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DETERIORATION OF VEGETATION AND EROSION IN THE GUTHEGA CATCHMENT AREA SNOWY MOUNTAINS, N.S.W.

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Dependent as this scheme is upon the long-continued supply of water of high quality from the high, snow-fed catchments of the Snowy Mountains, the individual catchment becomes important, particularly if, in any catchment area, deterioration or accelerated erosion is noted. Inefficiency of any major or minor catchment area is likely to jeopardize engineering structures, alter stream-flow patterns and sediment load, and the operational efficiency and the eventual life of the system as a whole.

Against the relative importance of the catchment areas for water yield compared with previous returns from snow leases (Taylor, 1956), consideration of the vegetation of any denuded or eroded area assumes national importance.

The high alpine, or high mountain vegetation of the Australian mainland occupies an area of some 2,000 square miles, of which 1,000 square miles lies in southeastern New South Wales. It is predominantly within the Snowy Mountains, and is the only extensively winter snow covered area on the continent.

The whole of the area under consideration is situated above the winter snow line and comprises those plant communities generally grouped as "alpine" and "sub-alpine" by Costin (1954). The alpine and sub-alpine tracts form virtually the inverted apex of the Snowy Mountains in the far southeast of New South Wales being, in their southernmost extent, no more than a few miles from the Victorian border. Within this area rises the Snowy River.

GUTHEGA CATCHMENT AREA

Since the major contiguous area of alpine vegetation lies within the catchment of Guthega Pondage, currently the highest water storage in Australia, and since this catchment best illustrates the changes which have taken place in the past 100 years, detailed consideration of vegetal changes will be limited to this area. The area is the very roof-top of Australia, being bounded on the northwest by the main divide, running from Mount Kosciusko (7,314 feet) through Mount Northcote (7,000 feet), Carruthers Peak (7,042 feet), Mount Twynam (7,208 feet) and on through Mounts Lee and Anderson; on the northeast by Guthega Pondage and in the southeast by the Ramshead and Crackenback Ranges (figure 1).

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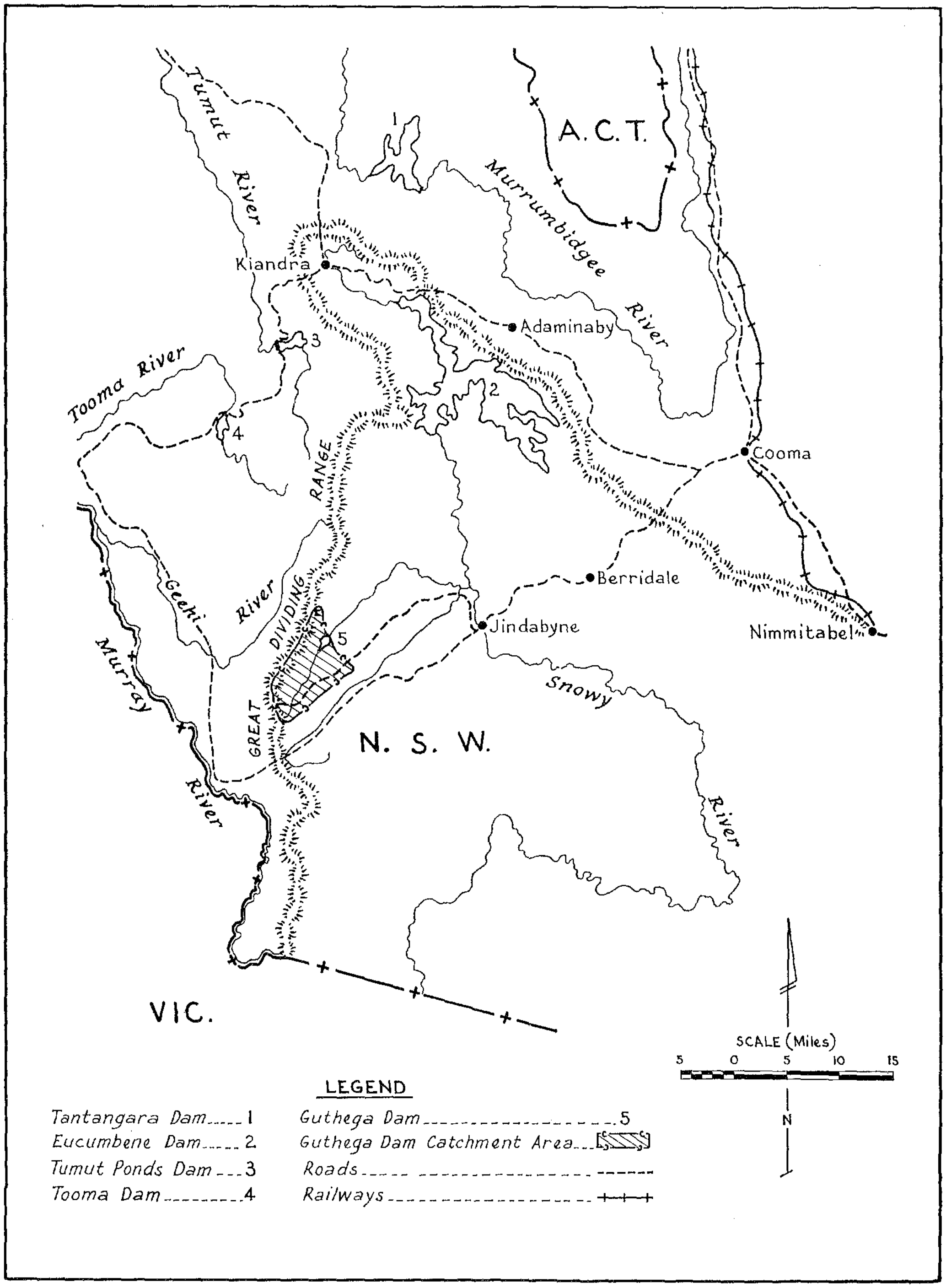

Figure 1—Guthega dam catchment area, showing its relationship to the Snowy Mountains area

The catchment comprises some 23,000 acres (approximately 36 square miles) of which 60 per cent is above the tree-line and 40 per cent is occupied by the sub-alpine woodland of *Eucalyptus niphophila* in its various forms.

Definitions

The high alpine zone may be described as the area having continuous snow cover for at least one month per annum, coinciding with the upper limit of the sclerophyll forest. It comprises, therefore,

SUB-ALPINE TRACT—characterized by a continuous snow cover of one to four months per annum and approximates to the range of the pure snowgum (*Euc. niphophila*) stands. The upper limit, at varying elevations between 6,000 feet and 6,500 feet, is the tree-line determined by the January mean temperature isoline of 50°F (Costin 1965), whilst the lower limit coincides with the upper limit of other tree species at about 5,000 feet.

ALPINE TRACT—is characterized by a continuous snow cover for at least four months, and a January mean temperature of less than 50°F. The vegetation is characteristically herbaceous, comprising grasslands, herbfields, heaths, bogs and associated communities. A number of the communities and of the species present are unique on mainland Australia and provide phytogeographical links with the sub-Antarctic islands and South America (Costin 1961).

PHYSICAL ENVIRONMENT

Climate

Precipitation varies from 68 inches per annum at Guthega power station to 120 inches per annum at Mount Twynam and decreases to 100 inches in the Lake Albina and Lake Cootapatamba areas, of which up to 25 per cent may fall as snow. Snow cover shows a definite altitudinal relationship modified by aspect in the alpine drift areas and at lower elevations it is modified by the degree of tree cover. Snow season at Spencer's Creek has varied from 3.3 to 7.4 months in the period 1954–1964 but is up to 1.5 months longer on the main range.

The distribution of precipitation shows a double peak in midwinter and spring and a distinct summer-autumn minimum. Rainfall in excess of 2 inches per month may be expected each month in 75 per cent of years. Intensities are not high. The highest recorded one-hour rainfall is 2.44 inches at Spencer's Creek. Figure 2 illustrates the precipitation characteristics at Spencer's Creek and Guthega Power Station.

Temperatures are mild in summer but during six months of the winter the mean of extreme values is less than 22°F. Frosts occur throughout the year but the period of least incidence is during January and February.

Wind velocities are high, 40 mph being frequently attained whilst 80-90 mph gusts are not infrequent.

Physiography and Geology

Relief is suppressed in comparison with alpine areas elsewhere. Local relief seldom exceeds 500-700 feet. Valleys are generally U-shaped showing evidence of previous glaciation, interfluves are generally rounded though sharpened somewhat on their south and southeast faces by semi-permanent snowdrifts. Stream patterns are oriented to snowdrift sources and often show partial structural control.

Geologically it is a relatively undissected massif, marginally faulted, and underlain by gneissic granites with a narrow band consisting of phyllites, schists and quartzites, running NNW from the Etheridge Range to Carruthers Peak (figure 3). It has been subject to one or more pleistocene glaciations of disputed extent and intensity (Galloway 1963, Brown and Vallance 1963) while there is also extensive evidence of former intense periglacial activity.

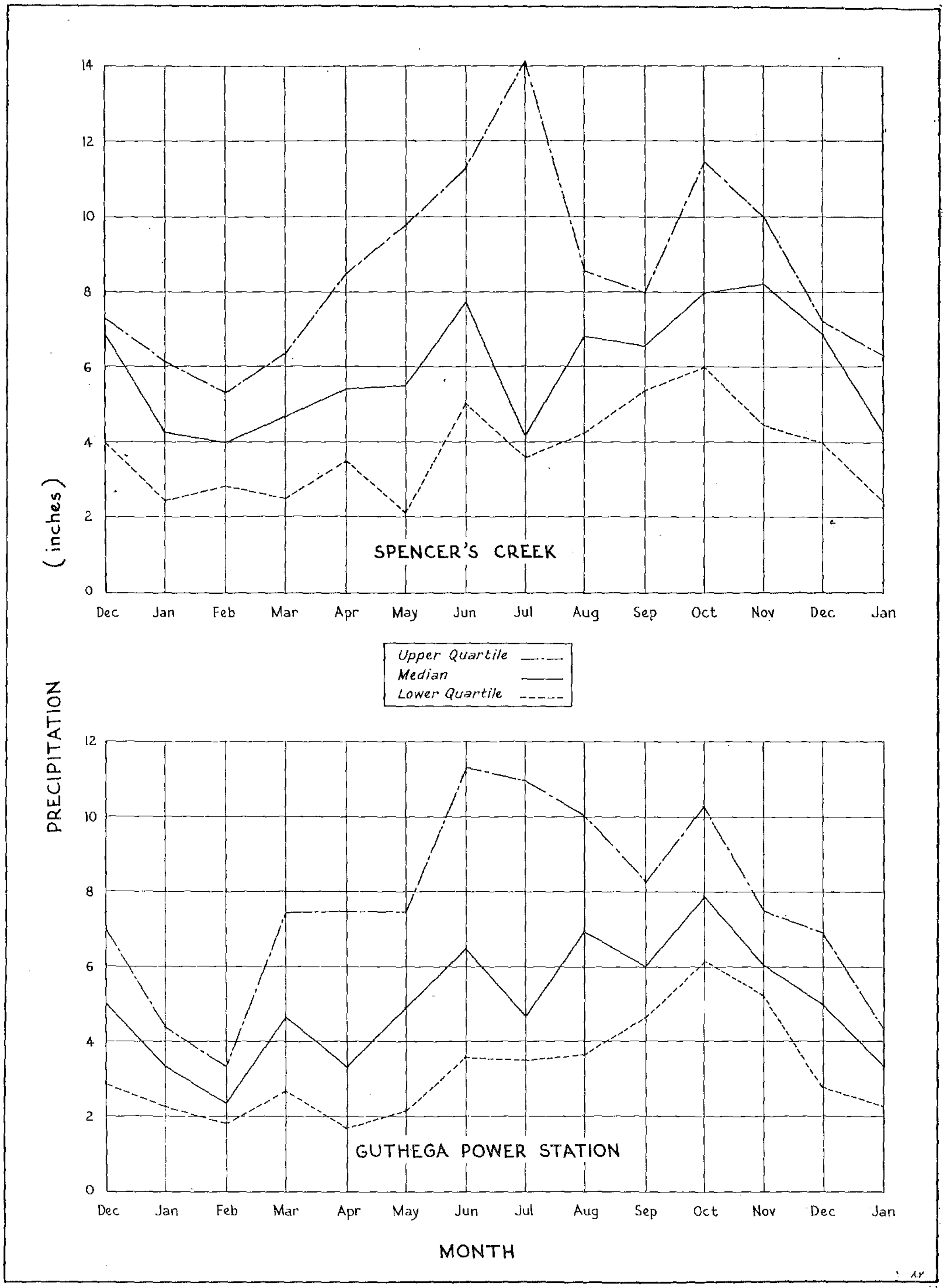

Figure 2—Precipitation characteristics at Spencer's Creek and Guthega Power Station

Soils

Within the catchment are seven major soil associations. These have been described by Costin (1954) and the most extensive of them fully described by Costin, Hallsworth and Woof (1952). These soils fall within four main groups.

(1) Soils showing no profile differentiation —largely mineral in nature—*Lithosols.*

(2) Soils in which the profile shows no eluviation of sesquioxides, acid to strongly acid in the surface—*Alpine Humus Soils.*

(3) Soils in which the water table is present in the solum for at least part of the year—

Silty Bog Soils

Snow Patch Meadow Soils

(4) Soils in which the profile is dominated by organic matter, the botanical features of which are partially visible—

Humified Peats

Bog Peats

Fen Peats

These soils are characteristic of most alpine areas but attain their maximum development in this area. The main features are their considerable depth, acidity regardless of parent material, high organic matter, and their relation to drainage and water table conditions. The base status of these soils is related to the occurrence of organic matter. Erosion therefore has a serious deleterious effect upon fertility as the subsoil horizons are acid, highly infertile, low in soil colloids and organic matter and are highly erodible.

VEGETATION PATTERNS

The vegetation patterns of the area are intimately dependent upon the relation of environmental factors as influenced by the biotic or anthropogenic factors. They are controlled by four factors:

(a) Climate—the high precipitation, the snow cover and low temperatures.

(b) Soils—their acidity, infertility, and the position and permanence of the water-table.

(c) Past geomorphic process.

(d) Settlement history.

Table I relates the major forms to current overseas synonyms.

TABLE I

VEGETATION FORMS—GUTHEGA CATCHMENT AREA*

Form	Sub-form	Synonyms
ALPINE HERBFIELD	Tall alpine herbfield .. Short alpine herbfield ..	Alpine meadow, herbfield, herb-moor. Mountain meadow.
FEN		Low-moor, nieder-moor, flachmoor, marsh, swamp.
BOG	Valley bog .. .. Raised bog	Mixed-mire, acid fen, transition fen. Raised moss, loch moor.
FJAELDMARK		Fellfield, wind-desert, feldmark, felsen-fluren, fjaeld-marker.
WOODLAND	Sub-alpine woodland ..	Alpine woodland.
HEATH		Heather.
GRASSLAND	Wet tussock grassland .. Sod tussock grassland ..	Meadow grassland. Mountain, alpine, sub-alpine, grassland.

*After Beadle and Costin (1952)

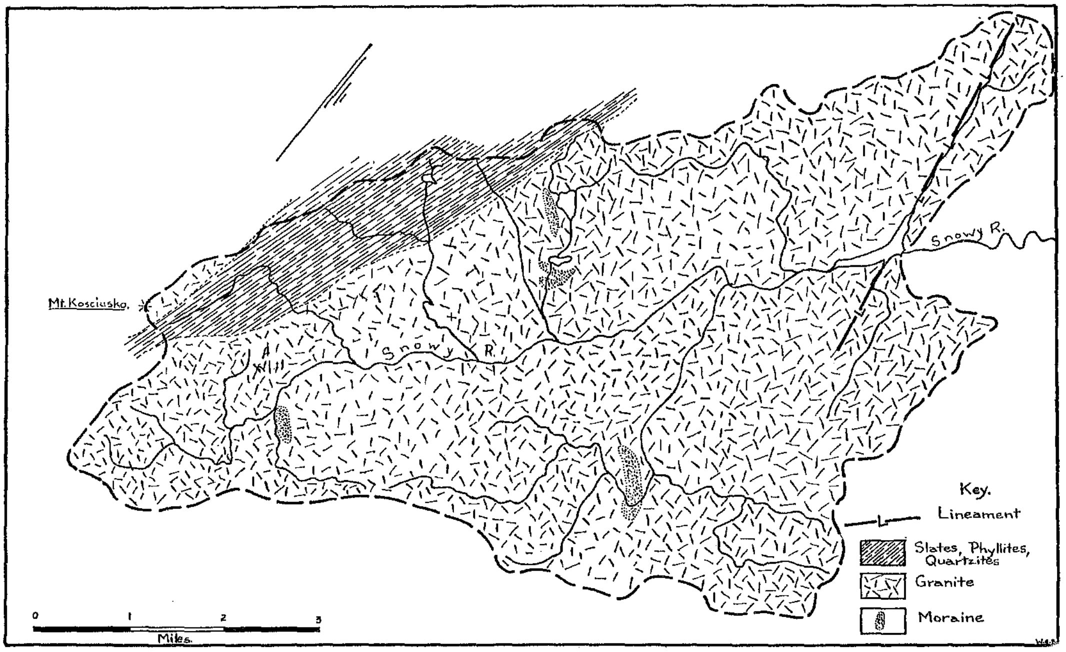

Figure 3—Geology of Guthega catchment area—after Snowy Mountains Hydro-Electric Authority geological survey maps

The major communities have been fully described by Costin (1954, 1957, 1961). They comprise:

(1) Tall Alpine Herbfields—a multi-storied, closed alpine community dominated by tall perennial herbs. There are two communities.
   (a) *Brachycome nivalis—Danthonia alpicola* alliance of steep rock-faces, crevices, and ledges.
   (b) *Celmisia longifolia—Poa caespitosa* alliance of freely drained soils throughout the area with species such as *Helipterum incanum* and *Epacris sp.* assuming greater importance in exposed situations.

(2) Short Alpine Herbfields—closed alpine community dominated by short, carpet-forming herbs and forbs—of restricted local occurrence.
   Plantago muelleri—Montia australasica alliance
   This community may be enriched by *Euphrasia, Ranunculus, Craspedia,* and *Aciphylla.*

(3) Fen—hygrophilous community characterized by free surface water and dominated in its undisturbed state by *Carex gaudichaudiana.*

(4) Bogs — hydrophilous communities dominated by hummock-forming mosses.
   (a) Raised Bogs of valley sides dominated by *Sphagnum cristatum—Epacris paludosa, Blindia robusta.*
   (b) Valley Bogs dominated by *Sphagnum cristatum.*

(5) Fjaeldmarks—open sub-glacial communities of dwarf plants, of which there are two naturally occurring forms.
   (a) *Coprosma pumila—Colobanthus benthamianus* of snowpatches.
   (b) *Epacris petrophila — Veronica densifolia* of windswept summits and cols.

(6) Heaths
   (a) *Epacris serpyllifolia — Kunzea muelleri* of poorly aerated situations.
   (b) *Oxylobium ellipticum — Podocarpus alpinus* of shallow rocky situations.

(7) Sub-Alpine Woodlands — open or closed woodland of *Eucalyptus niphophila,* at times reduced to the dimensions of scrub. Ground stratum varies from sod-tussock grassland or herbfield to low scrub (in rocky situations).

It is doubtful whether any part of any community has escaped the modifying hand of European man, and a number of altered community sequences can be recognized. One of the most common is the "erosion fjaeldmark" on eroded sites formerly supporting tall alpine herbfield *Poa caespitosa—Celmisia longifolia* communities.

The distribution of the main communities is shown in figure 4.

VEGETATION DETERIORATION AND EROSION

Deterioration involves the reduction in quality or value of the land and it is generally indicated by the loss of valuable species from the sward. In the extreme case, deterioration is represented by loss of ground cover and by accelerated erosion.

Deterioration of Vegetation

The original state and condition of the vegetation of the area has been described by early writers. Helms (1896) effectively summarises the situation in that year in his comments upon the continuous sward nature of the alpine grassland, stating that only on bare rocks and snowdrift areas is there not an almost alpine vegetation covering every available spot.

The deterioration process involves a number of independent factors operating in overlapping sequence. These are the gradual loss of palatable species, the invasion or increased dominance of less palatable, or more fire resistant species, the opening of the sward, and the depletion of such surface litter and humus as remains. Indications of deterioration and erosion of recent origin are reviewed by Durham (1959) and include exposed soil faces, pedestalled plants, soil and lichen lines, and humifying peats associated with sod-tussock grassland.

From the writings of the workers who have made detailed or passing examinations of the flora (e.g. Maiden 1898, 1899: McLuckie and Petrie 1927: Costin 1954) and from examination of changes currently apparent within the area, species lists can be compiled for each major community covering the "decreasers" and "increasers". Probable deterioration sequences can be constructed, and the potential for recolonization can be examined. Of the palatable species observed to have been most eliminated by grazing, special mention can be made of a few notable species. *Danthonia frigida* J. Vickery (*D. robusta* of McLuckie and Petrie, 1927) was recorded as common by Helms (1893), Maiden (1899) and McLuckie and Petrie (1927). Costin (1954) recorded it as formerly common and possibly co-dominant with *Poa caespitosa* (under review) but as rare and only found in inaccessible places by 1948. Reappearance from these "refuge" sites has been noted increasingly and the author made collections from three widely separated localities in 1964–65 where it was recorded as "from occasional to a frequent occurrence" in well drained, but moist situations of dense snowgrass (*Poa caespitosa*) sward. *Aciphylla glacialis,* an extremely palatable semi-succulent perennial herb which had decreased to the "rare" category by 1948 is now of occasional occurrence over wide tracts of the alpine herbfields and forms up to 50 per cent of the non-graminaceous component of the sward in selected sites above Lake Albina.

Other palatable herbs previously much sought after by stock include *Ranunculus anemoneus, Craspedia uniflora, Leptorrynchus squamatus* and the *Geranium* species of the inter-tussock spaces of the grassland and herbfield communities. Costin (1958) notes stock preferences for a number of bog and fen species, particularly the dominant fen species (*Carex gaudichaudiana*) various other sedges and species of *Astelia,* for *Montia australasica, Epilobium confertifolium, Ranunculus inundatus* and a number of other short alpine herbfield species.

He also points to the preference of the stock for damaged sites, further intensifying, by local overgrazing, the deterioration of these communities. From an examination of the various major communities the construction of deterioration patterns is possible.

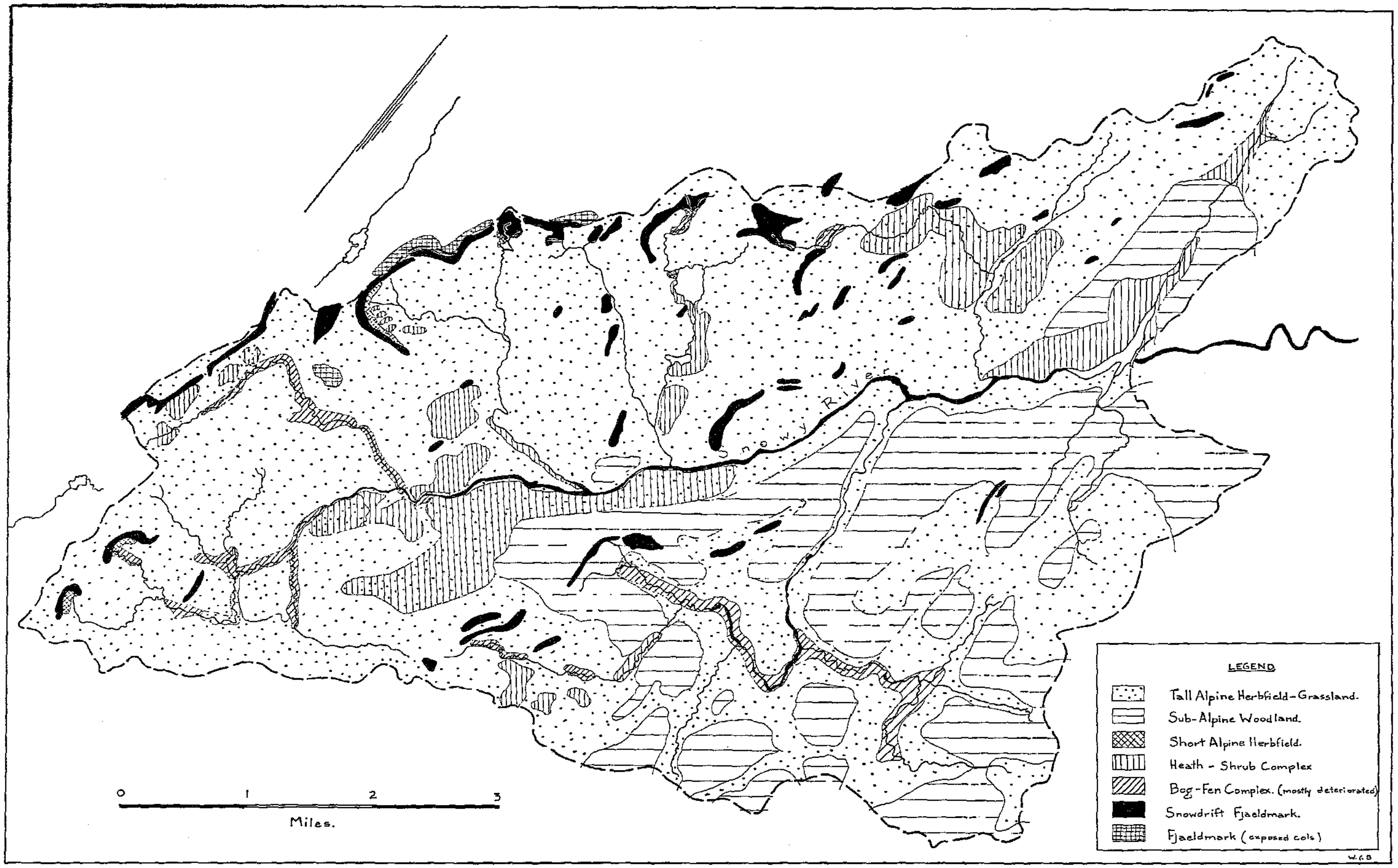

Figure 4—Vegetation patterns, Guthega catchment area

Many of the changes in soil and vegetation, due to causes now removed, are reversible and the trend toward the "climax" vegetation may be noted. In many other situations however, the changes are irreversible unless artificial soil conservation measures are also employed. Whether changes are reversible or irreversible is dependent upon the degree of deterioration, the type of community concerned and upon the delicacy of the original balance.

The pattern of deterioration of a number of communities has been studied by the author and are submitted as examples together with a brief assessment.

(i) Tall Alpine Herbfield (*Poa caespitosa–Celmisia longifolia Association*)

Two communities have been examined, the first near the saddle above the Soil Conservation Service hut at Carruthers, and the second on the Carruthers Ridge on the catchment area of the Club Lake Creek and the following sequence constructed.

Poa caespitosa-Celmisia longifolia (associated sub-dominant *Craspedia uniflora, Haemarthria sp., Euphrasia sp.*

⥮

Loss of inter-tussock species.

⥮

Loss of *Celmisia longifolia* and opening of the stand.

⥮

Poa caespitosa with up to 25 per cent inter-tussock spaces. Blowouts occur in more exposed situations, resulting in slight sheet erosion.

Interruption at this stage usually results in colonization by *Acetosella vulgaris* and *Senecio lautus* and ultimate re-invasion by colonizing native species.

↓

Poa caespitosa-Epacris to 50 per cent bare ground with associated deflation losses. In very exposed situations such as this, deterioration is now irreversible, proceeding to the stone or erosion pavement stage, where an open community of fjaeldmark* species dominates.

Within the *Poa caespitosa—Celmisia longifolia* community quite distinct and sharp boundaries have been observed on freely drained slopes and reasons for their occurrence have been commented upon, (Costin 1954; Costin et al, 1959). Pure *Celmisia* beds frequently occur below snowpatch meadows where long-lying snow is the predisposing agent (Costin et al, 1959). Beds also occur on areas of recent instability, including soil slip areas, overfalls and disturbed areas, such as former stock camps, indicating the value of *Celmisia* as a colonizer compared with snowgrass (figure 5).

The main features of the deterioration pattern in this community are the loss of the inter-tussock herbs such as *Craspedia, Ranunculus* etc., the decrease in flowering and spread of *Celmisia,* the opening of the inter-tussock spaces allowing surface wash and wind deflation of fine material from around tussock roots, and the smothering of vegetation by saltating pebble streams. The triggering mechanisms were selective grazing of the palatable species, burning of the surface litter, and the subsequent frost, water, and wind action on the bare surface.

In this community, of largest areal extent in the alpine tract, considerable natural regeneration has taken place and it is only in the most severely exposed and the most severely damaged situations that the process is irreversible.

(ii) Short Alpine Herbfield (*Plantago muelleri—Montia australasica* Association)

Reputedly palatable, many of these communities are now truncated by rills and small gullies from the snowpatch to the communities below. Examples may be seen in the Upper Twynam Cirque, Club Lake and in the Kunama Cirque. These areas regenerate rapidly when channel flow is controlled.

(iii) Valley Side Bog (*Sphagnum cristatum—Richea continentis, S. cristatum—Epacris paludosa*)

Two sites, located on Carruthers walking track some 450 yards from the Snowy River and 20–30 yards above the Carruthers Creek crossing, have regenerated well since the removal of stock and fire and as stream

* The erosion fjaeldmark is distinct from, and should not be confused with the true *Epacris-Veronica* fjaeldmark.

Figure 5—Natural regeneration by *Celmisia longifolia* of a formerly denuded and moderately eroded area, at 6,800 feet in the Carruther's Creek catchment area

entrenchment had not proceeded far. The track, in concentrating and diverting the run-off water, has altered the downslope hydrologic conditions. The deterioration pattern is related specifically to run-off, water table and aeration conditions. The following succession occurs as free drainage increases:

Permanently wet—*Sphagnum cristatum* —*Richea continentis, S. cristatum* — *Epacris paludosa*

↓

Seasonally dry—*Richea continentis*—*Epacris sp*

↓

Richea continentis—*Calorophus lateriflorus*

↓

Seasonally wet— *Calorophus lateriflorus* — *Poa caespitosa* (a form)

↓

Freely drained—*Poa caespitosa.*

In the areas where water has flowed off the track, and truncated peat and gravel has smothered the *Sphagnum* and helophyte communities downstream, snowpatch meadow species, among which *Montia, Caltha* and *Luzula* are prominent, are among the primary colonizers. Several *Ranunculus* species establish in fringing wet areas where the peat soils have not been gravel covered.

Additional stages involving a number of heath-like *Epacridaceae* may be found to predominate under certain conditions.

(iv) Valley Bog and Fen Complex

Costin et al (1959) quote Petersen and locals as evidence of the much greater former extent of the valley bog complex, stating that deliberate and repeated burning took place in the early 1900's and the deteriorative effects were most extensive following the 1939 bushfire.

Certainly no completely undamaged communities have been seen in the study area by the author, although several of relatively good vigour are present on restricted areas. Typical degenerated communities examined are located at Thompson's Plain in the sub-alpine tract and on the low interfluve between Merrit's Creek and the Snowy River some 400 yards upstream from Main Road 286.

The communities at Thompson's Plain show typical hummock and hollow patterns topographically oriented but consisting of the following species:

HUMMOCKS	HOLLOWS
Richea continentis	*Agrostis sp.*
Calorophus laterifiorus	*Montia australasica*
Poa caespitosa	*Caltha introloba*
Epacris serphyllifolia	*Carex spp.*

The spring fed streams of the area are entrenched and the extent of the bog and fringing heath communities is much reduced. The bog area has a surface water table only during the thaw and shrinkage cracks and tunnelling beneath the peat may be noted. Transect studies carried out on this area over a period of some ten years* since stock removal have not revealed any reversal, or even halting, of the deteriorative process.

In the Merrit's Creek-Snowy River situation, the same pattern, more severely developed, is apparent. The streams are now 3–5 feet entrenched whereas originally they lacked precise definition.

Natural regeneration in these communities is unlikely except in the extreme long view. Any attempt to regain the bog communities would entail water spreading and stilling structures to encourage *Sphagnum* regeneration.

(v) Fjaeldmark

Of the two major fjaeldmark communities the *Epacris petrophila—Veronica densifolia* alliance (figure 6) of the exposed cols has extended somewhat in size at the expense of the *Poa caespitosa* herbfield community due to the processes outlined above and in marginal situations on Mount Twynam a community having affinities to both the true fjaeldmark and the snowpatch fjaeldmark is found. The latter is considered an "erosion fjaeldmark". Open communities similar to this, but lacking the woody *Epacris*, are characteristic of sites where accelerated erosion has proceeded to the stone pavement stage. These communities are, in themselves, fairly stable, but the accelerated run-off has a serious deteriorative effect on the surrounding stable vegetation.

(vi) Sod Tussock Grasslands

This community has itself extended into areas where formerly bog and fen communities were dominant after alteration of the drainage pattern. The community has also undergone continued deterioration after burning and grazing in the form of a general thinning of the turf, the isolation of individual plants, the entry of unpalatable species such as *Spergularia rubra, Poranthera microphylla,* and *Asperula conferta,* and the invasion by heath species such as *Kunzea muelleri* and *Pimelea curviflora* var. *alpina.*

(vii) Sub-Alpine Woodland

The community was originally an open or closed woodland of fantastically twisted small trees near its upper limit and had, as the subordinate strata, a continuous grassy sward beneath with a discontinuous shrub stratum on drier lithosolic sites. The area is today one varying from the little altered open woodland, in the vicinity of the Kosciusko Chalet chairlift, to the ghost forest of the Dainers Gap area, created by the 1939 fire and prevented from regenerating by subsequent grazing.

The snowgum (*Eucalyptus niphophila*) is fire sensitive and a hot burn will kill even mature trees and may damage the lignotubers which, especially on young seedlings, are at or near the surface. Coppice-type regeneration from the lignotubers occurs. Additionally, if bare ground occurs as a result of the fire a dense stand of pyric shrub growth may occur (Costin et al 1959;

* Soil Conservation Service unpublished records, Cooma Office.

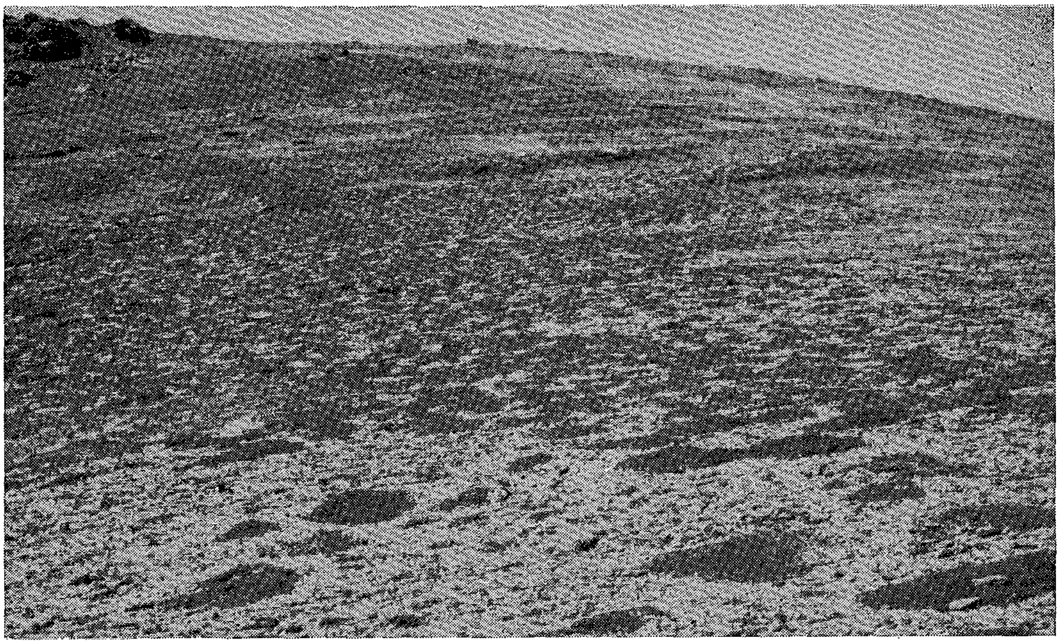

Figure 6—Fjaeldmark community of an open windswept saddle near Carruther's Peak showing the low open *Epacris-Veronica* community oriented to, and growing in, the path of the prevailing wind. Stable terraces may be seen in the background

Bryant, 1969; Hamilton and Bryant, unpublished). This growth includes *Bossiaea foliosa, Hovea longifolia, Phebalium ovatifolium, Prostanthera cuneata* and *Drimys vickeriana.* Where grazing has taken place the regeneration from seedling and lignotuber is avidly grazed by stock resulting in complete suppression of regeneration (Bryant, 1969).

Costin (1958) draws attention to the dramatic difference between the occasional seedling tree at Dainers Gap and the dense coppice growth on the adjacent water reserve subsequent to the 1939 fire.

Erosion

That the extent and severity of erosion damage visible today is of recent origin is apparent from the comments of early observers and from recent studies.

Helms (1896) comments upon the Carruther's Peak area—"A few bogs are found, but except in the most rugged places it is covered with a dense carpet of grass and herbage and with stunted shrubs on several slopes."

Again Helms (1896) states—"Nearly everywhere the ground is covered with a dense vegetation. The valleys, flats and slopes are covered with a compact sward of grass . . . At the highest elevations an almost alpine vegetation covers every available spot between the rocks. A few narrow stretches only do not produce the faintest particle of vegetation. This occurs in places where the snow accumulates in masses on the eastern slopes——"

Observations in 1927 (McLuckie and Petrie, 1927) confirm the recent origin of erosion—"These occasional patches (snowpatch areas) are the only area of granitic soil which, in the summertime, are not clothed with a dense carpet of vegetation".

These comments and observations can be compared with the photographic evidence presented in figures 7 to 10. Particularly, the erosion damage in the vicinity of Carruthers Peak and Mount Twynam should be noted. It is from this area that Costin et al (1959) estimated an erosion loss in the past 50 years of more than one million tons of soil from three square miles. It would appear therefore, that severe erosion damage post-dates the visits of Helms (1890, 1893, 1896) to the summit area, although it is fairly certain that vegetal deterioration had, by this time, commenced.

Studies by CSIRO* on buried peat beds on the sediment filled cirque above Blue Lake, using radioactive carbon techniques, have dated the uppermost bed as of approximately ninety years of age. This bed is buried beneath 6–12 inches of silt and granitic gravel derived from the severely eroded camping reserve above.

* A. B. Costin, CSIRO, pers. comm.

The current extent and severity of erosion damage has been mapped by Greenup (unpubl.) for the whole of the catchment of the Snowy River above the proposed Jindabyne storage, at a scale of 1:15,840. This survey covered the degree and extent of sheet, gully, track and streambank erosion, and the extent of snowdrift areas and associated areas which had become unstable. Those formerly eroded areas which had been stabilized and revegetated were mapped and have been adjusted to include areas treated since completion of the survey. That portion of the survey covering the Guthega Dam catchment, an area of 22,976 acres (35.9 square miles) is reproduced in figure 12. The detailed mapping criteria are given in table II whilst the areas in each individual sub-catchment so classified, are presented in table III. The location of the sub-catchments and the distribution of erosion is illustrated in figures 11 and 12.

TABLE II

EROSION CLASSIFICATION CRITERIA*

Symbol	Erosion Class	Percent Bare Area	Soil Loss—inches	Indicators
S	SHEET EROSION			
S_0	Negligible	10%	3″	
S_1	Slight..	25%	3″–6″	Pedestalled plants.
S_2	Moderate	26–75%	6″–9″	Pedestalled plants, exposed rocks.
G	GULLY EROSION			
G_0	Negligible			Rilling sparse less than 3″ deep.
G_1	Slight..		12″	
G_2	Moderate		12″–36″	
G_3	Severe		>36″	
T	TRACK EROSION			
T_1			1″–3″	Rilling due to water concentration.
T_2			4″–12″	
T_3			>12″	
SD	SNOW PATCH			Rilling and sheeting associated with margins of snowdrift area.

* After Greenup (unpubl.)

TABLE III

AREAS AFFECTED BY EROSION WITHIN GUTHEGA CATCHMENT AREA—ACRES

No.	Sub-Catchment name	Area of Catchment	Sheet Erosion				Area Treated‡	Snow Patches
			Nil	Slight	Moderate	Severe		
1*	Guthega River	2,030	1,910	105			2.0	15
2	Pounds Creek	2,000	1,010	770	80	15	2.0	125
3	Twynam Creek	970	475	350	95	10	..	40
4	Blue Lake Creek ..	1,720	627	650	200	143	102.9	100
5	Club Lake Creek ..	1,810	788	695	195	12	0.5	120
6	Upper Snowy River ..	1,485	510	770	80	5	7.0	120
7	Merrit's Creek	2,500	1,645	740	40	5	4.0	70
8	Charlotte Pass	1,765	1,645	120				
9	Wright's Creek	745	450	245	5	5		40
10	Trapyard Creek	840	430	395	15			
11	Bett's Creek	2,240	1,580	620	20	15		5
12	Upper Spencer's Creek ..	510	353	155	2			
13	Spencer's Creek	1,390	1,020	350				20
14	Illawong Lodge	535	465	70				
15	Blue Cow Creek	1,460	845	570	45			
	TOTALS..	22,000†	13,753	6,605	777	210	118.4	655

* Location of the sub-catchments is indicated in figure 11.
† Actual area is 22,976 acres based on S.M.A. survey.
‡ Not included in catchment area and erosion class figures.

From this information it is apparent that the catchments of the left-hand tributaries of the Snowy have suffered more extensive, and more severe damage than have the right-hand tributaries and that the erosion damage is predominantly sheet erosion. Damage from advanced (S2 and S3) sheet erosion in a concentrated form over appreciable areas is confined to the highest country of the region and is particularly noticeable along the saddles and upper slopes between the North Ramshead and Mount Tate. In many cases several acres are completely bare (e.g., Mount Twynam) where soil, to a depth of several feet, has been removed. In this section Greenup reports that deterioration of moderately and severely sheet eroded areas is continuing though possibly more slowly than has previously been the case. Gully erosion appears confined to the three situations of tracks, in and around damaged snowpatch outflow areas, and former camping reserves, while incipient gullying is present on severely sheet eroded areas.

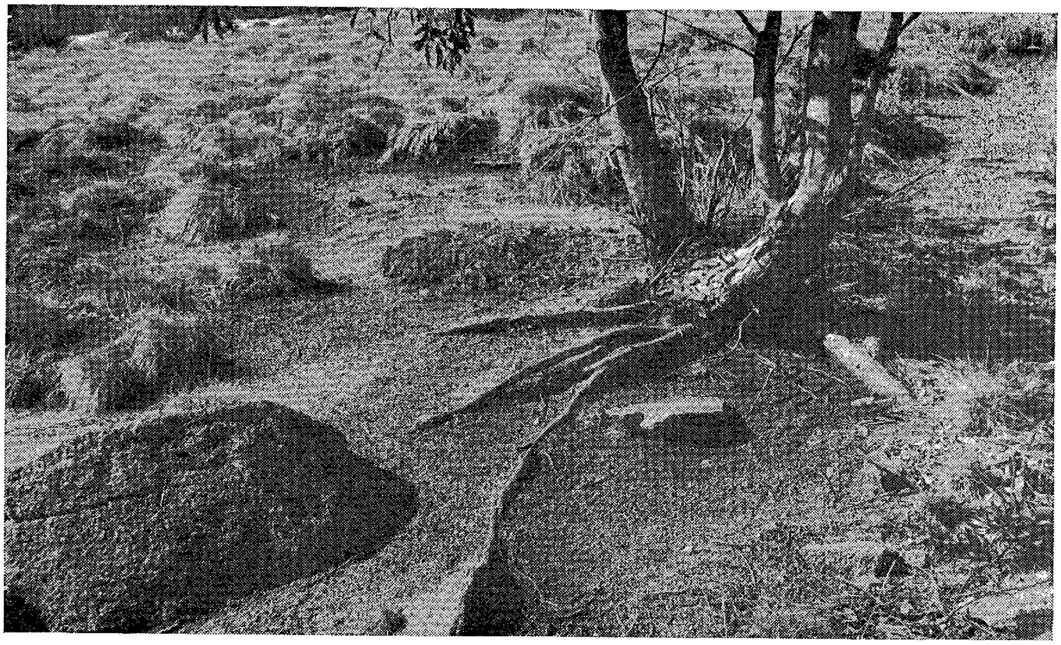

Figure 7—Sheet erosion in open sub-alpine woodland near Dainer's Gap. Note the exposure of roots and pedestalling of plants after soil removal by erosion

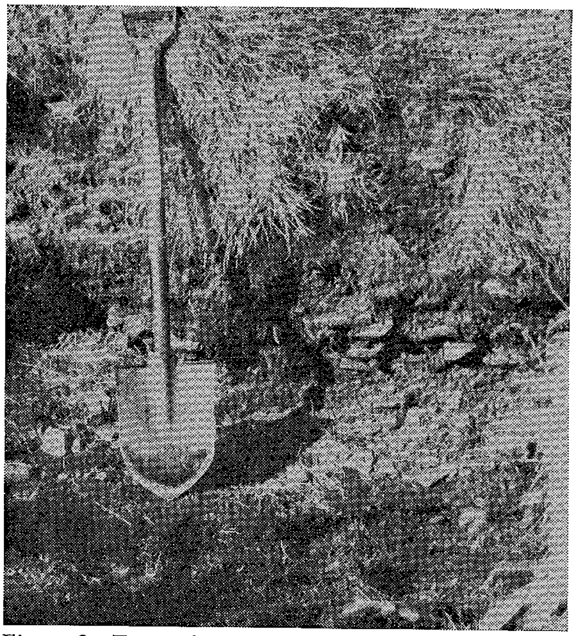

Figure 8—Truncation of a buried peat overlain by 30 inches of Alpine Humus soil by concentrated run-off from an erosion pavement area above. This occurred during the 1964–65 summer

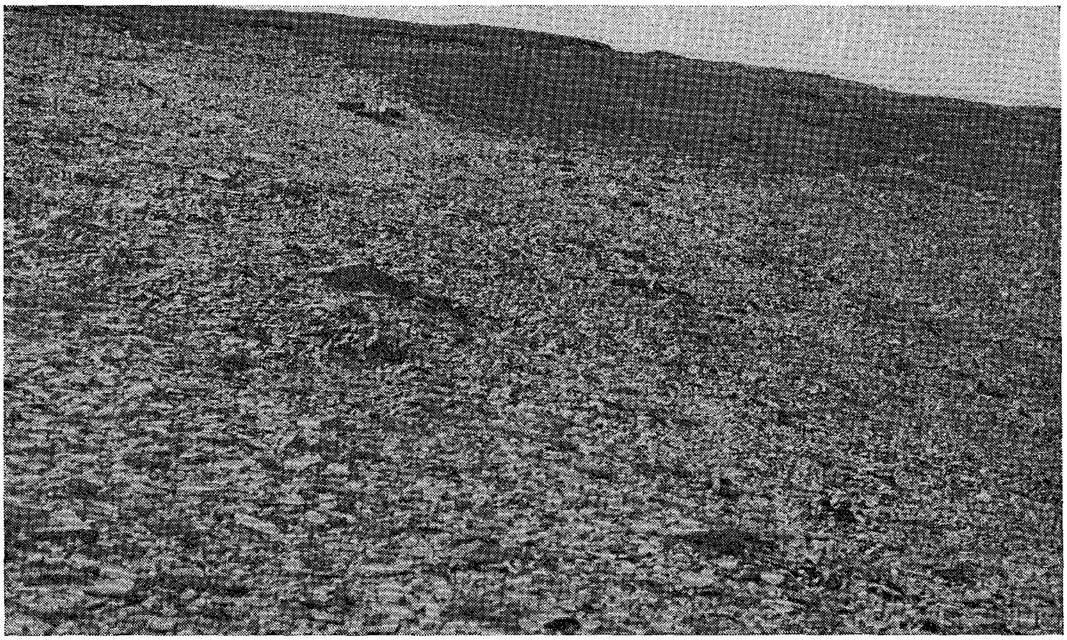

Figure 9—Severe sheet erosion on the upper slopes of Mount Twynam above Blue Lake at an altitude of 6,900 feet

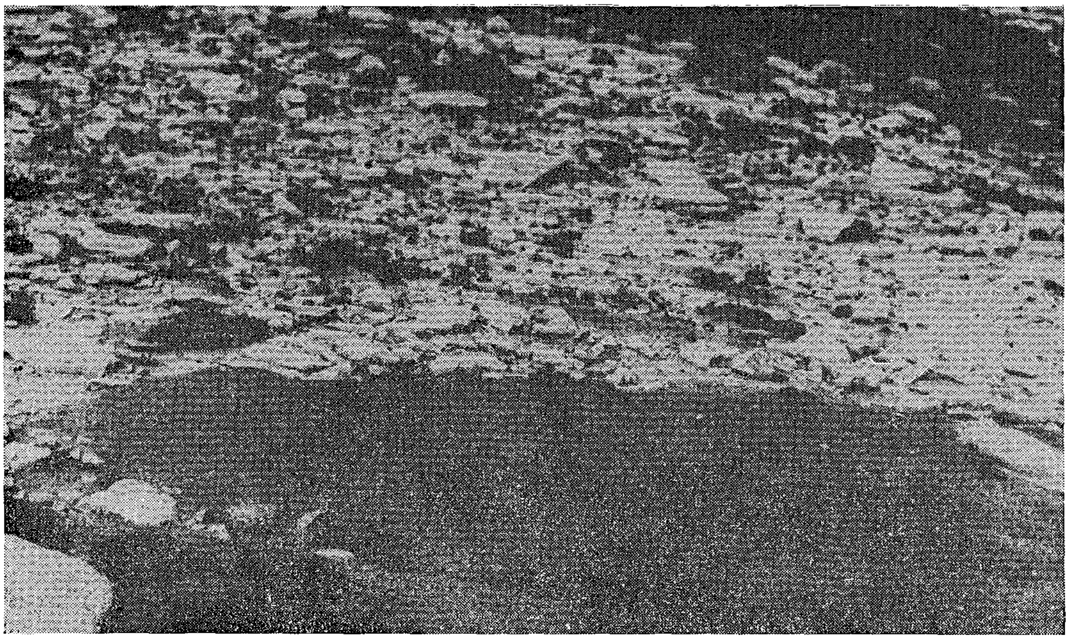

Figure 10—Sheet erosion advanced to "erosion pavement" with only remnants of soil and vegetation remaining on the upper slopes of Mount Twynam

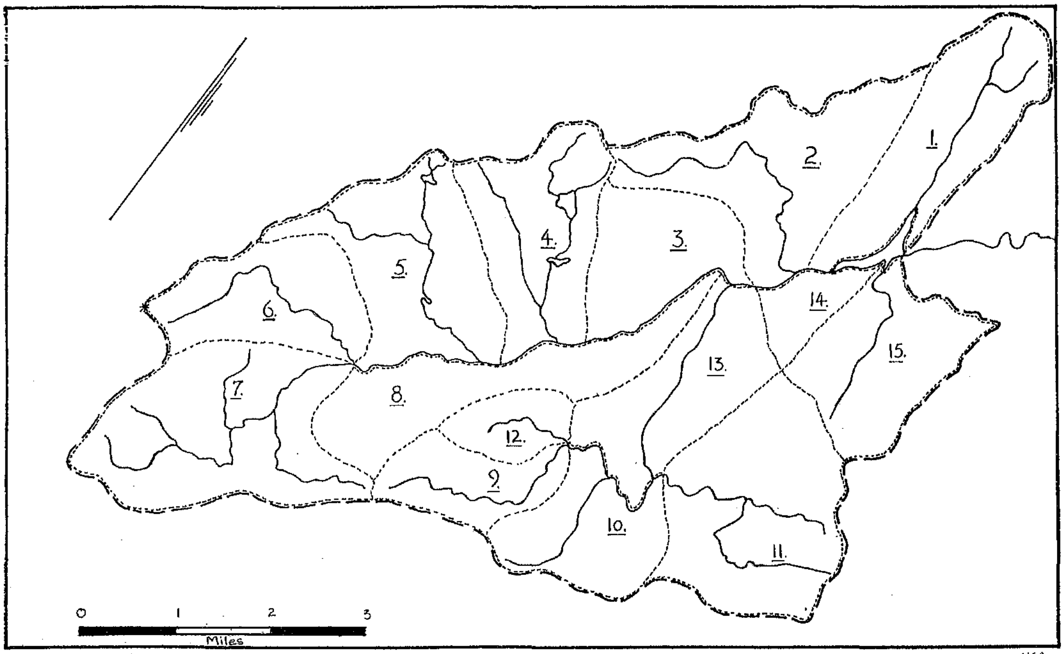

Figure 11—Guthega catchment area, showing location of sub-catchment areas. The numbers refer to the sub-catchments listed in table iii

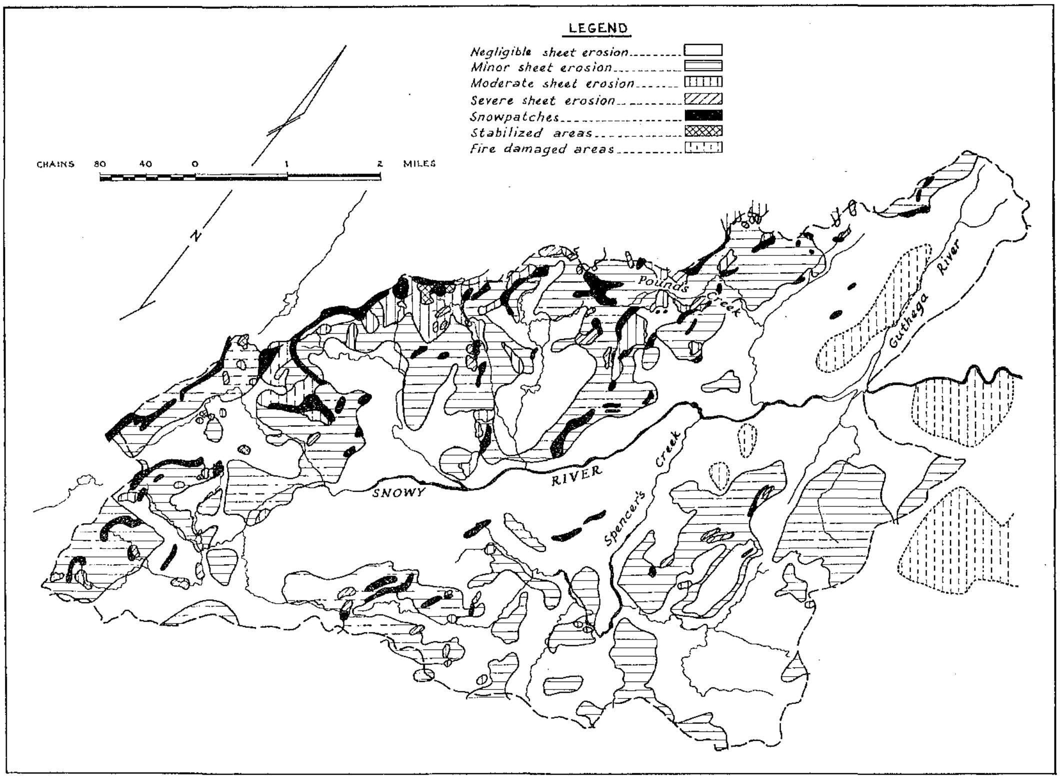

Figure 12—Erosion damage in Guthega catchment area. (After Greenup, unpubl.)

DISCUSSION

The relation between those areas most severely eroded and the interplay of the physical environment and former land use is most striking. Immediately apparent are the interrelations between the area of greatest climatic severity, the main range access track and stock route, and the apparent spread of erosion damage outwards and downwards from the upper slopes of the main range. Add to this the apparent recency of the damage, the increased regularity and intensity of grazing, initially under the influence of a series of drought years (1896–1903), the increased frequency of the use of fire as a management tool and the nett result is sheet erosion damage of a severity requiring "artificial remedial measures" over 987 acres of the most vulnerable and valuable country in the catchment area. Vegetation has been shown to have deteriorated over most of the summit area within the tenancy of European man.

The native and naturalized fauna have frequently been blamed for much of the erosion damage and vegetal deterioration. Firstly it should be noted that prior to the advent of European man the faunal component had been part of the stable ecosystem. If they now contribute to the degradation of soil and vegetation it is logical to state that the effects are "man-induced". In fact the wallabies, kangaroos, and wombats no more than marginally inhabit the roof top of our continent above the treeline.

Similarly much denudation has been blamed upon the case moth, yet long term quadrat studies* have shown damage to be localized and regeneration, in the absence of fire and grazing, to be rapid under the protective plant mulch.

The cosmopolitan pest, the European rabbit, introduced with the settlement of Australia by European man has assisted in the devastation of pastoral lands over much of Australia, but has had little effect in the Guthega catchment area. The combination of low palatability and low nutritive value of the snowgrass, extended snow cover and severity of winter temperatures has limited the upward spread to about the 5,000 feet contour.

In attempting to understand the causes of deterioration and erosion within the Snowy Mountains, a number of studies have been undertaken by CSIRO, this Service and other bodies vitally interested in the area.

Studies in soils and vegetation, undertaken by the author, on the Nungar High Plain, a large frost valley having an altitudinal range between 4,400 and 4,800 feet and typical of areas perhaps 1,000 feet higher, have proven illuminating.

Examination of seedling regeneration under mature snowgum woodland, of mean age 85 $\pm$ 15 years, showed dense regeneration during four years protection from grazing. The reintroduction of grazing initiated a progressive decrease in the numbers of surviving seedlings whose initial height had been less than three feet. Seedling trees taller than three feet escaped grazing.

Fire, either wild or controlled, destroyed saplings of at least 10 feet in height. Subsequent grazing effectively suppressed regrowth of survivors (Bryant, in press).

Similarly, at Long Plain in the Upper Murrumbidgee, a comparison over a fourteen-year period (Bryant, 1969) has resulted in a definite reduction in seedlings being established under grazing, whilst protection from grazing has resulted in a slight increase in numbers.

In studies of the effect of grazing and fire upon open and closed swards of snowgrass and various herbaceous and shrubby constituents (Bryant unpubl.), grazing has resulted in a decrease in the inter-tussock species on both closed and open swards. On closed swards grazing over seven seasons has resulted in the opening of the sward, whilst the effect of a fire of only moderate intensity reduced ground cover by an average of 30 per cent and regeneration under grazing after two years was only 60–70 per cent of that protected from grazing. On open swards a definite and persistent decline in ground cover under grazing has been established (Bryant unpubl.).

* Soil Conservation Service, Cooma (unpubl. data), "Case Moth Studies".

These results highlight the severe deteriorative effect grazing and fire combined can have, even within a four-year period, on this class of country. They support the contention that catchment efficiency for water yield and snow lease grazing management are incompatible, and that—"the alpine ecosystems are not well adapted to human interference and have mostly undergone deterioration due to the recent activities of European man" (Costin et al., 1959).

In conclusion the recent statement of a noted alpine ecologist is here worth quoting (Costin, 1967)—"Most of the plant communities have been modified by burning and summer grazing of sheep and cattle. Large areas of snowgum have been converted to dense pyric scrub, or replaced by disclimax grassland and heath. Grassland and herbfield communities generally have been opened up, and ground water areas partly dried out following the development of creeks and gullies through them. Slight to moderate soil deterioration is widespread. These conditions can be extended or reduced, depending on the degree of control of fires and grazing".

To successfully reclaim these deteriorated and eroded areas, and others in a similar condition within the Snowy Mountains, detailed investigation and reclamation programmes are currently in operation.

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