable to the time of year and temperature range, a hypothetical location at 1050 m elevation has been extrapolated from the Benalla data to illustrate monthly mean maxima and minima, and also the likely extremes. The two sets of data are shown in Fig. 6 for comparison.

Table 1 - Average mean Monthly and Annual Temperature (°C)

(All but Benalla temperatures have been estimated from the regression of temperature on elevation (Rowe 1967).)

Locality—Elevation (m)	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Benalla—175	23.2	23.3	20.2	15.7	11.9	8.8	8.2	9.6	12.2	15.5	18.8	21.4	15.7
Warrenbayne and Lima East—245 ..	22.2	21.9	19.9	15.2	11.7	8.7	7.7	8.9	11.3	14.4	17.8	20.4	15.0
Mansfield—365	21.3	21.1	19.0	14.3	10.9	7.9	6.9	8.2	10.4	13.7	16.9	19.6	14.2
Langley (Table Top)—520 (approximate)..	20.2	20.1	18.0	13.3	9.9	8.1	6.0	7.2	9.6	12.7	15.9	18.6	13.2
Strathbogie North—550	19.8	19.6	17.6	12.9	9.6	6.6	5.7	6.8	9.1	12.3	15.4	18.1	12.8
Tolmie—800 (approximate)	18.3	18.2	16.1	11.5	8.2	5.3	4.4	5.5	7.8	10.9	14.1	16.6	11.4
Archerton—900 (approximate)	16.7	16.5	14.6	10.0	6.8	3.9	3.1	4.1	6 3	9.4	12.5	15.1	9.9

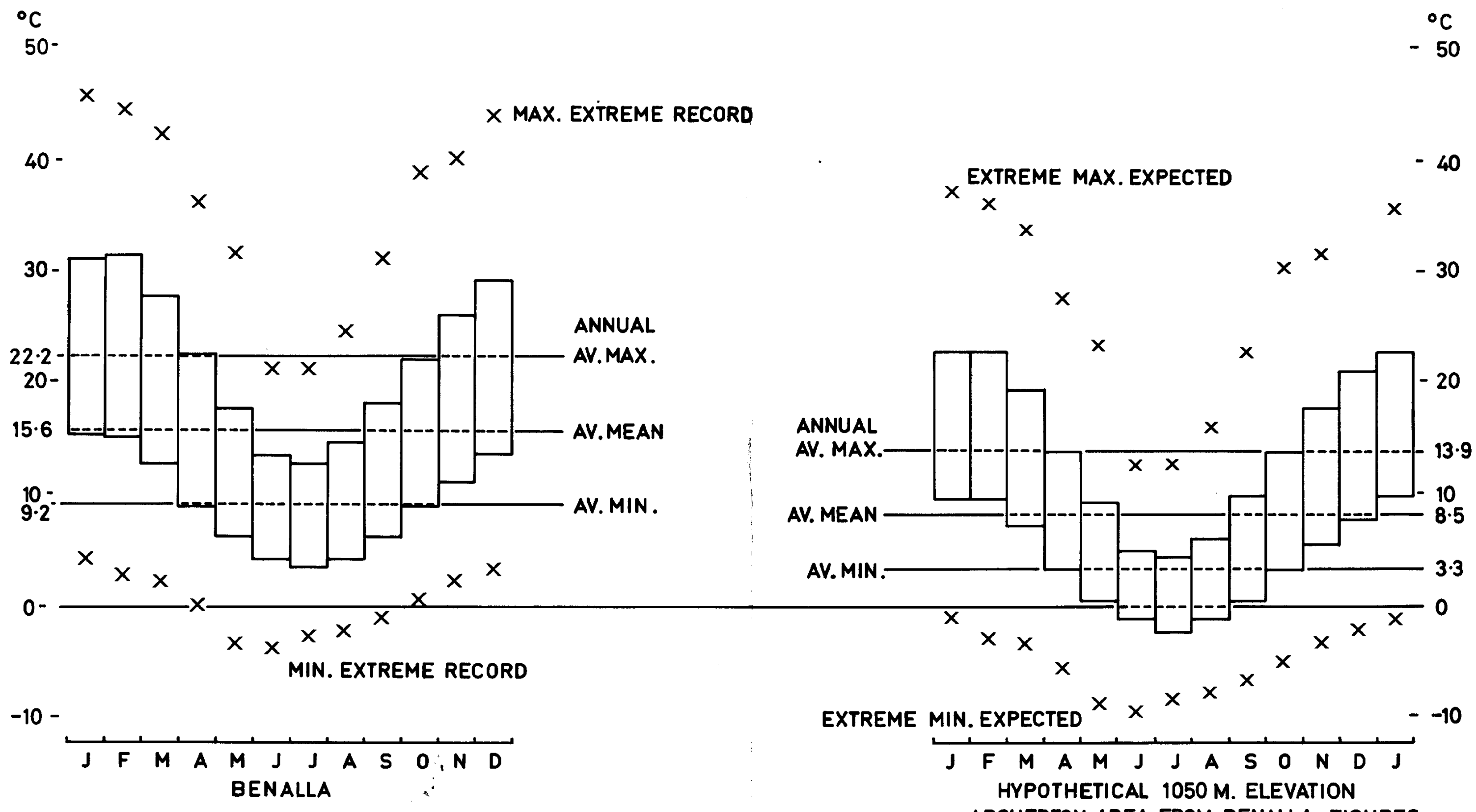

FIG. 6

Fig. 6 - Extreme and average monthly maximum and minimum temperatures at Benalla, and predicted temperature data for an hypothetical location at 1050 m elevation.

Frost is an important limiting factor to plant growth and it is worth noting that frosts may occur at any time of the year above about 1050 m elevation. At Benalla severe frosts are generally limited to between April and September. The first frost is likely about mid-May, and the first severe frost in mid-June. The last severe frost is generally in late August, and the last frost of spring may often be in September, but light frosts may continue until mid-November (from Central Planning Authority 1951, p. 23).

The estimation of minimum temperatures at other stations is made difficult by the phenomenon of cold-air drainage. Very severe frost situations may occur in hollows or clearings in the forest at higher elevations, while the slopes may remain frost-free. By inspection of the available data a rough rule has been developed for the purpose of drawing growing-season graphs. For each 305 m increase in elevation it may be assumed that the first frost will occur 20 days earlier, and the last frost 20 days later. (Carrying the extrapolation to the extremes, this would indicate daily frost, approximating a permanent snow line, at about 3650 m elevation.)

Maximum temperature extremes can be very marked. Although at Benalla the summer mean maximum is about 31^0C, the maximum extreme on record is 46^0C in January. Temperatures over 38^0C may occur from October to the end of March. Generally these extremes correspond to a dry, turbulent, northerly or north-westerly wind and represent very hazardous fire conditions.

WIND

There are no wind records available, which is unfortunate because of the importance of the effect of wind on the rate of evapotranspiration, and because of its relation to fire-danger weather. Most of the rain falls when westerly or south-westerly winds prevail, and occasionally very strong, cold, southerly or south-easterly winds occur in mid-winter. Easterlies are rare, except for local effects such as the common downslope or down-valley winds which occur in the valleys when the night sky is clear. Winds associated with thunderstorm activity in late summer can be very destructive. Tornadoes, including the full development of the hose or funnel cloud, are probably more common in the area than is usually appreciated. The funnel is frequently hidden in low scud, or rain, but the narrow swath it cuts across the country is clearly marked in uprooted or broken trees and poles. These storms rarely cause injury but do account for significant annual damage.

HUMIDITY: EVAPORATION

The nearest meteorological station at which humidity is recorded is Wangaratta, 40 km north-east of Benalla and outside the catchment. However the pattern there is probably typical of much of the plains country. The figures are presented in Table 2.

Table 2 - Mean Monthly 9.00 am Saturation Deficit at Wangaratta (mm of mercury) (from Central Planning Authority 1951).

Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Year.
13·06	12·29	8·66	4·80	2·34	1·27	1·37	1·96	3·73	5·87	9·09	10·64	6·38

In order that an assessment of water losses in the catchment may be made, potential evapotranspiration has been estimated on the basis of Leeper's modified Thornthwaite formula (Leeper 1950). This is an empirical approach in temperatures which, in this study, have been derived from the regressions mentioned above. Since the estimate of temperature is dependent on elevation the evaporation estimates may also be presented as a function of elevation. Monthly curves of average potential evapotranspiration for north-eastern Victoria are presented in Fig. 7 and these have been used as a basis for a discussion of water budgets, growing seasons and runoff.

The potential evapotranspiration calculated in this way is generally about 75 per cent of evaporation from a free water surface.

WATER BUDGETS

Charts have been drawn to give an indication of the monthly changes in the water-balance at several locations chosen as representative of various parts of the catchment (Figs. 8, 9, 10, 11, 12).

In these diagrams the histograms of rainfall and potential evapotranspiration are shown superimposed with the areas of overlap labelled according to whether there is a surplus or deficit of rainfall.

Areas marked as "Water Lost" indicate the portions of monthly rainfall which are used as evaporation or transpiration. The "Loss from Storage" parts of the graph indicate the portion of the potential evapotranspiration loss which is not satisfied from monthly rainfall. Where the soil still contains available water this will be withdrawn until, the limit of availability is reached. Thereafter until rainfall exceeds potential evapotranspiration again, and the soil moisture deficit is made up, "Loss from Storage" is potential loss only. The month in which available soil moisture is exhausted is indicated in the upper part of each figure.

The areas shown as "Excess of Rain over Losses" indicate the portion of monthly rainfall which is not used by evapotranspiration and is therefore available to reduce the soil moisture deficit and, when that is satisfied, to appear as runoff. The upper part of each figure expresses this relationship graphically.

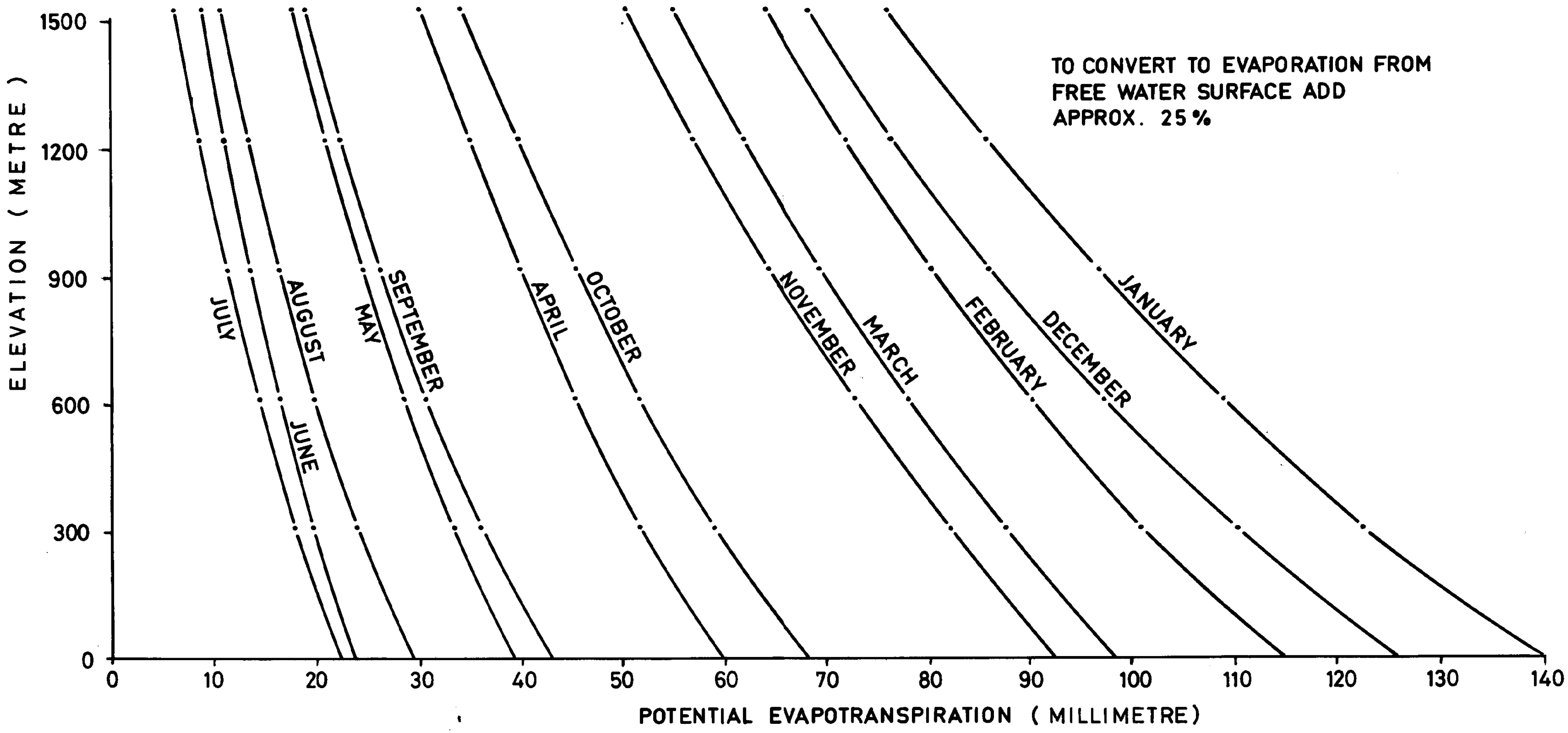

Fig. 7 - Curves of potential evapotranspiration on elevation.

Losses resulting from deep seepage will be included with runoff.

The sequence Benalla-Mansfield-Lima East-Strathbogie North-Archerton, is one of increasing average rainfall, 658 mm, 689 mm, 925 mm, 1047 mm and 1359 mm respectively.

Since the results are based on data estimated from a variety of sources they should be used as a guide only. Furthermore they are made on the basis of average data and so do not indicate likely annual variations. However despite these limitations the patterns and trends revealed are useful in showing the differences between the various parts of the catchment.

One of the more important results of the water-budget analysis is a prediction of monthly and annual yield of water as runoff. This aspect is discussed in the sections dealing with hydrology and land use problems. The other main effect, on plant growth, is discussed below under "Growing Seasons".

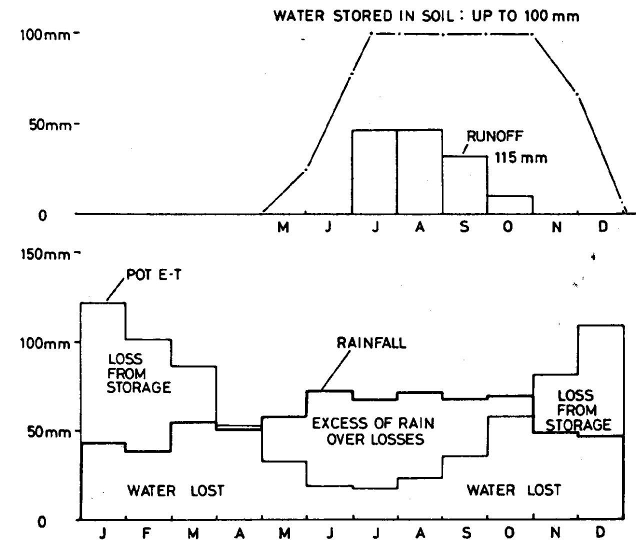

Fig 8. - Water budget for Benalla

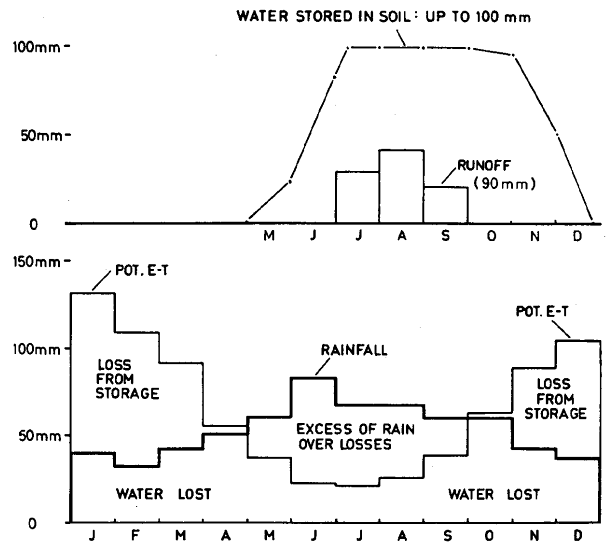

Fig 9. - Water budget for Mansfield

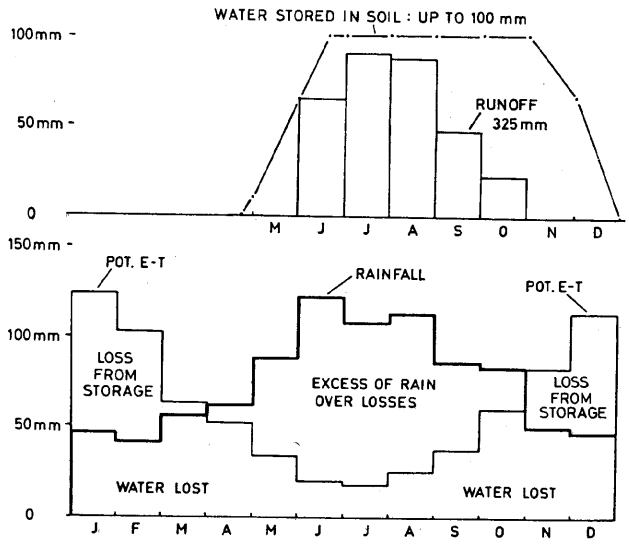

Fig 10. - Water budget for Lima East

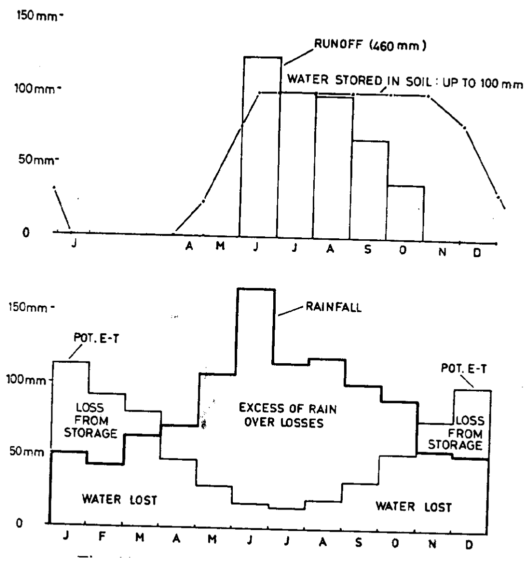

Fig 11. - Water budget for Strathbogie North

GROWING SEASONS

An attempt has been made to construct a picture of the growing season for pasture at three representative stations, Benalla, Strathbogie North and Archerton (See Figs. 13, 14, 15). The theoretical basis of comparison is the maximum growth of a mixed pasture of cool-climate species growing under full summer-daylight conditions with temperatures of optimum levels and with adequate moisture. The graphs depict the percentage of this maximum growth which may be achieved at the three localities. Where temperature and moisture availability vary below optimum levels from month to month growth is restricted. The method used to construct these curves is set out in Appendix 1.

The area enclosed by the curves may be taken as a guide to the herbage production of a hypothetical pasture. In order to give a basis for quick comparison arbitrary units have been used representing proportionally the area within the various boundaries on the diagram.

At Benalla (Fig. 13) the growth rates in spring would be appreciably higher than in autumn. Total growth potential could be increased if additional soil moisture was available to continue the high growth rates into early summer. The spring growth potential is about 180 units if 50 mm of soil moisture is stored, with an additional 60 units available for a further 50 mm. of storage.

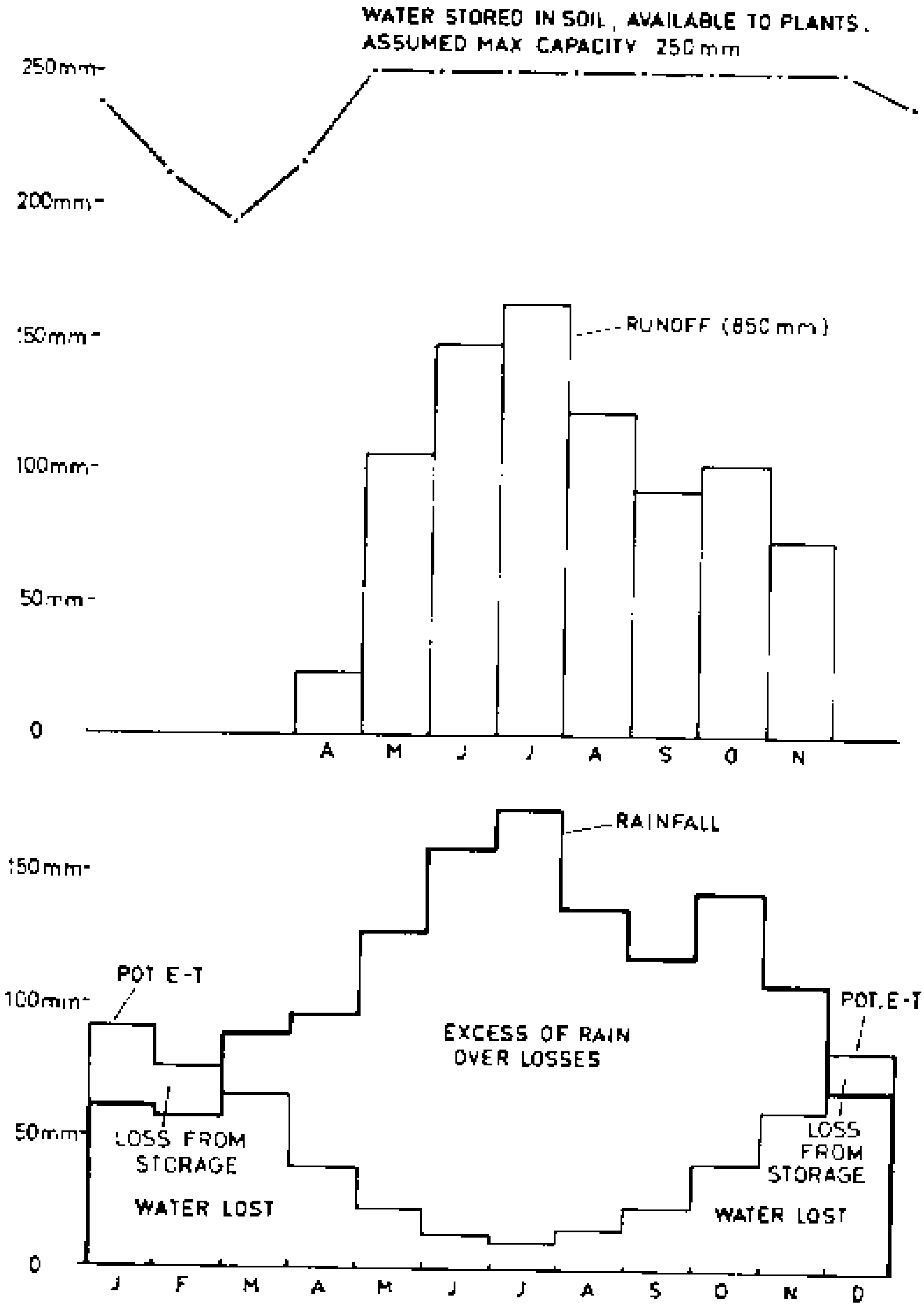

Fig 12. - Water budget for Archerton

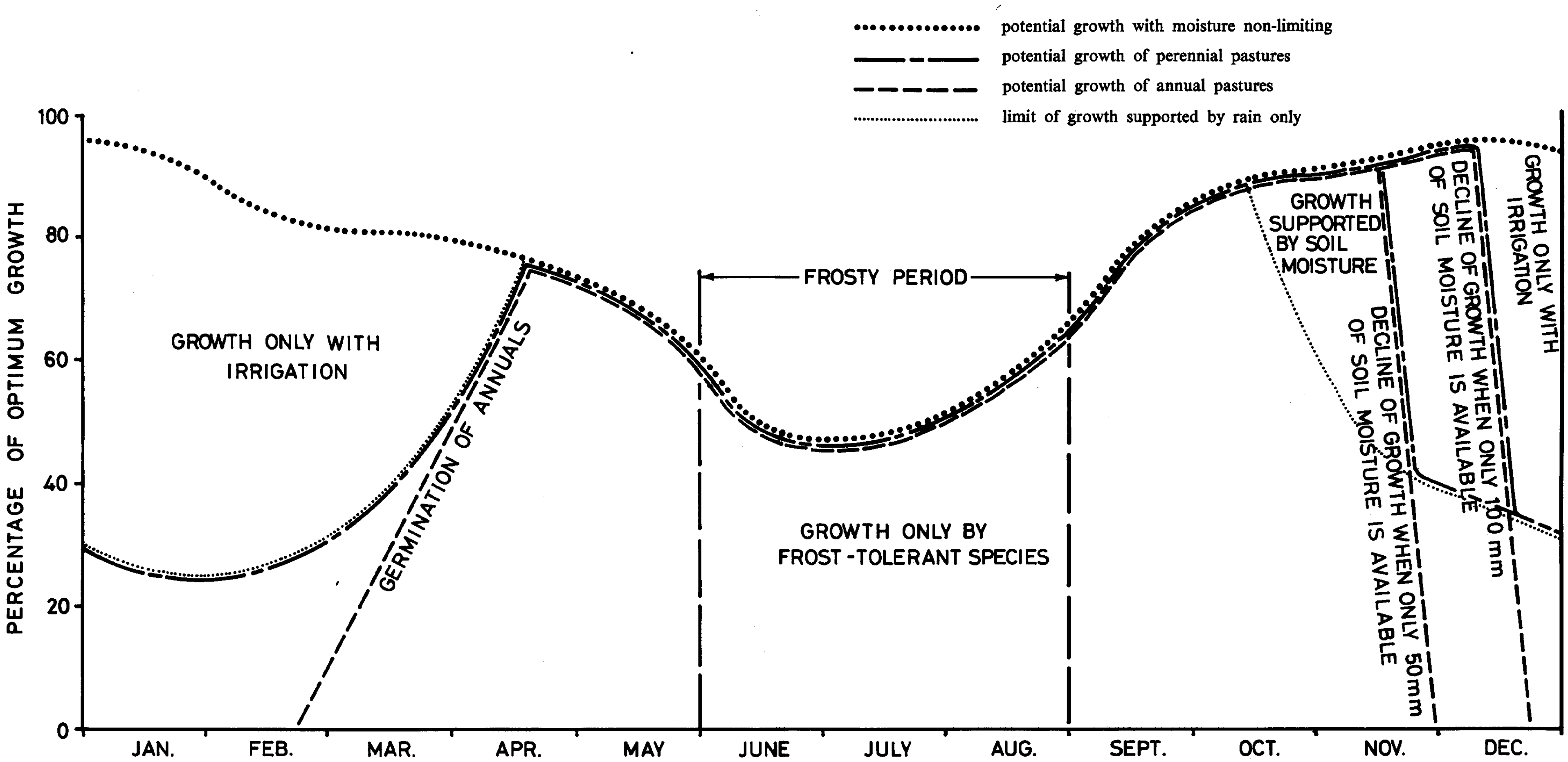

Fig 13. - Monthly relative potential growth of perennial and annual pastures as a percentage of growth at optimum temperatures with adequate moisture and nutrients and 15 hours per day of light at Benalla

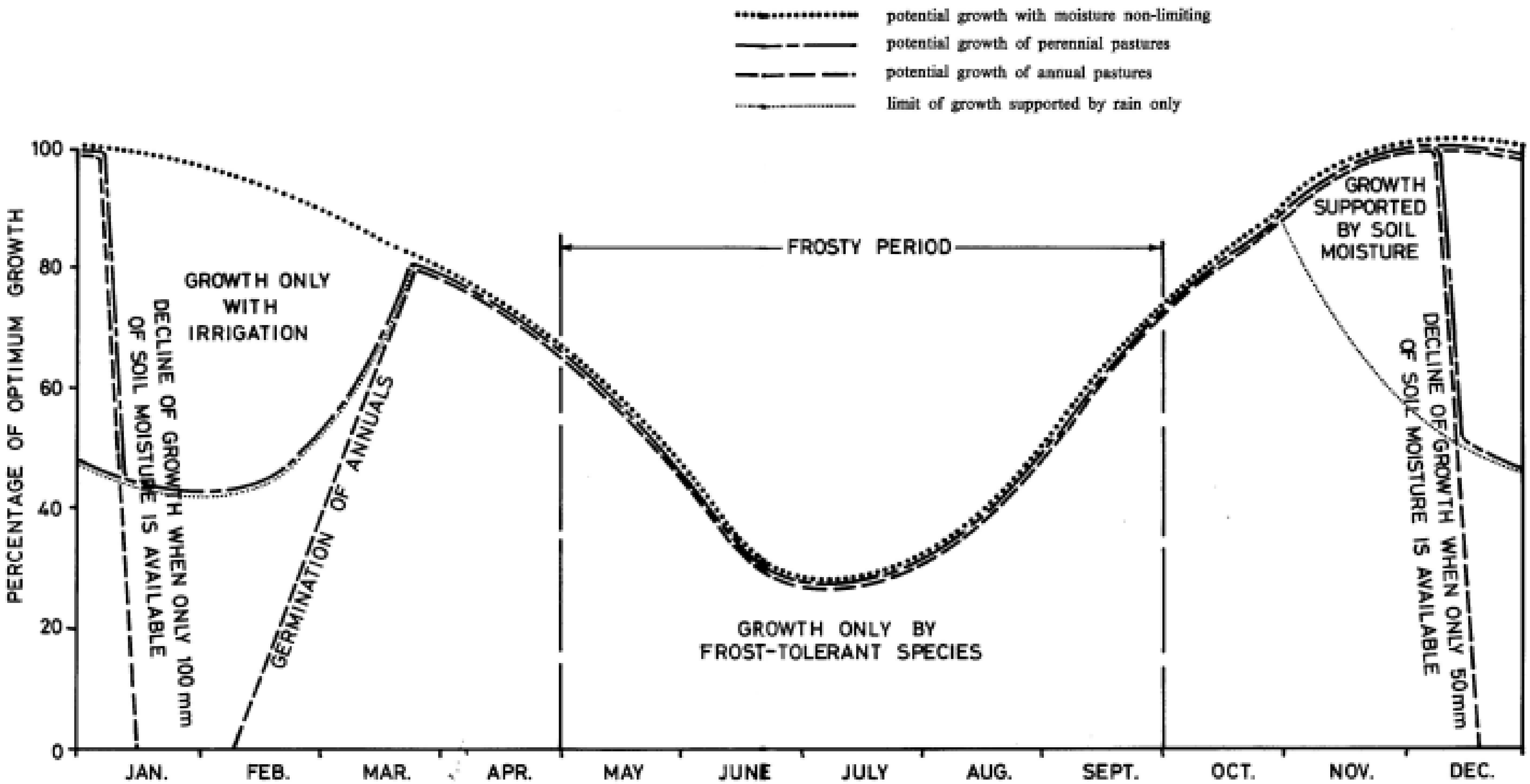

Fig 14. - Monthly relative potential growth of perennial and annual pastures as a percentage of growth at optimum temperatures with adequate moisture and nutrients and 15 hours per day of light at Strathbogie North

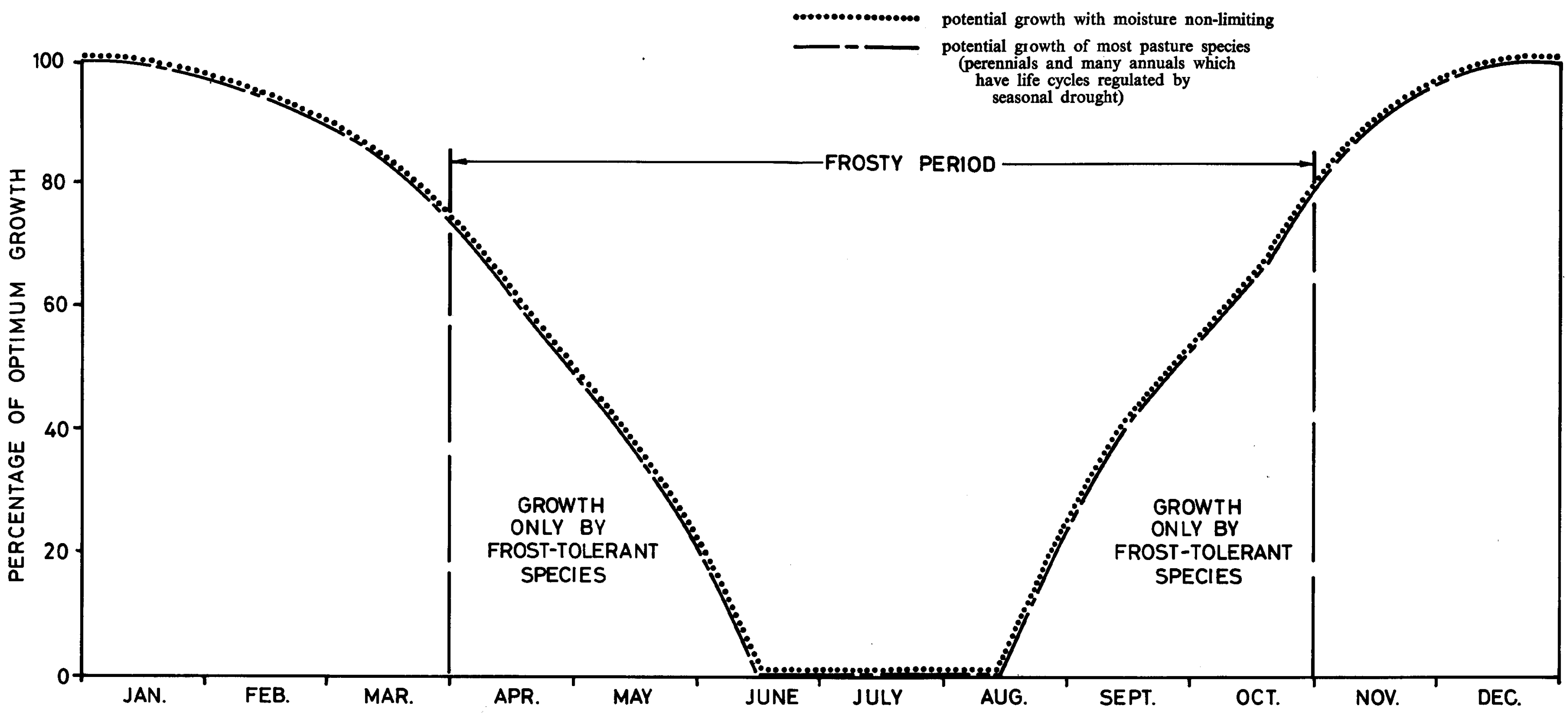

Fig 15. - Monthly relative potential growth of most pasture species as a percentage of growth at optimum temperatures with adequate moisture and nutrients and 15 hours per day of light at Archerton

The growth after the autumn break should be about 130 units before frosts begin. There is useful potential winter growth of about 120 units if the plants are not inhibited by frost damage or waterlogging. On the same basis, if a plant is capable of utilizing intermittent summer rain, growth of the order of 60 units is available from this source. If summer irrigation is available a further 160 units is possible. If summer irrigation of warm-climate pastures was possible the summer yield at Benalla would be even further increased although the higher temperature optima of these species would penalize growth in the spring and autumn a little.

The comparison with Strathbogie North (Fig. 14) shows that while the autumn break is a month earlier, and the spring response a month later, the predictions are otherwise similar. The total potential growth is not much less, but in fact the proportion which is unavailable because of frost-induced dormancy is greater. Using the same arbitrary units as the Benalla examples spring growth should produce between 170 and 250 units, according to how long the moisture is available in the soil. The extra benefit of the soil storage is greater in this locality because of the lower evaporation.

Autumn growth amounts to about 100 units before frosts commence. With frost-tolerant species a further 180 units would be available during the longer winter. Summer rain would produce 60 units with aestivating perennial species. With irrigation about 160 units of growth could be expected during the summer up until the autumn break.

On this basis, it appears that on similar soils the spring flush at Strathbogie North, though later, would result in more herbage than at Benalla, but that autumn growth would be curtailed by earlier frosts. The loss of potential in winter would be greater, but the amount of growth in summer would be comparable.

At Archerton, (Fig. 15) the situation is very different. Here in the average year there is only one growing season which extends from late spring through summer to early autumn. For any but shallow rooted species there should be only very short periods of moisture stress in mid-summer, and the potential production over this period is about 360 units. With frost-tolerant species a further 80 units would be available in both spring and autumn spread over about two months in each case. At these elevations mean winter temperatures in the months June to August are too low for effective growth, even in the absence of frost-induced dormancy. Summer frost is possible and may set growth back in mid-season. There is virtually no peak in production potential.

The comparisons are, of course, optimistic in that they neglect the inherent variability of the climate. It is not suggested that pasture will never dry off in the higher plateaux, or that one area will each year be more reliable than another or have superior production.

However they do give a basis for comparison and highlight several important features. For instance they emphasise potential value of irrigation, even if only for a few weeks, in prolonging the spring flush into early summer when both temperatures and light are at, or near, optimum levels. Also emphasised are the benefits to be achieved by preferential treatment of relatively frost-free sites and the high overall potential of some of the higher, cooler environments. The benefit of careful selection of pasture species for the temperature range in which they will be used is also shown.

HYDROLOGY

The amount of water which a catchment yields as stream flow depends on how much falls as rain, snow, hail or fog drip, and how much is lost as evaporation, transpiration or deep seepage below stream levels. Because average precipitation and evapotranspiration vary over the catchment some parts have higher yields of runoff than others. In this section an attempt is made to determine the relative importance of different parts of the catchment with respect to water yield.

One of the variables in the "loss" side of the water balance equation is the amount of water needed to re-wet the dry soils after the summer. In the hypothetical simplest situation, where rate of rainfall does not exceed the rate of infiltration, the moisture deficit must be made up before the soil yields any water. The water required to satisfy the deficit is retained by the soil until evapotranspiration exceeds rainfall, when it may be drawn upon by plants to sustain growth for a further short period.

As a basis for estimating the amount of water needed to satisfy the moisture deficit in the typical duplex soils of the Broken River valley at the end of the summer-autumn dry period, a qualitative comparison has been made with the red duplex soils (red podzolic soils) of the Hume Catchment (Rowe 1967 p. 214). Reasonable estimates for available water capacity would seem to be: A_1-horizon 20 per cent by volume; A_2-horizon 12 per cent; B-horizon 8 per cent. Thus at the end of the summer-autumn period a typical duplex soil of this area could be expected to require about 100 mm of rain to raise its moisture content to field capacity to a depth of 100 cm.

This value of 100 mm has been used as the average amount of water which the soils of most of the lowlands would withhold from runoff and which would be available for use by plants or evaporation, and this is shown in Figs. 8-11. For the soils of the higher rainfall areas, e.g. at Archerton (Fig 12), a value of 250 mm has been used. This is comparable to the values for similar soils described by Rowe (loc. cit). These graphs show estimated annual water yield for several localities and these values have been combined with the rainfall values at those localities to produce the curves in Fig. 16. These curves may be used to convert the isohyets in Fig. 2 to lines of equal runoff and these values may then be used to estimate the runoff from various parts of the catchment.

The assumption that water yield follows the same pattern as rainfall is based on the fact that in this area rainfall increases with increased elevation, and temperatures decrease so that evapotranspiration losses decrease with increased elevation. As the placement of the isohyets in Fig. 2 is to a large extent dependent on topography these should also reflect patterns of water yield.

Table 3 and the following generalisations are based on the estimated values expressed as percentages of the total estimated yield. A ratio of percentage runoff to percentage area is used to express the relative value of the various rainfall zones in the catchment.

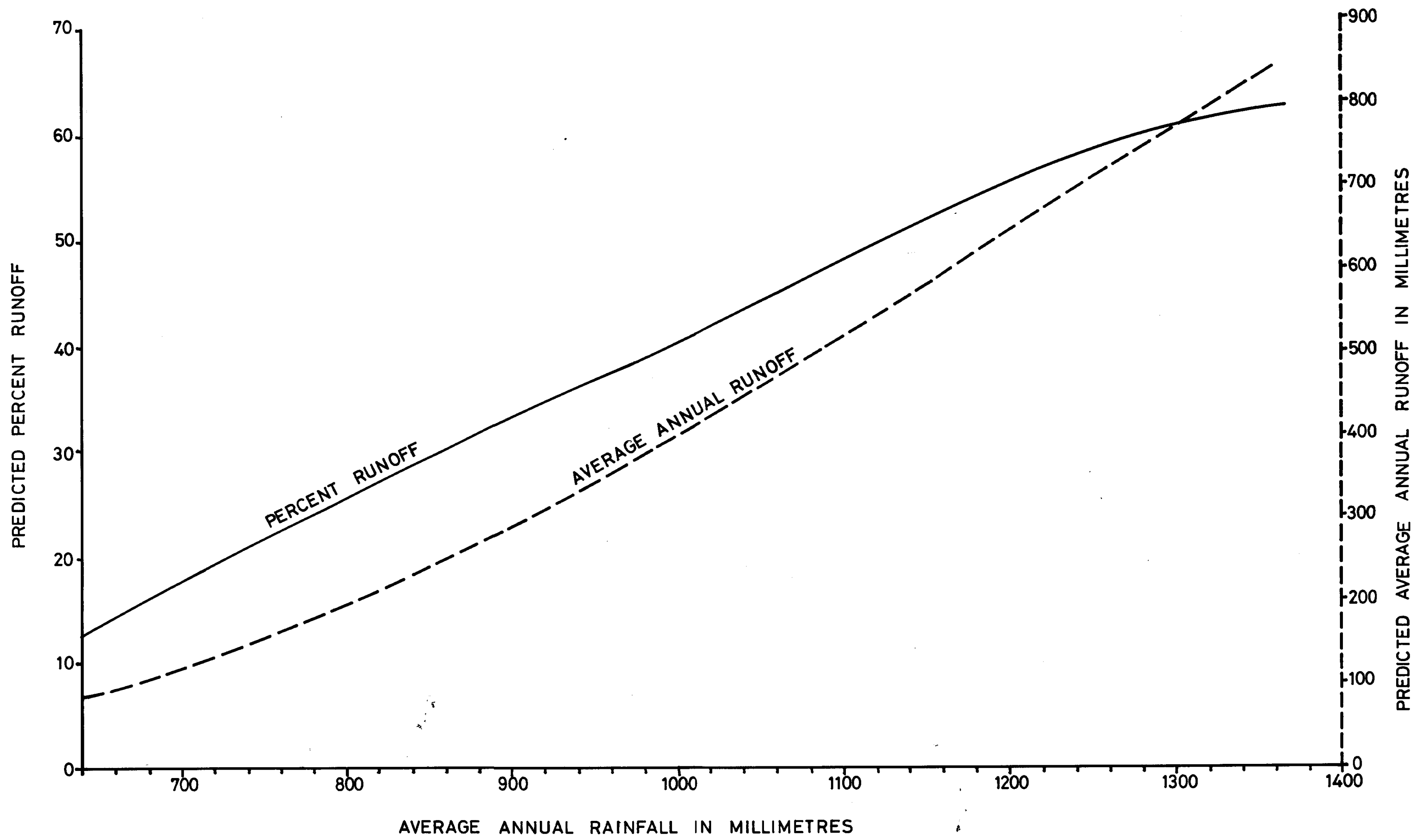

Fig 16. - Predicted runoff parameters for the Broken catchment based on average annual rainfall

According to this calculation the high rainfall areas yield seven to eight times as much runoff per unit area as does the drier northern part of the catchment. About 40 per cent of the total water yield may be expected from the 18 per cent of the catchment which receives more than 1150 mm annual rainfall.

Table 3. - Proportions of runoff contributed by different parts of the catchment, based on distribution patterns of annual rainfall.

Rainfall (mm).	Proportion of catchment (*a*) (per cent.)	Proportion of annual runoff (*r*) (per cent.)	Relative value $\frac{(r)}{(a)}$
>650	11·5	3·5	0·3
650– 750	32·5	13·5	0·4
750– 900	17·5	13·5	0·8
900–1 000	9·5	11·0	1·2
1 000–1 150	11·0	18·0	1·6
1 150–1 250	13·5	29·5	2·2
>1 250	4·5	11·0	2·4

In Table 4 the land systems are rated according to their yield of water to the Broken River. This has taken into account both the estimated runoff from the unit and its area.

Table 4. - The land systems are grouped according to their importance as water sources to the Broken River catchment, taking into account area as well as estimated average runoff.

Low Yield.	Moderate Yield.	High Yield.
Warby	Table-Top	Cambatong
Lurg	Swanpool	Archerton
Benalla		Tolmie
Mansfield		Moonee-Moonee
		Tiger Hill

GEOLOGY AND SOIL PARENT MATERIALS

This section is based on information from the Regional Resources Surveys (Central Planning Authority 1951), field observations and the 1:250 000 maps of the Geological Survey of Victoria relevant for the catchment (Wangaratta S J55-2: Warburton S J55-6).

STRATIGRAPHIC SEQUENCE

Cambrian

The oldest known rocks in the area are cherts and altered basic igneous rocks outcropping near Tatong and to the east and north of Mt Samaria Plateau. Evidence of Cambrian Age is scanty and the dating depends on inference from other similar exposures along an axial line extending from Dookie to the Mt Wellington area, via Tatong and the Howqua River, and on Cambrian fossils from the Wellington area. They apparently form the core of a major anticlinal structure and are exposed here and there by faulting.

The cherts are apparently silicified argillaceous sediments and are closely jointed and banded. As soil parent material and cherts are similar to the Ordovician and Silurian rocks the small outcrop area does not justify separation at this scale of survey. The altered basic lavas, referred to as greenstones, weather in a very similar fashion to the basalts and have been treated as a distinctive parent material in drawing up land systems.

Ordovician

These sandstones and shales apparently follow the Cambrian beds conformably. Their detailed stratigraphy is based on graptolites, as other fossils are rare, and the lithology is fairly uniform. The 1:250 000 maps show all the outcrops in the north and east as Ordovician, and those south and west of a line running approximately 32^0 T through Benalla are shown as Silurian-Lower Devonian. This line is slightly oblique to the strike of the folding (locally about 300^0 T) and also is close to the inferred anticlinal core. However fossils are rare and a separation from the Silurian sediments on lithology alone is impractical.

Silurian and Lower Devonian

These shales and sandstones are similar lithologically to the Ordovician beds and no distinction has been made between them in this survey. As a soil parent material there appears to be no appreciable difference between the Ordovician and Silurian sediments. The bulk of this material is argillaceous, but there are sandstones and a few limestone lenses. All these sediments are closely folded and much jointed.

Mid-Devonian

No rocks of this Age are represented but a period of major folding occurred and this is marked by a clear unconformity.

Upper Devonian

There are thin beds of conglomerate, sandstone and shale lying on the surface of unconformity beneath the extensive acid lavas but their occurrence is spasmodic. These sediments are similar to the Lower Carboniferous beds above the lavas but are probably of Upper Devonian Age.

The lavas are assigned an Upper Devonian Age on the evidence of fish remains found in the sediments beneath them, and of Lower Carboniferous fish in the overlying sediments. They form a thick series of mainly acid porphyritic rocks (rhyolites and rhyodacites) with a thin series of basic lavas low in the sequence. The exposures within the Broken River catchment are fairly uniform and outcrop over large areas on both sides of the river in the southern portion of the catchment; to the west in the Warrenbayne area (the Violet Town volcanics), and to the east in the region between Molyullah, Tatong, Mt Samaria and Archerton (Hollond's Creek rhyodacite sequence, Ryan's Creek rhyolite, Toombullup rhyodacite).

Although they are superficially similar in appearance to the local grey granites these rocks weather quite differently and the soils and topography produced on them are quite distinctive. The acid lavas have therefore been separated in mapping the land systems.

The final phase of the Upper Devonian was probably marked by mild earth movements and the emplacement of much of the granite, including probably the Strathbogie North-Blue Range mass. These granites intrude or metamorphose the acid lavas but not the sediments above them. Both intrusive and faulted boundaries with the Ordovician and Silurian rocks occur. The granites, while not in fact uniform in composition, form a distinctive soil parent-material and have been separated into several land systems distinct from other rock types in the area.

Lower Carboniferous

The Barjarg-Mansfield-Tolmie area is characterised by a thick series of purple to red sandstones, shales and conglomerates. There are some green and buff beds but "the red rock" is an apt brief name.

These beds contain fish remains indicating a Lower Carboniferous Age, and plant fossils are also present. They overlie the Upper Devonian lavas and older rocks, apparently with slight unconformity. Apart from the boundary to the acid lavas in the Archerton-Upper Holland's Creek area the extent of these sediments is defined by major faulting. Within the survey area, except for drag folding along faulted boundaries, the beds are nearly flat or dip gently south and west.

These rocks weather to produce very characteristic soils and the flat bedding has a marked influence on topography. The rock type has been used as a basis for land system delineation. There are exposures of similar sediments in the Tatong area and in places these appear to underlie the lavas where they would therefore be Upper Devonian in age. On the other hand they may represent downfaulted blocks. The structure in this area is complex.

Permian

Pebbley mudstones, containing marine fossils which have been assigned a Permian Age, occur just outside the catchment in the Greta area, and a small occurrence has been reported in the catchment at Taminick. As a soil parent material they are fairly characteristic, though generally similar to the Carboniferous Age sediments. The area involved in the catchment is very small and does not warrant separation.

Tertiary

There are no known rocks in this area representing the time interval from Carboniferous to the Tertiary. During this long interval the area was apparently a highland, suffering erosion. Faulting doubtless occurred during this time and broad areas of low relief developed. These are now represented by the several plateaux remnants.

Within the catchment only the "older" basalts of the two main Tertiary volcanic epochs are represented.

In many places the basalts lie on thin beds of gravels and clays, apparently the stream deposits of the valley into which they flowed. The most extensive areas of older basalt form plateaux in the Tolmie-Archerton area. Under the local wet climate these areas have developed very characteristic deep, friable reddish gradational soils and have been separated as a distinct land system. There is also a very small occurrence at Taminick in the north-western corner of the catchment.

ECONOMIC GEOLOGY

There is minor mineralisation associated with both periods of folding and igneous activity, i.e. the mid-Devonian and the epi-Upper Devonian epochs. The earlier one seems to have been responsible for most of the quartz reefs and dykes associated with mineralisation, though there is some tin and gold associated with the granites attributed to the later epoch.

There has been little commercial exploitation of mineral deposits within the catchment apart from minor finds of gold and a little tin. A variety of collectors items, including agates and turquoises, are found in the area but there is no known large deposit of any economic mineral, nor any large scale quarrying industry.

SOILS

The distribution patterns of the soils of the catchment show a clear relationship to the vegetation patterns, and hence to the topography and climate. They have been classified into a number of general descriptive groups (after Rowe 1972) which correspond approximately in level of classification to Great Soil Groups (Table 5).

Rowe (1972) which correspond approximately in level of classification to Great Soil Group (Table 5).

1. **The montane assemblage:** The soils from the lower elevation mountain slopes and the drier end of this sequence are usually weakly-bleached gradational soils. However in the higher rainfall areas there is increased accumulation of organic matter and bleaching is less apparent.

The soils range from pale or reddish weakly bleached gradational soils at lower elevations to friable brownish gradational soils in the higher areas. Friable reddish gradational soils occur on gentle topography at the upper elevations on a range of parent materials.

2. **The foothills and lower slope assemblage:** Soils of this assemblage include both gradational and duplex soils. They develop a variety of parent materials ranging from in-situ weathered rock to slope detritus. The detrital material may be derived from rock, or from a previous soil, or may be mixed. Thus a wide range of materials is present, varying from fresh rock to well weathered and variably sorted soil remnants, and this is reflected in the variability of the soils.

The main soil groups recognised in this assemblage are: stony loams, undifferentiated sands and loams, pale gradational soils, weakly-bleached gradational soils, reddish gradational soils on alluvium, non-calcareous dark clays and reddish or yellowish duplex soils with acid subsoils.

3. **The plains assemblage:** The foothills merge with the plains and several soil groups are common to both. The characteristic soils of the plains are reddish or yellowish duplex soils with acid subsoils. These grade into reddish duplex soils with neutral to alkaline subsoils to the west of the catchment and are replaced by calcareous dark clays in swampy areas. Pale gradational soils and reddish gradational soils on alluvium occur along drainage lines and overlie the duplex soils in many places.

4. **The river terrace assemblage:** There are four terrace levels, each with characteristic soils. On the top level, the Benalla plain, reddish and yellowish duplex soils with acid subsoils are dominant. The Kilfeera (second highest) terrace set has yellowish-brown gradational soils, reddish weakly-bleached gradational soils, reddish gradational soils on alluvium, and non-calcareous dark clays. The soils of the Goomalibee terrace, the next lowest, are typically brown and grey loams. The lowest levels consist of undifferentiated sands and loams, and shingle deposits. .

Table 5. - Soils of the Broken River Catchment

—	Profile Nos.	Distinctive Parent Material.
Uniform soils—		
1. Undifferentiated sands and loams ..	..	Alluvium
2. Stony loams	566, 570	Palaeozoic sediments
3. Coarse sandy loams	396, 397	Granite
4. Grey and brown loams	565	Alluvium
5. Calcareous dark structured clay ..	403, 404	Alluvium
6. Non-calcareous dark structured clays ..	..	Alluvium
Gradational soils—		
7. Pale gradational soils	..	Alluvium /colluvium
8. Weakly bleached gradational soils ..	564, 401	Colluvium from varied rock types
9. Friable brownish gradational soils ..	398, 406, 572	Palaeozoic sediments, granite, acid lavas, carboniferous sediments
10. Friable reddish gradational soils—		
(*a*) with well structured subsoil ..	405, 571	Cambrian greenstone, basalt, sometimes those in (*b*)
(*b*) with weakly structured subsoil ..	569	Palaeozoic sediments, granite, acid lavas, carboniferous sediments, sometimes those in (*a*)
11. Reddish gradational soils on alluvium ..	568	Alluvium
12. Yellowish-brown gradational soils on alluvium	567	Alluvium
Duplex soils—		
13. Reddish duplex soils	573, 574	A wide range of p.ms. mainly in the form of alluvial or colluvial deposits
14. Yellowish duplex soils	399, 407, 402, 400,	A wide range of p.ms. as above

UNIFORM SOILS

1. Undifferentiated sands and loams (None sampled)

Deep, undifferentiated sands and loams consist of the relatively recent sediments which accumulate at the margins of most streams. They may also occur as alluvial fans of recent origin. They are typically without profile development except for darkening by organic material near the surface.

2. Stony loams (Profile Nos. 566; 570)

On the higher, steeper slopes the upper member of each catena is generally a stony loam. In the higher rainfall areas there is usually some depth of soil on most ridges, but in the drier foothills and lower slopes shallow stony residuals are more typical. These stony soils usually have some features similar to adjacent soil types and may be a degraded form of the typical soil of the area. They are very acid soils.

They have little water-holding capacity and this is reflected in the vegetation they support, and particularly by the lack of vegetative ground cover. The areas involved are fairly small and widely separated so their effects on the catchment hydrology are probably not marked.

Plate 5. The coarse sandy loams on the Warby Range are widely used for road surfacing material.

3. Coarse sandy loams (Profile Nos. 396; 397)

These are common soils on the slopes of granitic areas (Plate 5). They have a uniform texture profile which is dominated by the coarse-textured products of rock weathering, mainly quartz, but felspar is also an important constituent. Although a slight increase in clay content may be revealed by particle-size analysis this is usually masked by the dominance of the coarse components in field textures.

A typical coarse sandy loam would have about 10 cm of brown to dark brown, coarse sandy loam with weak coherence and lacking structure. This gradually changes to a lighter coloured but otherwise similar horizon which may extend to 30 cm. Below this depth the colour may gradually change to strong brown or yellowish brown, but with no appreciable change in texture, structure or consistence. Weathered rock usually occurs at less than 1.5 m depth on slope soils, but profile depths of greater than two metres occur in deposits at the base of steep slopes.

They are moderately acid soils and although they contain abundant primary minerals the lack of colloidal material probably results in a relatively low nutrient status. Furthermore, their coarse texture also results in a low availability of moisture, and this is the dominant factor affecting the suitability of these soils for plant growth.

Their ability to absorb runoff is high but they drain rapidly. These soils play an important part in the hydrologic cycle of granitic areas which typically produce prolonged seepage, often in the form of highly reliable springs.

4 Grey and brown loams (Profile No. 565)

These soils are formed on alluvium and generally have a uniform texture profile. However as they are relatively young soils there may be changes in texture related to the sedimentary bedding, particularly in the lower part of the profile. Because they occur in a relatively low topographic setting, on the Goomalibee (lowest) terrace, they are often associated with a fluctuating watertable which causes gleying of the subsoil.

Soils of this group usually have a dark and strongly structured surface which may be the result of the gradual accumulation of fine sediments from frequent flooding in association with a vigorous herbaceous vegetation. Below about 10 cm colours are not as dark and the structure is usually a weakly developed prismatic. They become hard as they dry out.

The grey and brown loams are amongst the more fertile soils in the area and provided they have adequate subsoil drainage should be very suitable for intensive agricultural use. As they are close to streams they could be readily irrigated.

They are not of great extent and because they are adjacent to streams changes in use of these soils would have little effect on catchment hydrology. However deep-rooted perennials, such as lucerne, may effectively reduce the watertable in small streams.

5. Calcareous, dark, structured clays (Profile Nos. 403; 404)

These dark grey to black, calcareous, cracking, heavy clays occur along drainage lines on the Mansfield Plain and in the swampy areas on the Benalla Plain.

Those of the swampy areas are generally gilgaied. The gilgai depressions may have a surface soil of light grey loam, particularly near drainage lines. This loam appears to be a more recent surface deposit, in which elsewhere the pale gradational soils have formed, rather than being part of the calcareous dark clay soils which form a catena with the duplex soils on the plains.

A typical profile in a gilgai hollow consists of a few centimetres of dark brown clay loam to light clay at the surface, grading rapidly into a black massive or coarsely structured earthy clay. This becomes better structured with depth, changing to strong, very fine angular blocky, with shiny and well-defined ped faces. At about one metre this material changes to grey heavy clay with large slickensided peds.

The puffs or rises of the gilgai pattern consist of dark grey to light olive, heavy clay, with abundant lime concretions up to about 10 cm across. The reaction of these clays is from pH 8 to 9. The hollows are slightly acid at the surface but the pH rapidly increases to slightly alkaline at a depth of about a metre. There are associated soils which are very similar, but not as black, and these grade into the situation described above where more recent deposition of sediment has completely swamped the accumulation of organic matter. Some of the members of this group are barely gilgaied. This range of types appears to correspond to the Upotipotpon Series of Downes (1949).

The cation exchange capacities are high, apparently being related to the high clay content, and are dominated by calcium throughout. In contrast to the heavy subsoils of the yellowish duplex soils magnesium is always much less abundant than calcium. Sodium becomes quite significant as an exchangeable ion at depth in the depression phase of these soils but is relatively low in the puff phase.

The water-holding properties of these soils have not been measured but it seems reasonable to assume that the clays would have a rather high wilting point which would limit the availability of water for plant use. The clays crack deeply, particularly on the puffs, and in summer the soil dries out to considerable depths. This allows water initially to penetrate very quickly so that summer rain is largely lost. However in winter the clay swells and forms a barrier to drainage, and areas of these soils remain flooded much of the time. In their present condition these soils present a rather severe plant environment.

The calcareous dark structured clays of the Mansfield Plain (Plate 6) are similar in profile characteristics but are rarely gilgaied. The dark clays are shallower and lime accumulation is not as marked. These soils are found along creek lines rather than in swampy areas, and their generally higher fertility and more friable nature make them potentially useful although they occur only as small areas.

6. Non-calcareous, dark, structured clays (None sampled)

Moist but well drained sites on relatively unbleached parent materials are usually occupied by non-calcareous dark clays, sometimes with mildly bleached A2-horizons. These soils are typical of creek banks and terraces.

A typical profile has a few centimetres of dark brown friable loam, grading rapidly into a black clay loam to light clay with well-developed, fine, subangular blocky structure. This dark layer is usually about a third to half a metre deep and grades through grey mottled clay into unaltered parent material which usually shows current bedding.

From comparative analytical data it is inferred that the pH is slightly acid to neutral. Organic carbon content is moderately high as is the exchange capacity. The base status may be fairly good with the exchange capacity only mildly hydrogen-dominated. Calcium is the most prominent metal ion, but there is no free lime in the profile.

The physical properties of the soil are good, although there is a tendency for it to be heavy and sticky when wet. The percentage of clay is high, and consequently wilting points may be expected to be fairly high, so that water storage for plant use may be fairly limited. However since the soils occur commonly in moist sites this will be important only during drought. Because of their limited area, the infiltration characteristics will have little effect on flooding. Lighter textured forms can be expected to have greater moisture holding ability.

Plate 6. Calcareous, dark, structured clay exposed in a stream bank in the Mansfield Plain.

GRADATIONAL SOILS

7. Pale gradational soils (None sampled)

These soils have weakly-bleached A2-horizons and light coloured B-horizons. They occur mainly in depressions and drainage lines but are also developed generally in a layer of apparently redeposited, weathered materials spread from the foothills over the plains. The profile usually comprises from a few centimetres to about half a metre of light grey, vesicular, apedal silty or sandy loam. This grades into yellowish apedal light clay or clay loam, containing numerous buckshot concretions particularly toward the base. It often overlies a yellowish-brown clay typical of the B-horizon clays of the yellowish duplex soils of the plains. In these situations the soil appears to be developed in the A-horizon of an older soil but the more common profiles are developed on deeper alluvial deposits and lack the underlying heavy clays.

Bleaching of the whole profile, and gleying with iron oxide concretions, are typical of the maximal development, but the better drained sites tend to more strongly coloured profiles, and intergrades trending toward the reddish gradational soils occur.

The pale gradational soils have fairly low clay content. This appears to be largely a reflection of the nature of the parent material. The following comments are based on analyses of similar soils elsewhere and limited data from this catchment. They are generally acid with reactions about pH 5.5, but rising a little in the B-horizon. The influence of organic matter is restricted to a few centimetres from the surface and the cation exchange capacity is moderate in the surface horizon and the more clayey horizons but low elsewhere. Much of the material is probably undergoing at least a second cycle of leaching after apparently having been originally eroded from older A-horizons. The plant nutrient status is variable but generally low.

The moisture holding capacity, both of water available for plant growth, and at saturation, is probably moderately high because of the generally light textures. However the flat-lying areas in which they occur tend to become waterlogged early in winter so that there is little potential for storage of flood rains. Rapid surface runoff may be expected from these soils through much of the winter.

There may be up to 20 per cent of the soil volume in the loamy horizons available for temporary storage of flood rain if the soil is moist but not waterlogged; this amounts to about 5 cm of water in shallow profiles and perhaps twice this in deep ones. The clayey horizons contribute virtually nothing to the absorption of flood rain as they are apedal, of low porosity and inclined to disperse. They are thus difficult to wet quickly and slow to drain. The moisture held after drainage and available to plants is probably also about 20 per cent of soil volume. This would result in about 5 to 15 cm of available water being held, depending on the depth of soil.

8. Weakly-bleached gradational soils (None sampled from mountain areas; Profile No. 564 from plains)

The weakly-bleached gradational soils differ from the brownish gradational soils in that the bleaching of the A-horizon is quite evident in the field and they are not as friable. Also the humus-enriched layer under the litter is much shallower, but the tendency for metal ions to be concentrated in the top few centimetres is still apparent.

There are many variants of this group, according to parent material and site, but they share the following characteristics.

The profile typically consists of a few centimetres of brown to greyish brown humic loam at the surface grading into light reddish clay loam or light clay. In less freely drained sites subsoil colours may be yellowish. The structure of the B-horizon is usually only moderately developed, but at some sites there is a well-structured clay at the base of the profile. This latter appears to be the relic B-horizon of a previous soil. Particle size analysis shows a moderate increase in clay content with depth but no pronounced zone of accumulation. Similarly trends in the values for free ferric oxide demonstrate that iron eluviation has occurred but rarely show a marked zone of accumulation. The pH is about 5.0 to 5.5, varying little with depth. The cation exchange capacity is moderate in the humic surface horizon and decreases lower in the profile. These soils are generally moderately base-saturated.

A typical profile a metre deep would hold about 15 cm of water available to plants. The ability of a moist soil to absorb surface water amounts to about 25 per cent of the soil volume in the top 15 cm, and about 15 per cent at lower levels. Thus a profile one metre deep, at field capacity, could absorb about 130 mm of rain before becoming saturated.

9. Friable brownish gradational soils (Profile Nos. 398; 406; 572)

The typical soils of the mountainous, wetter forest areas are the friable brownish gradational soils which are developed on a wide variety of parent materials, and include soils intergrading between the weakly--bleached gradational soils and those in which humus accumulation is a dominant feature. The group is highly leached but is not podzolised, and there is only a slight increase in clay content down the profile.

The soil surface is typically overlain by a layer of litter several centimetres thick grading into a dark brown, humic, friable loam with fine crumb to very fine subangular-blocky structure. With increasing depth the profile at first becomes lighter in colour and then usually more reddish or stronger brown. In the B-horizon the texture increases to a clay loam, or light clay, and the structure becomes a little coarser. The organic-matter content decreases rapidly below the surface few centimetres. The profile is porous, friable, well-drained and permeable throughout. Analyses generally show small and gradual increases in clay and free ferric oxide content with depth, although some profiles could be classified as having a uniform texture profile. Colours may be more yellowish on the acid lavas. This is thought to be because these rocks weather to more clayey material than does granite or the Palaeozoic sediments.

An important feature of these soils is the concentration of plant nutrients in the surface layers as a result of recycling by plants. They are acid soils throughout (about pH 5.5) although the surface is usually a little less acid. The cation exchange capacity is moderately high at the surface but decreases with depth. This is apparently mainly due to the organic colloid rather than the clay. The ions on the colloid are dominated by hydrogen, with calcium the dominant metal cation near the surface, and magnesium generally slightly less abundant.

Soils of this group are usually deeply weathered or overlie fractured and weathered rock and are very porous and permeable. Unless surface roughness and permeability are reduced, for example by compaction by vehicles, surface runoff is not likely to occur, even on steep slopes. The volume of water held at saturation is about 60 per cent of soil volume in the top metre, and may still be about 50 per cent by volume at the base of the profile.

The moisture remaining in the soil at field capacity amounts to about 35 per cent of the soil volume, and the available water capacity is about 20 to 25 per cent.

If a soil was at field capacity it would take about 300 mm of heavy rail to saturate a 1.5 metre-deep profile and produce surface runoff.

In areas of lower rainfall and elevation the friable brownish gradational soils have less humic A-horizons and are gradually replaced by the weakly bleached gradational soils.

At these lower elevations the surface soil is usually a dark brown, friable well-structured loam, under dry litter, and there is a gradual change to a reddish brown clay loam or light clay at about a metre depth. The structure of the B-horizon may be fairly well developed, or only moderately so.

10. Friable reddish gradational soils (a) Soils with well-structured subsoil (Profile Nos. 405; 571)

These soils typically consist of a few centimetres of finely structured dark brown or greyish-brown loam to clay loam, which gradually changes to moderately structured clay loam or light clay, and which at greater depth grades into a progressively more red, well-structured clay. Weak bleaching of the A_2-horizon may be apparent but there is no clear zone of ferric oxide accumulation in the B-horizon.

They are acid soils with some reactions as low as pH 4.8 in the profiles sampled.

The cation exchange capacity is fairly high at the surface in the organic horizon but is only moderate in the more clayey B-horizon. Base saturation, though still relatively low, is higher than in the other montane soils and is particularly so in those derived from basic rocks.

The clays, though well structured and friable, are fairly dense and hold about 40 per cent volume of water at saturation, and about 30 per cent at field capacity. About 15 per cent of the soil volume in the B-horizon and about 20 per cent of the A-horizon, holds water available to plants.

A profile one metre deep could hold about 15 cm of water available for plant use. The ability of these soils to absorb flood-rains when wet is more limited than for the other montane soils, but is most pronounced in the top half metre or so. A profile one metre deep at field capacity could absorb about 10 cm of water before reaching saturation. The generally greater depth of these soils may compensate for their lower capacity to absorb water.

Most of these soils are reddish-brown but there are yellowish variants in low topographic positions.

(b) Soils with weakly-structured subsoil (Profile No. 569)

The colours of these soils are generally similar to those of the group with well-structured subsoils, although the strongest reds (2.5YR) do not usually occur. Also the texture profile follows the same trend down to the B_2-horizon which is usually not as thick and may become less clayey with increasing depth. Generally the porosity is high throughout the profile.

The reaction (pH) of the weakly-structured group is very acid (pH 5.0) and may be expected to have lower base saturation than the well-structured group.

The water holding characteristics of the group may be more comparable to those of the friable brownish gradational soils than to the well-structured friable reddish gradational soils. It is estimated that available water capacity would be about 20 to 25 per cent volume, and a profile 1.5 metres deep at field capacity could absorb another 300 mm of heavy rain before surface runoff occurred.

11. Reddish gradational soils on alluvium (Profile No. 568)

These soils of the alluvial deposits are friable reddish loams to clay loams with little structural organisation. A typical profile shows a few centimetres of brown fine sandy loam grading into a reddish-brown loam to sandy loam which becomes a little more strongly coloured, and of slightly heavier texture, with depth. The whole profile is friable and porous and there is little development of secondary organisation.

These soils are typical of the outflow areas from small catchments and alluvial fans. They also occur in the terrace sequence and sporadically on the plains. Morphologically they closely resemble the weakly-structured reddish gradational soils described above.

The soils are mildly leached and appear to be moderately fertile, but are more notable for their excellent physical properties.

They may be slightly superior to the weakly-bleached gradational soils in their ability to retain moisture available for plant growth.

12. Yellowish-brown gradational soils on alluvium (Profile No. 567)

These are relatively common soils on the Kilfeera (mid) terrace although in total area they are not of great importance.

The gradational texture profile of these soils is usually well developed although on the coarser sediments it may not be as obvious. The texture ranges from loam or sandy loam in the A-horizon to light clay in the B-horizon at between about 30 to 80 cm. Below this the texture becomes less clayey and pedogenetic organisation declines rapidly.

The A_2-horizon is usually moderately bleached and the colour in the B-horizon may be strong brown, although more yellowish colours are usual.

The typical profile lacks structural development except in the B-horizon where weak to moderate fine subangular-blocky tending to prismatic structure is usual.

These are moderately acid soils with fairly high natural fertility. The cation exchange capacity is fairly low but is moderately saturated with metal ions of which calcium is clearly the most abundant. Although values for available phosphorus in Profile 567 are relatively high the amounts in the HCl extract are low. Potassium appears to be in adequate supply.

No moisture studies have been carried out on these soils, but because of their similarity in texture, structure and porosity to other soils studied elsewhere reasonable estimates may be made.

The quantity of moisture which can be held in a form available for plant use would probably range from about 15 per cent of the soil volume in the A-horizon to about 20 per cent in the B-horizon.

In a moist soil about 20 per cent of the A-horizon and about 10 per cent of the B-horizon would be available to absorb heavy rain. Thus without considering infiltration rates or deep subsoil percolation it may be estimated that a profile a metre deep could absorb about 130 mm of rain before becoming saturated and contributing to overland flow.

DUPLEX SOILS

13. Reddish duplex soils (Profile Nos. 573, 574)

These soils are widespread throughout north-eastern Victoria. Both the Warrenbayne Series on igneous rocks and the Gowangardie Series on Ordovician sedimentary rocks, which were described by Downes (1949) from the adjacent Dookie area, are of this group. Rowe (1967) described them as red podzolic soils in the catchment of Lake Hume.

A typical profile would have a surface horizon of dark grayish-brown loam or fine sandy loam overlying a paler greyish-brown or brown loam at about 5 cm. The paler A_2-horizon is usually about 20 to 25 cm thick and overlies the reddish-brown clay of the B-horizon with a clear to abrupt boundary. The A-horizon is usually apedal and sets hard when dry although it may be relatively porous. The B-horizon has moderately developed subangular-blocky structure with ped faces about one centimetre across. When moist the clay is reasonably friable but it becomes hard when dry.

The reddish duplex soils are often associated with residual land forms, and weathered rock may occur at a depth of one metre, or less. Also fragmented rock may occur throughout the profile.

The soils of this group typically have moderately to strongly acid subsoil reaction. The B-horizon colloid has exchangeable magnesium dominant over calcium and there may be measurable quantities of exchangeable sodium. There appear to be substantial reserves of available potassium but phosphorus levels are generally low.

In terms of ability to retain water for plant use and to absorb flood rains the acid reddish duplex soils are notably less effective than the soils of the montane sequence. In these soils the top half-metre would store about 65 mm of water available to plants and a profile one metre deep would hold about 115 mm. The loams of the A-horizon have relatively high moisture capacity but the clays have high wilting points. This materially reduces the effectiveness of the soil to store water in a form available to plants.

Similarly in the clay, there is a relatively small difference between the volume of water held at field capacity and that held at saturation, so that the ability of the soil to temporarily hold flood rain is quite limited. The loams of the A-horizon have about 15 per cent of the soil volume available to accept such water, but in the underlying clays the available volume would usually be about 10 per cent but may be as low as 5 per cent. Although there is a tendency for the clays to swell when wet it is not as pronounced as in the yellowish duplex soils. However the swelling tends to seal the lower portion of the profile which is usually somewhat more porous in summer when dry, so that the soils drain more slowly after the first thorough wetting. Thus the potential of the upper layers to accept surplus water is seldom realised because of the lack of free drainage through the B-horizon.

Plate 7. Gilgai micro-relief is typical of the yellowish duplex soils on the Mansfield Plain.

14. Yellowish duplex soils (Profile Nos. 399, 400, 402, 407)

The predominance of yellow or yellowish-brown subsoils distinguishes these profiles from the reddish duplex soils. Comparable soils described by Downes (1949) are the Koonda Series on alluvium and the Caniambo Series on material derived from Ordovician or Silurian sedimentary rocks.

Two forms of this group may be recognised.

(a) Soils of this, the more common group, are generally widespread on the Mansfield and Benalla plains and on similar old plain surfaces elsewhere. Commonly a mantle of younger alluvium of varying thickness overlies them and causes considerable variation in depth of the apparent A-horizon. This mantle may be thick enough for pale gradational profiles to have developed above the heavy clay of the B-horizon. They usually have gilgai micro-relief (Plate 7) but where the younger alluvial mantle is thick this may only be apparent from the undulating surface of the B-horizon.

A typical relatively unaltered profile consists of several centimetres of organic-darkened surface and about 20 cm of pale grey, apedal, silty loam, often moderately vesicular and with increasing amounts of small iron oxide concretions (buckshot) lower in this horizon. There is an abrupt and usually wavey boundary with the yellowish-brown heavy clay B-horizon. The clay is strongly-structured with large (2 cm) angular-blocky peds which readily break to smaller fragments when dry. The heavy clay may extend to depths of greater than two metres. (Plate 8)

Although the surface horizons are usually acid to very acid (pH 5.5-4.7) the subsoils are variable. Soils with acid subsoils are the more common but those with neutral to alkaline subsoil are relatively common and may be closely associated with the former. The pattern of variation appears to be related to the gilgai micro-relief. The more alkaline soils are usually the "puff" soils.

A notable feature of the subsoils of these soils is the dominance of exchangeable magnesium over calcium and the presence of measurable quantities of sodium. These ions contribute to the highly dispersible nature of those subsoil clays. There may be substantial reserves of available potassium in the B-horizon but phosphorous levels are generally low.

In summer there is a tendency for the subsoil clays to crack as they dry out. In this condition they allow rapid infiltration of storm rain, however they swell when wet and the deep cracks become tightly closed in winter.

The heavy subsoil clays can retain only small amounts of water available for plant use and when moist, do not contribute to the temporary storage of water from heavy rain. The A-horizon may retain moisture available to plants to 20 per cent of its volume and could provide temporary storage for water from heavy rain. However the generally shallow depth of the A-horizon of much of these soils results in a relatively poor ability to absorb high rates of rainfall. Thus these soils soon become saturated, particularly in winter, and may cause substantial surface runoff. They frequently remain waterlogged for long periods in winter.

(b) The second form of yellowish duplex soil has a clear or even somewhat gradational boundary between the A- and B-horizon. The B-horizon clay is not as dense and is usually yellowish-brown with reddish-brown mottles. The clay content of the B-horizon usually decreases below about one metre.

Plate 8. In the yellowish duplex soils there is a sharp change from the loamy and light coloured A-horizon to the yellowish-brown clay of the B-horizon.

This form is not as widespread and is usually found in the plains tract associated with the more sharply differentiated form or in the foothills where it occurs on the lower slopes or sometimes on a terrace in tributary streams.

They are acid soils but when in low topographic situations may have neutral to alkaline subsoil, sometimes even with small limestone nodules.

VEGETATION

VEGETATION CLASSIFICATION

There are thirteen main species of eucalypt comprising the dominant vegetation of the catchment. The distribution of these species is related to regional rainfall over the range 650 mm to 1300 mm per annum in approximately the following order-red ironbark (red gum), grey box, yellow box, long-leaf box, red box, red stringybark, broad-leaf peppermint (blue gum, swamp gum), candlebark gum, narrow-leaf peppermint and messmate.[*] Those species shown within brackets are additionally influenced by site characteristics which affect soil wetness. The relationship to rainfall is however an over simplification as elevation, temperature and aspect all influence the distribution. But in general the higher and cooler locations also have higher rainfall, and aspect effects seldom cause a discontinuity of more than one species ranking in the list. In practice the order of increasing wetness of climate works out well.

Local influences such as rock type, topography or drainage cause variations in dominant species within the limits imposed by the regional climate.

The species listed above, and several other less dominant species, have been grouped into three alliances which are characteristic of large areas and easily recognized. The major groupings are: the peppermint-gum forests *(Eucalyptus radiata-E. dives-E. rubida* alliance); the box-ironbark forests *(E.*

[*] Botannical names and the common names used in this study are listed in Appendix IIIA.

Polyanthemos-E. sideroxylon alliance); and the box-red gum woodlands *(E. microcarpa-E. camaldulensis* alliance).

Each alliance contains a number of characteristic species groups, or associations. Within each alliance groups of association have been recognised (sub-alliances) and are used as the main descriptive units. Several of the sub-alliances correspond directly to groupings which were designated as full alliances in a description of the vegetation of the adjacent catchment to Lake Eildon (A. S. Rundle report to Soil Conservation Authority of Victoria).

The sub-alliance groupings are introduced to provide a basis for broad scale mapping, since mapping at the association level is not appropriate for this scale of study. A map of distribution of vegetative communities (Fig. 17) has been compiled from field observations, plus reference to Forests Commission assessment work in the Strathbogie forests.

Because of the influence of climate on vegetation distribution, and the fact that climate is a continuously variable factor, many vegetative boundaries cannot be drawn with great precision there is always a gradient across the mapped line, and also aspect may reverse climatic trends in the vicinity of the boundary.

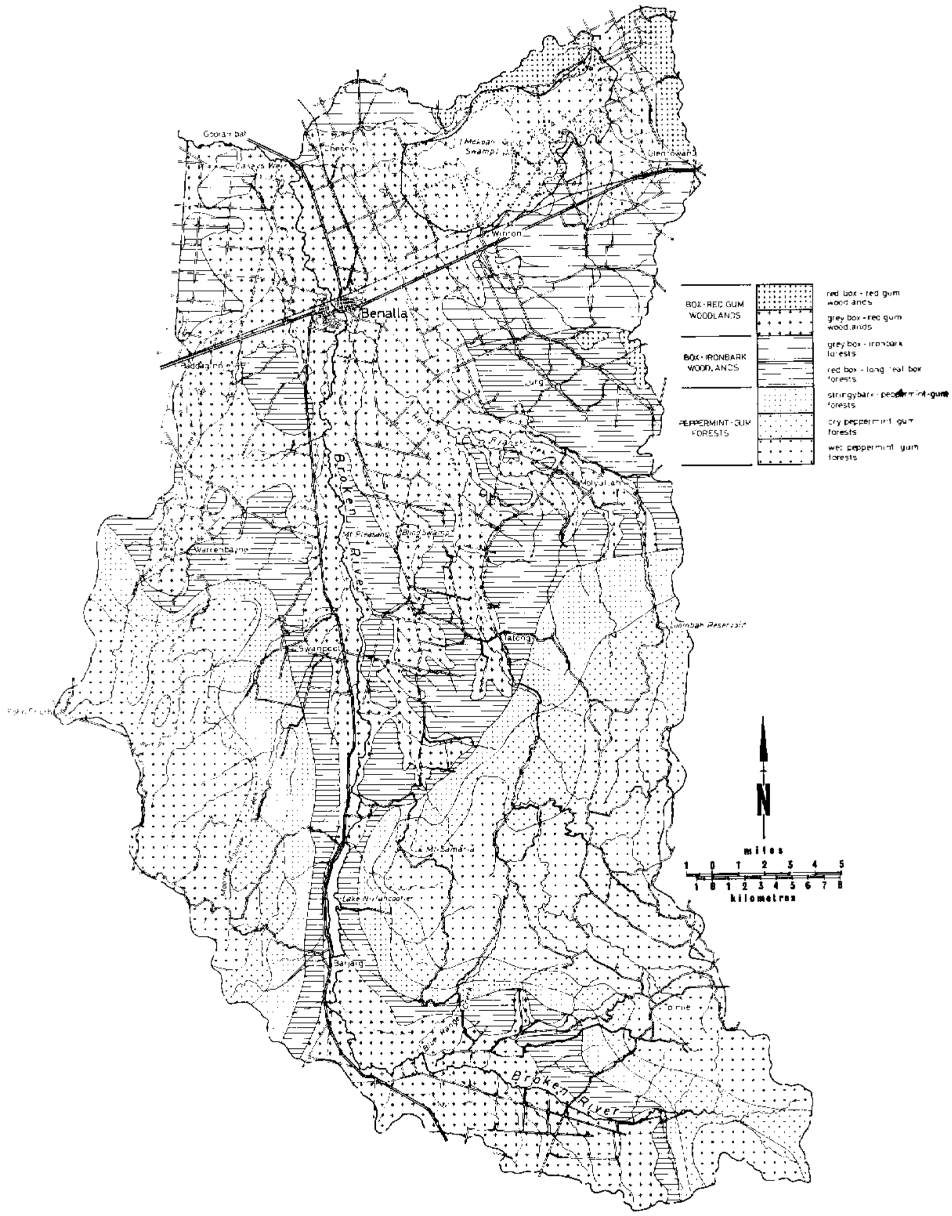

Fig. 17—Distribution of vegetative communities.

Fig. 17 - Distribution of vegetative communities

However where a change in vegetation is directly related to topography, as for example over most of the length of the boundary of the grey box-red gum community, the mapped boundary has greater precision. In the southern half of the area the boundaries are predominantly a reflection of climate, and for instance, the concentric pattern illustrated in the three sub-alliances of the peppermint-gum forests can be more or less directly related to variation in regional rainfall.

Isohyets (Fig. 2) have in fact been derived from this relationship using the known stations as checks. These, while useful for other purposes, are therefore not valid for comparison with the vegetation map.

The three alliances and seven sub-alliances are described below and their classification is set out in Appendix 111B.

DESCRIPTIONS OF THE VEGETATIVE COMMUNITIES

1. PEPPERMINT-GUM FORESTS

(a) Wet Peppermint-Gum forest

The open-forest* of narrow-leaf peppermint *(E. radiata)* and candlebark gum *(E. rubida)* (Plate 9) is the dominant vegetation in much of the upper parts of the catchment, which receive an annual precipitation of between 1150 mm and 1500 mm. The wetter areas also carry messmate *(E. obliqua)* (Plate 10) and in favoured sites this species may be present in virtually pure stands. In these areas the form may be tall open-forest.

Although most of the "gum" component of the peppermint-gum forests is the candlebark gum *(E. rubida)*, white brittle gum *(E. mannifera)* and manna gum (E. *viminalis)* occur in places, the former in the drier areas and the latter chiefly in the moister environments such as along creek lines, and on the plateaux or gentle slopes. The relationship of mountain gum *(E. dalrympleana)* to these species is not clear in this area.

The canopy may be almost closed (70 per cent projected cover) in the wetter forests, and a patchy understorey of silver wattle (A. *dealbata)* is common. Blackwood (A. *melanoxylon)* grows to a fairly large tree along the watercourses. On south and east aspects a wet-gully flora is usually present, dominated by hazel *(Pomaderris aspera)* and various daisy-bushes *(Olearia* spp.). Musk daisy bush *(0. argophylla)* occurs in the wetter gullies and blanket-leaf *(Bedfordia salicina)* is often found in the same situation. Tree ferns *(Dicksonia antarctica)* mark the stream lines in the gullies.

The forest floor layer is usually closed with herbs and native grasses.

Plate 9. This open-forest of narrow-leaved peppermint and candlebark gum has ground cover of tussock grass, scattered bracken fern, herbs and abundant forest litter.

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* Structural form terminology conforms to that of R. L. Specht, Vegetation Chapter, "The Australian Environment", 4th Ed. (1970) Ed. G. W. Leeper

(b) Dry Peppermint-Gum forest

The foothill areas which receive about 1000 mm. annual rainfall typically carry open forest of broad-leaf peppermint *(E. dives)* and candlebark gum *(E. rubida).* Blue gum or white brittle gum *(E. mannifera)* is found in the lower gullies and swamp gum *(E. camphora)* occurs in poorly drained areas. On ridge tops some red-stringybark *(E. macrorhyncha)* may persist. The transition to wet peppermint-gum forest is marked by the change from dominance of broad-leaf peppermint to narrow-leaf peppermint *(E. radiata),* and this is first apparent on south and east aspects. A shrub layer is usually present but is rarely continuous. The silver wattle (A. *dealbata)* and common cassinia *(Cassinia aculeata)* occur frequently, and native cherry *(Exocarpus cupressiformis)* may be present. Smaller shrubs are typified by *Dillwynia sericea* and *Hibbertia stricta.* The forest floor is normally closed, with native tussock grasses *(Poa australis, Danthonia spp., Stipa spp.)* predominating.

(c) Stringybark-Peppermint forest

This type of forest occurs as a transition from the box country where rainfall is about 650 mm to 750 mm to the peppermint-gum forest of 900 mm to 1150 mm rainfall. It consists of open forest of red stringybark *(E. macrorhyncha)* and broad-leaf peppermint *(E. dives),* with blue gum *(E. bicostata)* in the gullies, long-leaf box *(E. goniocalyx)* on ridge tops and dry aspects, and red box (E. *polyanthemos)* (Plate 11) in moist sites on the lower rainfall edge of the unit. As rainfall increases stringybark-peppermint forest gives way to peppermint-gum forest. Candlebark gum *(E. rubida)* may be present on southern aspects in the wetter fringe.

Plate 10. In areas of high rainfall, messmate stringybark occurs in the open-forest formation with narrow-leaved peppermint and candlebark gum.

Plate 11. The stringybark-peppermint forest has been cleared from much of the lowlands in the north and is now mainly found as relics on roadsides where the trees develop a Woodland form, as shown by these red box trees.

The understorey is sparse and discontinuous. In gullies silver wattle (A. *dealbata)* and common cassinia *(Cassinia aculeata)* are typical, and in more open areas blackwood (A. *melanoxylon)* is common. Native cherry *(Exocarpus cupressiformis)* is usually scattered throughout and small grass-trees *(Xanthorrhoea minor)* are present in some areas. The forest floor is normally closed with native tussock grasses *(Poa australis, Danthonia spp., Stipa spp.)* predominating.

2. BOX-IRONBARK FORESTS

(a) Red box-Long-leaf box forest

The low hills of sedimentary rock, with low to moderate rainfall (approximately south of Benalla), carry a mixed dry open forest to woodland, largely dominated by red box *(E. polyanthemos).* This community grades into stringybark-peppermint forest which generally occurs higher up the slopes, but it differs from that community in that broad-leaf peppermint *(E. dives)* is absent. Longleaf box *(E. goniocalyx)* extends into higher rainfall areas and grey box *(E. microcarpa)* may extend into the community from the lower rainfall areas. Yellow box *(E. melliodora)* is found particularly on the footslopes in the areas adjacent to the grey box-red gum woodlands of the plains. As regional rainfall decreases (generally to the west and north of the catchment) this community gradually gives way to the grey box-ironbark forest, and in the fairly broad boundary zone, grey box and white box *(E. albens)* become increasingly more dominant.

The shrub layer is varied and discontinuous. It is often characterised by the red-stem wattle (A. *rubida),* and golden wattle (A. *pycnantha)* by the native cherry *(Exocarpus cupressiformis).* The small grass-tree *(Xanthorrhoea minor)* is not usually a common species, although it occurs in wetter areas or where the soil is deeper.

The ground cover is usually only partly closed, although in the absence of fire the non-vegetated patches are generally covered with leaf and twig litter so that bare soil is rare. Much of the area is, however, burnt regularly and a good deal of the floor is now sheet eroded. In high rainfall areas tussock grass *(Poa australis)* is typical, but as rainfall decreases the wallaby grasses *(Danthonia* spp.) become common. Although this community occupies a large area it is not easily separated from the adjoining communities and contains many species common to both, including the ground cover species.

(b) Grey box-Ironbark forest

The northern low hills of sedimentary rock which receive an annual rainfall of about 650 mm carry an open forest to woodland of grey and white box *(E. microcarpa, E. albens)* with red ironbark *(E. sideroxylon)* on ridges and exposed slopes, particularly those facing north or west. Red stringybark *(E. macrorhyncha)* is found on the southerly aspects and in gullies. Long-leaf box *(E. goniocalyx)* occurs mainly on the ridges where it is mixed with the other box species.

The smaller tree and shrub layers are fairly sparse although golden wattle (A. *pycnantha)* is usually common. Over much of the area these forests are regrowth after cutting for mine props or poles in the early days of settlement, and a good deal of the lower layers consist of suppressed regrowth or coppice. The ground layer is open, and in the absence of fire, accumulated dry twigs and leaf litter form much of the ground cover. Many small and interesting plants, including a number of orchids, are found in the ground and shrub layers. The generally open forest structure, particularly in the taller stands, provides habitat for a variety of birds and small animals which are perhaps more varied and visible than those of the vegetation of the higher rainfall areas.

Plate 12. Woodland of red gum occurs along many of the streams on the plains.

3. BOX-RED GUM WOODLANDS

(a) Grey box-Red gum woodlands

The riverine plain areas of low to moderate rainfall, including the Benalla and Mansfield land systems, carry the remnants of an extensive woodland to open woodland of grey box *(E. microcarpa)* and red gum (E. *blakelyi* or *E. camaldulensis),* with some yellow box (E. *melliodora),* white box *(E. albens)* and long-leaf box *(E. goniocalyx).*

The red gum occurs all over the plains, but along stream lines and in swamps it is found in pure stands (Plate 12), and seems in general to be the river red gum *(E. camaldulensis).* Grey box mainly occupies the rises (Plate 13), and yellow box is typically found on the lower slopes. On the drier rises in the north white box *(E. albens) occurs* instead of grey box. Long-leaf box is found with grey box in the south, but around Benalla and to the north apple box (E. *bridgesiana)* is more common. The species distribution can be seen on the four sub-system diagrams of the Benalla land system (Figs. 32, 33, 34 and 35).

Over most of the area the woodlands have been opened up or cleared for grazing, and where only partly cleared the lower tree and shrub layers are degenerate, with a generally grassy floor of wallaby grass *(Danthonia pallida).*

(b) Red box-Red gum woodlands

This community is the characteristic vegetation of the granitic hills in the north which receive an annual rainfall about 650 mm, and where the soils are dry in summer but are saturated in winter. It consists of a woodland to low open forest, dominated by red box *(E. polyanthemos)* with red stringybark *(E. macrorhybcha)* on moister aspects and long leaf *(E. goniocalyx*) on the higher ridge tops (Plate 14). The more gently sloping areas carry a mixed woodland with much forest red gum (*E. blakelyi*).* On plateaux, or along stream lines where drainage is impeded, red gum become dominant. In moister valleys tall silver wattles (*Acacia dealbata*) are common, and on the rocky spurs golden wattle (*A. pycnantha*) and red-stem wattle (*A. rubida*) occur with the drooping sheoak (*Casuarina stricta*). Austral grass-trees (*Xanthorrhoea australis*) are present in most of the sandy areas.

Plate 13. Woodland of grey box was the characteristic natural vegetation of the footslopes of the sedimentary hills in the north of the catchment.

A shrub layer is a feature of the rocky and better drained sites, and species such as the showy guinea flow *(Hibbertia abtusifolia)* and the woolly Grevillea *(G. lanigera)* make the area particularly attractive. Moister places carry tussock grass *(Poa australis)* and wallaby grass *(Danthonia pallida),* and other species of grass and herbs. The smaller shrub layer and the ground layer carry many attractive and interesting wildflowers except where the vegetation is heavily grazed.

Plate 14. Woodland of long-leaf box and red gum occurs on rocky slopes of the Warby Range.

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* The red gums of the low woodland in the hills are *E. blakelyi* and much of the red gum which occurs on the plains is the same species. However along the rivers and in swamps *E. camaldulensis* is the main species. Although these two species have been recognised no attempt has been made to separately map their distribution (Fig. 15).

The small rock fem *(Cheilanthes tenuifolia)* is abundant, particularly in the rocky areas, and mosses are a feature of the rock faces in water.

COMMENTS ON THE VEGETATIONAL PATTERNS

Prior to settlement the peppermint-gum forests occupied virtually all areas in the catchment with an average rainfall in excess of about 900 mm.

The driest community in this sequence is the stringybark-peppermint forest, and this gives way at about the 1000 mm isohyet to dry peppermint-gum forest which in turn is replaced by wet peppermint-gum forest where rainfall is above about 1250 mm, or slightly less on sheltered aspects. Messmate *(E. obliqua)* occurs in areas receiving in excess of about 1400 mm up to probably about 1550 mm. The typical sequence found in most of the major catchments of north-eastern Victoria, which continues with other species up to alpine vegetations or to tall closed forest according to altitude, is not represented in the Broken River catchment.

Within the peppermint-gum forests there are also patterns of species distribution in response to features other than regional climate. Manna gum *(E. viminalis)* and candlebark gum *(E. rubida)* are found in much greater proportion on the plateaux and in hollows. Their distribution may be related to the tolerance of their seedlings to frost damage and therefore to cold-air drainage patterns. Messmate favours moist gullies on the south and east side in the drier portion of its range, but where the rainfall is higher it is found over the whole topography. Some pure stands of messmate may also have resulted from fires. Blue gum *(E. bicostata)* occupies moist sites or, in the lower rainfall areas, sites with a high water table, and swamp gum *(E. camphora)* is restricted to areas of poor drainage. Snow gum (E. *pauciflora)* occurs within the catchment although there are no truly sub-alpine areas. It occurs typically in low open forest or woodland on the exposed ridge tops, where soil is shallow and drainage excessively rapid, and its distribution may be explained in terms of its tolerance to low winter temperatures and summer drought. Most of the species show variation in distribution with macro- and micro- climatic features. There are few instances of rock or soil type influencing the vegetation directly. The most obvious of these is the association of manna gum and basalt patches on the Tolmie plateau.

The box-ironbark forests are restricted to the hills of sedimentary rocks which receive an annual rainfall of less than about 900 mm. This community does not occur in the dry, granitic areas. The boundary with the stringybark-peppermint forests is gradational and dependent on climate, as also is the separation of this community into the grey box-ironbark forests and the red box-long-leaf box forests. However the lower boundary, to the grey box-red gum flats, is often the break of slope and is fairly sharply defined.

The grey box-ironbark forests are found in the north-western end of the area, where rainfall is lowest, between about 650 mm and 750 mm per annum. The red ironbark *(E. sideroxylon)* is most commonly found on ridge tops and exposed aspects where the soil usually consists of shattered shale chips, often in a matrix of red clay which is apparently the stump of an eroded ancient soil. Less stringent environments are occupied by white box *(E. albens)*, grey box *(E. microcarpa)*, red box *(E. polyanthemos)* and red stringybark *(E. macrorhyncha)* in order of improvement in conditions for plant growth. Long-leaf box *(E. goniocalyx)* occupies the drier sites in the red box-long-leaf box forests, but it differs in requirements from the red ironbark in that it apparently needs deeper soil and better drainage. The red ironbark, though capable of withstanding summer drought, will also tolerate impeded drainage and is found with grey box, though not as a dominant, in valley sites which become saturated in winter.

The granitic areas in the same climatic region normally carry a red gum-red box woodland, although the distinction between granite and sedimentary soil parent-materials becomes less important in regions of higher rainfall where weathering is deeper and more uniform. The combination of sandy soils which dry out in summer, and waterlogging caused by impervious rock layers seems to be the main reason for the difference between the vegetation of these areas and the hills of sedimentary rock.

The red gum *(E. blakelyi)* is tolerant of soils which become waterlogged for considerable periods each season. On the granite this occurs in stream lines and valley bottoms, and over much of the topography where the soil mantle overlies unbroken granite close to the surface. Red box, long-leaf box and red stringybark favour deeper soils where, although soil saturation may occur, it is not as frequent or as prolonged. The very well drained sandy soils among rocky outcrops support the native pine *(Callitris sp.)*, and the drooping sheoak *(Casuarina stricta)* occupies dry, rocky environments.

Drainage conditions are similarly important in the grey box-red gum woodlands which occupy the plains. Low lying areas, stream lines and swamps carry red gum *(E. camaldulensis).* The better drained country is occupied by grey box *(E. microcarpa),* and yellow box *(E. melliodora)* often occupies an intermediate position occurring in moister sites which have adequate drainage.

The situation where all three species are present in tall woodland formation is, however, quite common.

The Mansfield Plain carries mainly red gum (E. *camaldulensis)* with the other species characteristically restricted to rises. This pattern may also be the result of saturation of the soil above rock layers, which in this area are the very gently dipping sedimentary red-beds. Elsewhere on the plain gradients are low, and there is a thick horizon of clay below the topsoil which has a similar effect.