SOIL CONSERVATION SERVICE OF NEW SOUTH WALES

THE SUMMIT AREA WORKS PROGRAMME

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Very often in the past and even up to the present, the Soil Conservation Service has been given jobs to do, to repair, or mitigate the often disastrous effects of man's mismanagement of the environment. Results are often required quickly, while the areas themselves rarely provide easy conditions for rehabilitation.

One responsibility was the repair of erosion occurring in the Kosciusko National Park. Specifically, one of the main areas of concern was the alpine area. This is the highest tract of land in Australia, subject to relatively unfamiliar climatic conditions and having unfamiliar soils and vegetation. Man had used this land for grazing during summer months for over one hundred years. Fire was used as "pasture improvement" technique. In combination or alone, fire and grazing eventually denuded the soil from large areas in the alpine area.

The Snowy Mountains Scheme was developed to make use of these high mountains as catchment areas. Water yield for electricity generation and eventually irrigation became the prime concern. The attainment of high water quality lead to the exclusion of grazing and attendent management techniques. The repair and mitigation of erosion in the alpine areas was then necessary to maintain water quality and yield.

The Summit Area Works Programme commenced spasmodically from 1956/57 and then with concentrated attempts in 1960. It has continued each year to the present time. The efforts of the past decade and a half are finally nearing the desired goal. The time taken to repair a relatively small area seems long, but the total working time available has been (and still is) minimal. The main problems in the alpine area are the climate and the physical environment.

CLIMATE

The alpine area is the tract of land above the treeline. For practical purposes this can be defined as the area in which the average temperature of the hottest month(February) is less than 10^{o}C, and is above an altitude of 1 800 metres. The fact that it is above the treeline is an indication of the prevailing climatic conditions.

Meteorological records for the area are sparse. The Service maintains a small meteorological station for a few summer months each year, but more long term year-long records are only available in the sub-alpine zone. Some other fragmentary records are available.

Precipitation is high. Estimates from Snowy Mountains Authority storage gauges give average of over 3000 mm at Mt. Twynam and 2500 mm at Lake Cootapatanda (below the Summit of Mt. Kosciusko). Precipitation varies down to about 2200 mm at the treeline. There is a winter-spring peak and a summer-autumn minimum. Snow cover persists for at least four months each year. Drifts may persist all year. Snow cover is advantageous at high elevations, because it provides an insulating blanket and thus protection against erosive forces.

Rainfall intensities are not high when compared with coastal areas. Precipitation can therefore be relegated to a less important role when considering its erosive potential. However, erosion is caused by storms and hail during summer months, but only on disturbed areas.

Wind velocities can reach 150 km/h in the alpine area. Velocities of 75 km/h for long periods are common. If soil areas are bared of vegetation in exposed situations, then topsoil can literally be blown away. As well, gravel particles can then be blasted against living vegetation, gradually smothering it. Gravel particles of up to 15 mm in diameter can be moved. A relatively small area or blowout can be enlarged considerably in the direction of the prevailing wind.

Frosts occur during all months of the year. There is no frost-free period in the alpine area. Freeze-thaw cycles assume an importance during the snow-free period. Particularly in spring and autumn, needle ice can develop in the soil, causing frost heave. This is a major erosive force in areas bared of vegetation. During the freeze process, ice needles form in the soil, and can lift even large rocks, as well as soil particles, 5 cm or more. During the thaw, rock and soil particles are dropped back onto the surface in a loose, apparently self-mulching condition. These loose particles are then able to be washed and/or blown. The conditions for frost heave are ideal in the alpine area, with adequate moisture generally available, and frequent diurnal surface temperature variations above and below freezing. On sloping areas (e.g. cut road batters) frost heave is particularly severe in its effects, moving large quantities of material downslope.

Soil temperature records in the alpine area reveal a greater diurnal variation under bare ground than under vegetation. The risk of needle ice formation and frost heave is therefore greatest in bared areas.

Temperatures during summer months are generally mild. Recordings of maximums of 30°C are not common, but long periods of maximum temperatures above 20°C can occur.

The climate of the alpine area therefore limits plant growth to the December, January, February and March period. Soil moisture is adequate during this period. However droughts can occur. The soil tends to dry out very quickly at these high altitudes, and killing frosts can occur at any time during the growing period.

The use of a mulch in any revegetation works is therefore essential. When suitably tacked down, the mulch protects seed and fertilizer from the erosive forces of the alpine climate. It also retains soil moisture. However it can also reduce soil temperature. Trials during the works programme indicated that mulch was inhibiting plant germination and growth during the January-February period. This was because soil temperatures were being kept too low. As a result, low mulch rates during this period are used to encourage higher soil temperatures.

Higher mulch rates early and late in the season, while keeping soil temperatures low, are essential to counteract the effects of freeze-thaw cycles, which are more likely at these times.

(Some climatic details are given in Appendix III).

Soil freezing is generally unknown in the alpine area, due to the protection of the snow cover in winter. However, recent evidence suggests that in relatively snow-free years, some permanently wet areas can be frozen to depth, resulting in cracking. The exposure of columns of soil which results from the cracking is claimed to lead to loss of soil in these areas by erosion.

GEOLOGY AND PHYSIOGRAPHY

The alpine area is a high plateau extending north and south. It contains the main divide of eastern Australia. The plateau is derived from an oligocene-miocene peneplain which has been uplifted, lastly by the Kosciusko uplift. The plateau rises, to a height of over 2000 metres, with Mt. Kosciusko (2228 m) the highest point. Practically all of the works area is over 2000 metres. The highest points in the works area are Mount Townsend (2196 m) and Carruthers Peak (2145 m). The Soil Conservation Service Hut is at a height of 2040 metres, and is the highest "accommodation" available in Australia.

Topographically, the alpine area is suppressed, with relief rarely exceeding 200 metres. Valleys are U-shaped and broad. Streams are entrenched and meandering, generally originating at snowdrift sources.

The works area is situated along the main divide, and broadly speaking, is associated with snowdrift areas. These indicate sheltered areas, which were favourable sheep camps, and therefore heavily utilized. Much of the erosion which occurred was associated with the steep upper edges of snowdrifts, and their more gently lower slopes. Most of the areas worked over, were therefore steep, requiring careful manoeuvering of vehicles, practically all hand work. Where the erosion extended up onto the divide itself, use was made of mechanization, particularly during the early 1960's.

During the 1974/75 works, a particularly steep snowdrift areas was part of the area reclaimed. Access here was most difficult, as the drift and associated erosion extended about 1000 metres down a steep spur practically from the top of Mount Twynam.

Geologically, most of the alpine area, consists of gneiasic granites. These coarse-grained granites originated in the Silurian period. They are generally hard and have resisted erosion over geologic time. They are responsible for the existence of the highest land in Australia. A narrow band of metasediments runs through the alpine area. The phyllites, schists and quartzites of this band run in a north-northwesterly direction from the Etheride range, across Carruthers Peak, and to the west of Mt. Twynam. This belt is at its widest near Club Lake, at 2 kilometres in width.

The weathering of these rocks is predominately physical. A siliceous easily erodible subsoil develops in the granites. The rock types are also acid which contributes to the acidity and infertility of soils developed on them.

The Pleistocene glaciation was restricted on the mainland of Australia to an area within the Kosciusko National Park. Browne recognizes an area of 1100 square kilometres as showing evidence of glaciation. Three phases of glaciation occurred:

Nature	Features
1. Ice Cap Glacier	1. Ice Polishing 2. Erratics
2. Valley Glaciers	1. Stepped Valleys 2. Terminal Moraines 3. Recessional Moraines 4. Truncated Spurs 5. Ice polished and striated rock surface 6. Cirques
3. Cirque Glaciation	1. Re-occupation of Cirques 2. Terminal Moraines 3. Tarns

Galloway contends there was an absence of widespread glaciation. Most of the area was subject to periglacial action only. Further, there was only one glacial period, which extended over an area of 50 square kilometres. The glaciers retreated in two stages.

Regardless of which theory is correct, most of the alpine area was subject to glaciation. Much of the eroded area is situated at the head of cirquès formed during glaciation.

SOILS

The soils occurring in the alpine area are distributed according to exposure and water table relations. On free draining slopes the main soil type is the Alpine Humus Soil. This soil occupies most of the area. The soils in which the water table is present are generally peat soils. Some areas of alluvial soils occur in flow lines, and below snow drifts. Lithosols occur on exposed ridges and saddles.

The Alpine Humus Soils (Northcote coding Um7.11) are formed on well drained, moist slopes. Over 90% of the works area was, at one stage, covered by a mantle of this soil type. The surface layers are dark coloured, and high in organic matter. Texture is a loam or clay-loam. Due to the high precipitation and acidic nature of the country rock, these soils are very acid, and consequently infertile. They are base unsaturated, due to this acidity and the amount of leaching which occurs. The A horizons are formed largely by the build-up of organic matter, the rock type playing a minimal role in the soil formation process. Alpine Humus soils develop independently of parent material.

Winter snow and the high rainfall maintain cold and wet conditions for many months of the year, allowing an accumulation of organic matter in the diffuse organo-mineral upper horizon. Decomposition of litter proceeds rapidly once soil temperature rises in summer and autumn. There is an associated strong growth of vegetation, which helps to maintain the high amount of organic matter. The quick turnover of nutrients via humified organic matter enables this growth each summer.

Normally these soils support a closed stand of vegetation. Further protection is provided by a layer of litter and humifying organic matter. If this closed vegetation sward is killed, as can happen when case moths cause the death of snowgrass, regeneration can occur through the still attached dead litter. However, if the sward is opened by grazing, fire, trampling and the soil surface bared, accelerated erosion can proceed with wind, rain and frost heave removing the organo-mineral horizon.

The lower A/C horizon derived from physical weathering of the granitic or metasedimentary rock, is then exposed. This gravelly pavement resembles the lithosol soils developed in more exposed situations. The subsoil exposed is acid and infertile. Soil colloids are low and there is practically no organic matter. As well, they are highly erodible. They present a harsh environment on which to re-establish vegetation. Native colonizers are few, and rarely provide complete cover.

It was immediately realized that a mulch would be essential if these areas were to carry a complete sward. Exotic species, quicker growing than the natives, were also required to give a temporary cover while the natives slowly developed. And fertility would need to be improved to assist in the early and subsequent growth stages of both the exotic and colonizing natives.

Mulching techniques, the use of the correct seed type and fertilizer were experimented with from the start of the works programme, and have culminated in the use of the bitumen/straw technique in use at the present. As well suitable seed and the appropriate fertilizer are used.

Some 5% of the alpine area is covered by peat soils (Northcote O, acid). They are the result of accumulation of peat and are acid in reaction due to the high precipitation and drainage from acid rock types. Peat soils are confined to permanently wet areas. They are low in base status, and are very damage prone. Their importance lies in their role in catchment efficiency. They can hold large amounts of water, and release excess gradually. Once damaged, their regeneration depends on the regeneration of the peat. Small gully checks, which help to trap silt and raise the water table encourage peat formation.

Lithosolic soils (Northcote Um or Uc) are generally confined to exposed situations and ridge tops. They carry only a partial vegetation cover (feldmark) due to this exposure. Wherever possible, access tracks were located through these areas, in order to reduce to a minimum the amount of disturbance. Solifluction terraces, a mass movement feature, develop lithsolic soils and feldmark type vegetation. The terraces consist of flat area, or "tread", and a relatively protected steeper "risers". It is thought that erosion products from the tread accumulate in the risers and in the relatively depressed sites between terraces called the "recess". These erosion products are organo-mineral in nature and are deposited on top of the stony pavement (or lithsol). Herbs and grasses can then colonize in the risers and recess, building up the surface horizons. It has been theorized that the alpine humus soils over most of the alpine tract were formed in this manner. The development of the alpine humus soil by this process can occur in 40 to 50 years.

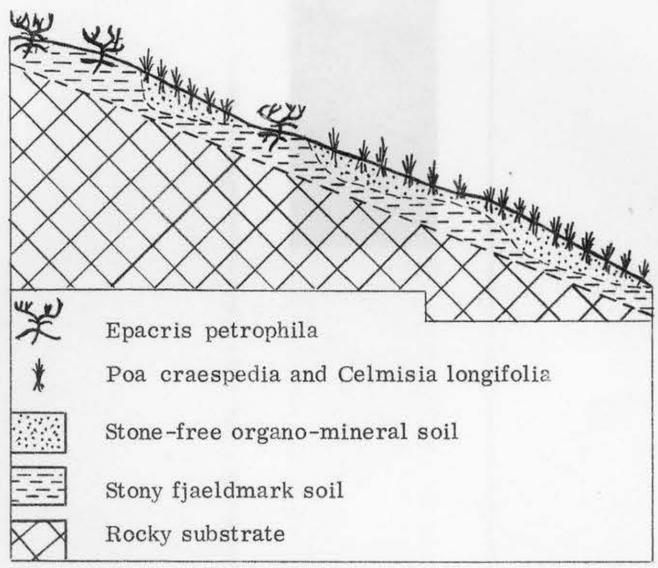

Figure 1. Slope cross-section. Development of Alpine Herb Rich Grassland and Alpine Humus Soil from solifluction terraces and feldmark vegetation. (After A.B. Costin et al. 1969).

VEGETATION

The vegetation communities occurring in the alpine area are distributed according to soil type and exposure. It was the breakdown and opening up of the vegetation sward which lead to the severe erosion which occurred. To achieve long term stability it was necessary to encourage some of the communities to re-establish by slowly replacing the exotics used in initial stabilisation. In many cases this has occurred, and native vegetation has re-established. Succession will probably occur as organic matter builds up and some of the original vegetation communities will re-appear.

Herb-Rich Grassland (Poa-Celmisia). This is the most common community in the alpine area. It is dominated by snowgrass (Poa spp.) and snow daisy Celmisia asteliifolis, syn. longifolia, with other herbs such as billy buttons (Craspedia spp.) also being common. Snowgrass and snow daisy may undergo cyclical changes with the herbs replacing grasses as a result of disturbances. Most species in this community are poor colonizers due to their rhizomatous habits, needing accumulations of topsoil to grow and survive. During works programmes, grasses and herb species are often hand planted around the shaped edges of erosion pavements. This helps to provide stable batters on the edges of eroded areas.

Tussock Grassland (Chionochica sp.). This is the giant wallaby grass community. It is found mainly on the steep western slopes of the main range, where it occurs in more sheltered areas. Burning and grazing have probably reduced the extent of this community. However, it appears to be on the increase, with small pockets re-appearing in sheltered sites on the eastern side of the range. The regeneration of giant wallaby grass is an indication of rehabilitation in the alpine area, at least in those areas of vegetation communities that are not completely altered.

Shrub Heath Communities. These communities occur mainly on the western slopes of the alpine area, although they also occur frequently on the more gently sloping eastern side. They are closed communities.

The tall, dry shrub (Phebalium oratifolium) is the tallest growing of the shrub communities commonly reaching 50 cm in height. It extends below the treeline.

The tall wet shrub (Paeckea-Richea) community occurs with areas of bog. They are found mainly on the eastern side of the divide. Shrub height varies between 25 to 50 cm.

The mat shrub (Podocarpus) community occurs only in sheltered sites among large rocks. The community forms mats of vegetation over the boulders.

Low shrub (Kunzea) communities reach heights of only 10 to 25 cm. They occur on spurs and ridges, generally with northerly and easterly aspects. These are more exposed sites than those occupied by tall shrub communities. Areas of erosion north of Mount Twynam are often associated with low shrub.

Dwarf shrub (Epacris spp.) communities occupy more exposed sites than low shrub. The plants reach heights of between 5 and 10 centimetres. The community occurs on ridge tops exposed to the west. Soil is generally lithosolic, compared with the mainly alpine humus soil of most of the other shrub communities.

Feldmark communities consist of open dwarf shrubs and stunted herb and grass species. The windswept feldmark (Epacris-Veronica sp.) occurs on very exposed cols and ridges, where wind is funnelled and concentrated. Soils are lithosolic. The cold feldmark (Copresma sp.) occurs above the semi-permanent snow drift areas. Herb species which occur in feldmarks may be found in colonizing situations.

Short, wet herbfield communities occur in wet areas generally below and fed by, snowdrifts. They can be open, as in the Marsh marigold (*Caltha*) community, or closed, as in the alpine tuft rush (*Crecholus*) and the alpine plantain (*Plantago*) communities. A number of potential colonizing species come from short herbfields, mainly in treated areas. A combination of mulch and fertilizer probably provide conditions similar to those of the native community. However, these colonizers do not perform as well during dry spells. This is to be expected, as the natural habitat is usually wet.

The species from feldmark and short herbfield are often transplanted into bare erosion pavements in order to encourage colonization. At one stage thousands of peat pots were similarly placed, but direct transplantations in the field have proved easier and more effective.

Bog communities (*Sphagnum*-*Hichea*-*Astelia*) are permanently wet, and are important for their role in the hydrology of the mountains. They are better developed in sub-alpine areas. They occur where spring water emerges, or where drainage is impeded.

Fens (*Carex* spp.) are dominated by sedges. They occur in sites which receive water from springs, or periodically inundated areas along creeks. Soils are alluvial and relatively deep. Areas of fen act as silt fans and silt traps.

The works programme has particularly encouraged the spread of a native vegetation community similar to the cold feldmark. Native exotics, mulch and fertilizer have helped build up organic matter. At first these "new" communities are open, but gradually become more closed and stable. Soil build-up rate will govern just how quickly these communities achieve full natural stability. The more level the site, the quicker the regeneration.

Seed of native species has proved difficult to harvest, and collection of large amounts is not feasible. Some of the natives have proved difficult to germinate and grow, even under glass-house conditions. However, natural regeneration can definitely be encouraged by providing protection, by means of the exotic grasses and legumes, and the mulch. Initial growth and performance of exotics is usually good, but persistence can be erratic. Low natural fertility also requires repeated fertilization of the exotics, while the natives, once established, are better adapted to these fertility conditions.

DEVELOPMENT OF THE SUMMIT AREA WORKS PROGRAMME

A brief outline of the programme is given in Appendix I. It was mooted to start a season earlier, but for various reasons, the 1956/57 season saw the beginnings of the first largely experimental programme on Carruthers Peak. The Snowy Mountains Authority provided the labour force, and the Soil Conservation Service the supervision. This initial work force was housed in tents. The tents blew down, were re-erected, and then during a storm, the camp was completely destroyed (presumably the mountains had had enough of human interference.) The works programme came to an abrupt halt, and the pack horses were put to pasture for another year.

Hand work in the early years was laborious and time-consuming. Consequently only small areas received treatment. It is interesting to note that the bitumen/straw technique was first tried experimentally during this first programme. Apparently it was not very successful. This could have been due to the type of hay used - cereal hay, which would have provided little protective covering. This was changed to meadow hay (usually first cut lucerne) in later years. Hand-built banks of rock and soil, drains and snow fences were features of the early work. Mulch was generally tacked down with forms of netting, either metal (fencing wire), synthetic or organic in origin. Seed rates were high, and many species were used, including cover crops.

The period 1957 to 1960 was spent patching up small areas of erosion at various places in the alpine area. The provision of permanent accommodation at the Carruthers site was not possible until the 1960/61 season. A helicopter was used to ferry in materials. The actual work was mainly by hand, using hay and netting.

The following year saw a D4 dozer being used for site preparation. Areas to be treated were first levelled and smoothed and if necessary, banked. After seeding and fertilizing and raking in the areas were mulched and netted. Tillering machinery was used if possible to cultivate before sowing. These were difficult to operate and generally unsuccessful.

Helicopters were used each year till the 1964/65 season. They transported most of the materials. Pack horses ferried in supplies for the work force. During the 1965/66 season the Haflinger vehicle was used for the first time. It ferried in all equipment and supplies and proved an excellent, light weight vehicle. However, there were still only relatively small areas being reclaimed each year.

In the 1967/68 season, the Soil Conservation Service recruited its own labiur for the first time. This brought an immediate improvement to the quality and quantity of the work performed. Gradually an experienced core of men was established with generally young men (students) being recruited when weather conditions became suitable.

D4 dozers had been used over most years up to the 1969/70 season. They have constructed banks, ripped, levelled and filled. Nowadays, their function is to clear snowdrifts from tracks, or to aid in track construction by removing boulders (but not by cuts and fills).

The recommended fertilizer mix was first used during the 1967/68 works season. Previously high analysis MPK fertilizers had been used. The mountains mix the result of pot and field trials, consists of high analysis fertilizers, lime, borax, and epsom salts, at a total rate of 1023 kg/ha.

12:22:0	125 kg/ha
11:15:9	250 kg/ha
Lime	625 kg/ha
Borax	6 kg/ha
Epsom Salts	17 kg/ha

From the 1970/71 season till the present the main techniques used has been mulching and tacking down with a light spray of anionic bitumen. There is a minimal amount of site preparation, with actively eroding edges being "battered" and transplantation of natives, if available in the area. Although the seeding, fertilizing and mulching is still done by hand, progress is relatively rapid.

Refertilization has been carried out each year. Some areas have been refertilized up to six times. This has also been done by hand. If necessary, areas have been reseeded. Aerial top-dressing was tried in the 1971/72 season. Results were erratic, and all refertilization is now done by hand.

Most restabilisation techniques used have been successful to some extent. Some were laborious and time-consuming. The use of galvanized wire netting proved to be an ecological disaster. This netting is pulled up wherever it is found, and each area receives a complete re-treatment. Zinc toxicity occurred, due to the build-up of zinc in the soil as the netting disintergrated. The use of wire netting (black wire), was successful while the mulch remained and/or provided a cover developed. Where treatment was unsuccessful, erosion can still occur, under the wire.

The use of banks in the alpine area was perhaps questionable in some cases. Their good point is, of course, water control and this was the reason for their construction. In certain areas, however, they cause concentration of large volumes of water, which kills the native vegetation. More careful location of discharge points may have prevented this. Banks are no longer used, but a criticism of mulching an area and not controlling water flow is that there is still a large run-off from erosion pavements, whether treated or not. Again, flooding of native vegetation below the eroded area can kill it, and then initiate further erosion downslope. Alpine humus soils are freely draining and the vegetation not adapted to short term periodic waterlogging that can occur. Treated erosion pavements at least slow down water flow to some extent because of the vegetal development which occurs. It has been estimated that to prevent erosion, 100% ground cover is required, at a rate of 4 tonnes/hectares.

The seed mix used in the programme has undergone dramatic changes. Large quantities of seed, of many species, were used. Success has been variable. The seed mix in use at the present is a minimal number of species. All are imported from New Zealand, where they are grown in high altitude, cold areas. All legume seed is multi-step inoculated, with seed being prepared on a weakly basis.

The use of jute mesh in drains/waterways is an established technique in the alpine area. The "gully" is shaped, seeded and fertilized, lined with jute mesh, and then sprayed with bitumen. A high rate of success in stabilising flowlines can be achieved using this technique.

Access has always been a problem in the mountains, as is evidenced by the variety of "commuter" systems used, from Shank's Mare to helicopters. The use of pack horses and helicopters in the early years meant limited amounts of equipment and supplies were brought in. The small but sturdy Haflingers increased efficiency. As larger areas were treated these vehicles literally wore out, and were replaced by larger four-wheel drive vehicles to keep up with the pace of reclamation. Consequently the tracks were forced to carry increased numbers of trips and heavier vehicles.

Originally the Charlotte's Pass to Blue Lake Bridle track was deeply gullied and causing excess run-off. This was stabilized and if necessary reconstructed. Other tracks were also carefully sited and constructed. Spoon drains are a feature of the tracks - as anyone who has been to Carruthers will tell you. There has been little improvement to the running surface, which means it is a combination of alpine humus soil and erodible subsoil. Wet weather and traffic are incompatible.

A significant proportion of the working time is spent maintaining the track. The spoon drains are continually "topped up", road drains desilted if necessary, culverts checked, and the road surface is reshaped and/or replaced. One such track was recently retired. The benefit of the continual maintenance it received enabled it to be stabilised quickly and effectively.

Tracks are repaired and stabilized as each works area is completed.

The works programme has always been supported by a series of investigations. Agronomic considerations have always been foremost. Species trials have been virtually continuous over the years. Recommendations from these assessments have resulted in the use of the species of grasses and legumes sown during the current works. Trifolium ambiguum, a legume adapted to high altitude areas and now being developed elsewhere as a potential pasture species, was tried during the investigations programme. It appeared very promising, but lack of a seed source has hindered its use to any large extent. Glasshouse and field trials enabled nutrient deficiencies to be defined for alpine humus soils. Recommendations concerning minimum rates were made. Materials and techniques have been varied over the years in a series of continuous practical trials. The native species have been assessed as to their potential role in the programme, and are being used wherever possible. Trials to determine rates of regeneration are current.

CONCLUSION

This brief condensation of the works of 15 years gives an indication of the problems encountered, and the general dynamic nature of the Summit Area Works Programme. Some 170 hectares of erosion have been treated in the highest perhaps, most important catchment area in Australia. The latest re-assessment reveals there are still actively eroding areas, and programmes, are being planned to arrest them. The ultimate revegetation and stabilization will be a result of the combined results and experience of past programmes.

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APPENDIX I

SUMMIT AREA WORKS PROGRAMME

SUMMARY OF AREAS TREATED, METHODS

Year (Season)	Area Treated Initially (Location)	Acreage Initially Treated	Methods Used (other than sowing and fertilis-ation)
1956/57	Carruthers	2 acres (.8 ha)	Largely experimental. Hand work. banks; stone retaining walls; bitumen and straw mulch; wire netting and mulch; stone pitched drains; rubble drains; snow fences. "Tent City".
1957/58	Rawson Pass Albina Lake	$2\frac{1}{2}$ acres (1 ha)	Bitumen and Straw Mulch; wire netting and straw mulch. Absorp-tion Banks and walls.
1958/59	Granite Peaks		Preliminary work only.
1959/60	Granite Peaks Consett Stephen Pass	7 acres (2.8 ha)	Straw Mulch
1960/61	North Ramshead Albina Track Carruthers	2 acres 4 acres 3 acres Total 9 acres (3.6 ha)	Rubble walls, drains. Hay and netting. All hand work. D4 dozer on Albina Track. Helicopter used. Hut erected.
1961/62	Carruthers Twynam	8 acres (3.2 ha)	Straw mulch; netting; earth on rock walls; paved waterways; D4 dozer site preparation and bank-ing. Helicopter used.
1962/63	Rawsons Pass Carruthers Twynam	$1\frac{1}{2}$ acres (0.6 ha) 6 acres (2.4 ha)	Smooth, fill; mulch, netting. Helicopter used.
1963/64	Carruthers	10.5 acres (4.3 ha)	Smoothing and filling etc. mulch and netting. Tiller. D4 dozer. Helicopter.
1964/65	Carruthers	4 acres (1.6 ha)	Smooth and fill etc.; banks; mulch and netting. D4 dozer on tracks and works. Helicopter used.
1965/66	Carruthers	$5\frac{1}{2}$ acres (2.2 ha)	Smooth, level fill, etc.; banks; hay and netting. Haflinger vehicle used for first time. D4 dozer.
1966/67	Carruthers	7 acres (2.8 ha)	Smooth, level, fill etc; banks; mulch and netting; mulch and bitumen. D4 dozer; tillers, still a lot of hand work (bank-ing etc.).

APPENDIX I contd.

Year (Season)	Area Treated Initially (Located)	Acreage Initially Treated	Methods Used (other than sowing and fertilis-ation)
1967/68	Blue Lake Track Carruthers Twynam Track	9½ acres (3.7 ha)	Level; cultivate; mulch; bitumen wire netting. D4 used; own lab or recruited; first year recommended fertilizer mix used.
1968/69	Twynam	10 acres (4 ha)	Absorption banks. Hay and bitumen more widely used. Netting. Some use of natives (seed and mulch). D4 dozer.
1969/70	Carruthers Twynam	36.5 acres (14.8 ha)	Ripped; mulch and bitumen. Some natives used. D4 dozer, Mulch rates varied.
1970/71	Bulls Peaks Twynam	25 acres 50 acres Total 75 acres (30 ha)	Mulch and bitumen. Banks and ripping at Bulls Peaks, no mulch.
1971/72	Twynam Bulls Peaks	75 acres 20 acres Total 95 acres (38 ha)	Mulch and bitumen. Jute mesh and bitumen in drains. Helicopter used for short time.
1972/73	Carruthers Twynam	35 acres (14 ha)	Bitumen and mulch; jute mesh and bitumen in drains. All seed from New Zealand. Removal of galvanized wire.
1973/74	Carruthers Twynam	67 acres (27 ha)	Bitumen and mulch.
1974/75	Twynam	30 acres (12 ha)	Bitumen and mulch.

Total Area Treated: 170 hectares (420 acres)

APPENDIX II

SUMMIT AREA WORKS PROGRAMME

YEARLY EXPENDITURES

1956/57	$ 3,300.20
1957/58	7,957.20
1958/59	Nil
1959/60	9,007.60
1960/61	33,400.00
1961/62	18,951.70
1962/63	19,282.64
1963/64	23,025.20
1964/65	18,690.08
1965/66	19,058.29
1966/67	26,591.53
1967/68	27,600.00
1968/69	27,877.11
1969/70	29,190.28
1970/71	27,792.32
1971/72	29,485.00
1972/73	35,823.00
1973/74	44,600.00
1974/75	44,600.00
TOTAL	$446,238.15
TOTAL AREA	170 hectares (420 acres)
COST PER HECTARE	$2,625 (or $1,062 per acre)

NOTE: Figures for some years are approximate only. These figures do not take into account those areas previously treated that will still require maintenance. Cost per hectare will be slightly higher.