Identification of values

The values assessed by the Independent Scientific Committee (ISC) related to the natural and cultural heritage phenomena of the park and its social, recreational and economic aspects. These values are: earth sciences, soils, karst, aquatic, flora, fauna, landscape, fire, cultural and social heritage, tourism and recreation, economic valuation and the economic value of tourism.

The information for identifying values was drawn from existing documents and data sources; given the time and resources available, the ISC did not attempt an exhaustive compilation of all of the knowledge about the park’s values, and for the same reason no new research was conducted.

Criteria used for assessing values

Condition

The criteria used for assessing condition were derived from existing recognised reporting frameworks or structures. The assessments include concepts of dependency, fragility, isolation and dispersion. In describing condition, some reference point or desired outcome is typically ascribed; for example, in vegetation assessments, pre-1750 extant is commonly used. However, it was considered inappropriate and outside the scope of the ISC to use such an approach for economic and social values; thus, in the chapters concerning these values, assessments of condition are not validated by describing reference conditions.

Trend in condition

Description of trend in condition is appropriate for some values but not others; where possible it has been measured within known timescales and referenced to the initial condition statement. The following measures were used as a guide:

- improving generally;
- improvement slight or patchy;
- no net change;
- declining in some places; and
- widespread or large declines.

Significance

Statements of significance have traditionally been used in natural and cultural heritage assessment. For this report, the concept has been extended to the recreational, social and economic values of the park to provide a comprehensive platform for analysis. Statements of significance were completed for each attribute of Kosciuszko National Park’s values. The legal status (if any) formed part of this evaluation. The significance of the individual values has been described in ways that are appropriate to each of the categories of values. Generally, a range of criteria was used to decide if the values were significant at the levels of

- international;
- national;
- state;
- regional; and
- local or park.
These criteria were further developed and refined as the ISC’s work proceeded, and the assessment appears in detail in the individual “topic” chapters.

**Pressures**

Pressures may arise from indirect or underlying societal and economic processes, or from activities that act directly on values, sometimes called proximate causes. A pressure on a value indicates that the value may be degraded unless the pressure is removed, reduced, or appropriately managed and its effects mitigated. Identification of pressures and their impacts is a valuable means of identifying where management strategies need to be developed.

**Opportunities**

The ISC identified positive management opportunities for some values, particularly those related to the legislative duties on National Parks and Wildlife Service (NPWS) to provide educational enjoyment and understanding of the park’s natural and cultural values. These opportunities can be considered in the review of the plan of management.

**Knowledge gaps**

Knowledge gaps that require further research or data to elucidate significant or potentially significant values were evaluated for each of the value areas. These will assist in the future understanding, conservation and management of Kosciuszko National Park’s significant values.

**Indicators**

The ISC was asked to identify key performance indicators required for the management of the park’s values, to provide managers with the data and capacity to make informed decisions. These are of a strategic nature and focus on practical, achievable and repeatable monitoring.

**Peer review**

All papers in this report were peer-reviewed by other professionals in the appropriate fields or by other ISC members. The peer review process was considered important in order to meet academic standards and maintain an objective assessment.
Introduction

The relevant sections of the National Parks and Wildlife Act 1974 (NSW) stipulate that a primary object of the Kosciuszko National park is conservation of significant landforms, geological features and earth processes. Also, management should seek to foster public appreciation and understanding of the earth science aspects of the park and sites of scientific significance. The following discussion has been written with these management aims in mind.

Geology and geomorphology are the basis of the entire Kosciuszko National Park. The geology is well displayed by a geological map at the scale of 1:250,000 (Wyborn et al. 1990). Copies of this map may be obtained from the Australian Geological Survey Organisation (AGSO) in Canberra. There is quite an extensive scientific literature bearing particularly on the solid geology, the effects of glacial and periglacial processes and the soils.

Earth science features of the park can be conveniently divided into four time-based groups. Each is discussed here with comments on significance at national, state and park levels.

- **Ordovician to Lower Devonian** (approximately 430-370 million years old). These rocks form the bedrock of the entire area. The formation of these rocks was followed by a prolonged period of erosion that lasted into the Tertiary.
- **Tertiary** (about 50 –2 million years ago). Uplift and continued erosion were features and basalt and stream sediments formed in the Miocene (about 20 million years ago).
- **Pleistocene** (the last 2 million years). Great climatic changes occurred, particularly over the period 70-10,000 years ago, that produced glacial and periglacial features.
- **Holocene** (approximately the last 10,000 years). The climate and earth processes have been roughly similar to those of today.

**Ordovician to Lower Devonian**

**Description**

The Ordovician to Lower Devonian sedimentary rocks are mainly sandstone, siltstone and shale forming greywackes deposited in deep marine environments, but including shallow-water limestones found at Cooleman in the northeast, Yarrangobilly in the centre and Indi in the extreme southwest. Some volcanic rocks occur, chiefly in the northern third of the area, including the Mount Jagungal Basalt which is the oldest rock in the park. These volcanics were extruded mainly under marine conditions but include some sub aerial occurrences. Granitic rocks were intruded at depth in Silurian and Devonian times, and now underlie most of the southern half of the park and the Bogong Peaks wilderness area in the northwest, plus scattered occurrences elsewhere. These rocks have been extensively affected by folding and faulting. LAI Wyborn (Table 3 in Good 1992) lists the following particularly significant geological features of this age.

- Geehi Valley: metamorphic rocks with abundant garnet, staurolite and amphibolite;
- Ravine Basin: Devonian shallow water sediments;
- Mount Talbingo: Devonian lava flows forming cliffs;
- Cabramurra serpentine along major faults with nickel and chromium;
- Cooleman Plain: Silurian limestone and chert;
- widespread Ordovician marine sediments forming hard quartzites and softer phyllites and schists;
- Tumut Ponds, Tantangara, Kiandra and Byadbo areas: graptolite fossils;
- The Pilot and Byadbo: Ordovician hard, green, platy quartzite;
- Yarrangobilly: Silurian limestones, fossils, shales and tuffs;
- Cowombat Flat, Marble Creek and Pilot Creek: limestones and tuffs;
- Pilot Ridge and Cowombat Flat: Devonian rhyolites and breccias;
- Main Range: three types of granitoid rocks;
- Nungar: folding of Bowing tecntonic episode;
- Cooleman: slump bed folding; and
- Black Perry: skarn rock with garnets.

Knowledge of the solid rocks has been enhanced by the extensive and intensive studies required for the Snowy Mountains Hydro Electric Scheme and the ski tunnel between Bullocks Flat and Blue Cow Mountain. Economic minerals, including gold, copper, tin and lead accumulated at many places but mostly as minor occurrences.

After the Mid Devonian, the area was subject to prolonged erosion for some 250-300 million years which exposed the granites and reduced the area to a lowland with ridges on more resistant rocks. Some features of this lowland have been partially preserved by the Miocene basalt: notably, a north-flowing valley near Kiandra. Part of the Great Divide that separates west and east-flowing drainage in New South Wales now occurs in the park.

**Condition**

These rocks are obviously robust and in their natural condition.

**Trend in condition**

These rocks are a permanent feature of the landscape and, assuming quarrying and mining continue to be banned, no change in condition is expected. Possibly there may be some reduction in their scenic value if additional buildings and roads are created. No special management is required to maintain their condition other than retention of the existing ban on prospecting, mining or unlicensed collection of samples.

**Significance**

These rocks form part of the Lachlan Fold Belt that occupies much of eastern Australia (Wyborn LAI 1977). They are of national and state significance. Areas of particular significance at state and park levels are the limestones with associated karst features (discussed by A Spate in Chapter 7). The landforms surviving from the later part of this period and on into the Tertiary are likewise of significance in understanding the evolution of much of southeastern Australia, including the history of the Great Divide.

Gold around Kiandra and the Grey Mare Range, copper and gold at Ravine-Lobs Hole and in the southwest were economically significant and formed the basis of former mining activities. The surviving associated cultural features (discussed in Chapter 13) are now of state and park significance.

**Pressures**

While the major rocks and landforms are immune to any conceivable pressure, large numbers of visitors can affect their scenic attractiveness by damaging the overlying soil and vegetation. This is occurring around Mount Kosciuszko. It is conceivable that pressure will arise from fossickers seeking fossils in the limestones and interesting minerals such as the garnets at Black Perry Mountain. Construction of roads and building can reduce the scenic attraction of the area.

**Opportunities**

There is some scope for educational signing at conveniently situated outcrops, notably the quarry on the road between Dead Horse Gap and Tom Groggin. Provision of leaflets setting out the geological story would assist leaders of educational excursions.

**Knowledge gaps**

There is much scope for more detailed geological mapping in most parts of the park. Research by university and state geologists will gradually meet this requirement (e.g. Wyborn, LAI 1977, Wyborn D 1983). Such future research should continue to be controlled through licensing by the New South Wales (NSW) National Parks and Wildlife Service.

**Indicators**

In accord with the permanency of the rocks in terms of human lifespan, indicators of changing condition are not apparent in the values themselves but there may be changes in their accessibility and visibility. A good cover of soil and native vegetation indicates good condition while bare rock surfaces, slumps and gullies indicate poor and probably deteriorating condition.
Tertiary

Description

Earth movements in the Tertiary uplifted the area, especially in the south and west, enabling stream erosion to cut deep linear valleys along lines of rock weakness, such as the Thredbo Valley aligned along the Crackenback fault. The dissection resulting from the Tertiary uplift has produced spectacular scenery – notably the mile-high drop from the summits of the Main Range to the Geehi Valley. Miocene basalt extruded over the central part of the park covered stream valley deposits of lignite, silt and clay containing alluvial gold and fossils of rainforest trees. Later erosion has reduced the basalt to scattered remnants.

Notable areas and features of the Tertiary geology as listed by LAI Wyborn (in Good 1992) include:
- Round Mountain: Tertiary basalt flows;
- Kiandra, Cabramurra and Yarrangobilly: columnar basalt pinnacles; and

The wet and warm climate of the Tertiary favoured deep weathering. The effects are still visible in road cuttings throughout the park where granite has lost its cohesion but is still in place. Over much of the park, later erosion has removed some of this unconsolidated material to leave resistant core stones exposed as tors. Some insights into the landform history can be found – for example, the sub-basalt valley at Kiandra and the mature gentle slopes of upper valleys (e.g. Long Plain) perched above deep lower valleys cut by later erosion.

Condition

The major landforms resulting from the geomorphic history of the Tertiary are generally robust, as is the Tertiary basalt. The surviving remnants of the Tertiary stream deposits are liable to loss by erosion. The evidence of deep weathering was clear in fresh road cuts made when the Snowy Scheme was under construction, but in many places it is now obscured by rain wash, slumping and vegetation.

Trend in Condition

While the scenery will survive unchanged in terms of human lifetimes, there will probably be a gradual deterioration in accessibility and visibility of the mining evidence. However, reasonable maintenance should maintain the surviving features indefinitely. Ironically, further loss of evidence of deep weathering in road cuts will be caused by soil conservation measures.

Significance

The spectacular scenery of parts of the park, notably the Geehi Valley, is certainly of Australia-wide significance. The gentler relief typical of most of the park has state-wide significance. The rainforest fossils found in stream sediments under basalt at Kiandra are rare testimony of a time when Australia’s climate and vegetation were very different and contribute to understanding the climatic evolution of the entire continent. The alluvial gold was the focus of an important gold rush around 1850, followed by half a century of placer mining. The relics of the mining are significant at state and park levels. The deep weathering of granitic rocks seen in road cuttings is a common feature in Australia and most mid- to low-latitude countries; it is of park significance only.

Pressures

Some increase in tourist pressure on the more accessible mining sites can be expected. However, because these sites are well away from the main attractions of the ski areas and the highest country, such pressures should not be unsustainable. Any attempt to resume mining would greatly increase pressure but is most unlikely to happen.

Opportunities

If major faults are exposed in road cuttings, information notices would be helpful. Public knowledge of deep weathering effects could be furthered by suitable notices. Deeply weathered granite in place is well exposed in road cuts near Island Bend and is regularly demonstrated to geology students on field trips.

Knowledge gaps

There is always scope for more research and knowledge about these rocks and the geomorphic history. Such research is best carried out by academic researchers under park licensing.

Indicators

As was the case for the older rocks, no visible change is to be expected in the rocks themselves but access and visibility may be affected. A good cover of soil and native vegetation indicates good conditions, while bare rock surfaces, slumps and gullies indicate poor, and probably deteriorating, condition of the sites.
Pleistocene

Description

During the Pleistocene, comprising about the last two million years, the world experienced remarkable climatic events, including the repeated growth and decay of immense ice sheets in North America and Europe, while glaciers developed on mountain ranges through the world. In Tasmania there were several extensive glacial events but, on present evidence, in mainland Australia only the very highest land in the Kosciuszko National Park had small glaciers during the last part of the Pleistocene. Cold-climate periglacial processes beyond the ice were more extensive and produced distinctive landforms and deposits.

Glacial features of the park include cirques, moraines, lakes, erratics and ice-scratched surfaces. The cirques formed mainly in the lee of the Main Range where accumulation of snow was maximal and melting minimal. Some 13 cirques have been identified (Galloway 1963, Barrows et al. 2001).

Both terminal and lateral moraines occur. They usually form bouldery ridges but one case of hummocky moraine exists in Mawson’s cirque. Radiometric dating of boulders in the moraines has shown that there were several successive ice advances and retreats during the last glaciation (sens lat) (Barrows et al. 2002).

There are five glacial lakes. Only Blue Lake is at least partly formed by glacial erosion of the bedrock; the others are shallower features formed by morainic dams. Pollen in lake sediments has provided valuable evidence of vegetation and climate changes since the ice disappeared about 15,000 years ago (Martin 1986).

Glacial erratics are rocks ranging in size from pebbles to boulders which differ from the underlying bedrock. They are believed to have been transported to their present position by former glaciers. Erratics near the cirques provide incontrovertible evidence for glacial transport but elsewhere their significance is problematic because of imperfectly known variations in the underlying bedrock and because rocks on the surface can creep downhill from one lithology to another. Further confusion can be caused by anomalous material imported to make roads and tracks.

Ice-scratched surfaces that occur on lower slopes overlooking Lake Albina demonstrate the former direction of ice movement. Ice-smoothed rock surfaces are well developed in Blue Lake cirque.

The periglacial evidence is less striking but more widespread and can be found in most areas above the 1000 m contour and possibly as far down as 600 m. Features include frost-shattered bedrock, boulder fields, solifluction deposits, stone streams, stone-banked lobes, non-sorted steps and nivation features.

Frost-shattered Ordovician sedimentary rock – evidence of former permanently frozen ground (permafrost) - is exposed in a roadside quarry one kilometre east of Mount Kosciuszko. This is almost the only evidence for past permafrost known in mainland Australia. Angular rock debris around tors at high altitude is a product of former frost-wedging.

In many parts of the park, solifluction (the downslope movement of unconsolidated rock debris by freeze-thaw processes, interstitial ice and snow melt) has produced smooth slopes. The northwest-facing slope of the Kangaroo Range is a good example. Where the debris included boulders, the fine fraction may be subsequently washed out to leave boulder fields and stone streams (Caine and Jennings 1968) which are now a favoured habitat for the Mountain Pygmy-possum. Striking block streams, dated to about 20,000 years ago occur at about 1100 m altitude near Ravine. In detail, solifluction can result in irregular low steps formed by the fronts of solifluction lobes and terraces. Sometimes these fronts are barely discernable through soil and vegetation (e.g. on the Kerrie’s Range). In road cuttings, solifluction deposits can be seen to fill valleys and gullies cut in the weathered granite.

Nivation is a complex of land-forming processes found in and around long-lasting snow patches, particularly where the ground surface is bare. It includes splitting of rocks by freeze-thaw and mass movement of wet soil and rock debris. In the long term it produces shallow hollows that form incipient cirques; there are many such nivation hollows in the higher parts of the park (e.g. the Rolling Grounds).

Condition

The glacial features are generally clearly visible, although the older ones have lost much of their pristine form through natural erosion. Glacial erratics have become more difficult to find since the termination of grazing has encouraged vegetation to recolonise bare areas. The periglacial deposits are best exposed in road cuttings and quarries where they gradually become less identifiable because of rain wash, growth of vegetation and soil conservation measures. A road has cut through the block stream at Ravine.

Trend in condition

Continued obscuring of relevant exposures through vegetation growth and soil conservation measures is to be expected. The quarry showing permafrost evidence near Mount Kosciuszko mentioned above will be concealed for reasons of conservation.
Significance

The glacial features are of high scientific and educational significance for Australia. They are an outstanding example of a glaciation that developed under extremely marginal conditions (Galloway 1989) and are the only occurrences on the Australian mainland. They also help our understanding of ice age climates. The Helms moraine near Blue Lake is a particularly clear example of glacial transport of one kind of rock onto another. The so-called ‘Railway Embankment’ moraine near Mueller’s Pass is another example. It is also the site of an early estimate for the date of glaciation (David et al. 1901) and is consequently significant for the history of geology in Australia. The periglacial phenomena are amongst the most striking in Australia and demonstrate that the effects of cold climate in the Quaternary spread far beyond the limited glaciers.

Pressures

The glacial features are well outside the ski resort concessions and consequently should not experience greatly increased pressure although there will be some increase in foot traffic along and near access tracks. The more widespread periglacial features may suffer some loss through building and road construction. On the other hand, such work may expose new examples of solifluction deposits. A more immediate possible pressure is the smoothing of ski runs. In the past there has been some bulldozing on ski runs but such extreme measures are not now employed.

During early stages of constructing the Snowy Mountains Hydro Electric Scheme it was proposed to dam Spencers Creek. This would have seriously affected the integrity of the landforms, especially the ridge known as the David Moraine (whose morainic origin is very dubious). However, the proposal was abandoned and is no longer a problem although traces of disturbance by exploratory excavations still exist.

Opportunities

There is considerable public interest in the glacial history of the park but the periglacial story is less well known. Opportunities exist for informing the public with signs at appropriate locations. Existing signs may need to be updated in the light of recent research. There is a case for recording features temporarily exposed during construction of roads and buildings. It may be possible to illustrate the development of a small glacier by means of a kaolin model that could be an item in an educational video on the park.

Knowledge gaps

There is scope for further radiometric dating (Barrows et al. 2002) to increase understanding of both glacial and periglacial history. Current work in progress is successfully dating block streams. More detailed mapping of the granites and inclusions of other rocks therein should assist in resolving the question of exactly how far the ice extended and whether earlier glacial events occurred. There are probably many evidences of past vegetation such as described by Caine and Jennings (1968) still to be discovered under solifluction layers and many more periglacial features remain to be identified. All such research will need to be done carefully in view of the need to avoid damaging the environment.

Knowledge gaps more relevant for conservation include the distribution of periglacial features in relation to proposed development. Also of potential importance is the location of old gullies cut in the soft weathered granite and then later infilled by soliflucted material. The presence of one such gully may have contributed to the Thredbo landslide disaster.

Indicators

Indicators of changing condition include fresh rock surfaces stripped of their usual lichen cover, soil erosion and damaged vegetation.

Holocene

Description

By 15,000 years ago the last glaciers had melted as the climate warmed with the close of the ice age. The tree line, which had been lowered by as much as 1000 m at the glacial maximum, gradually rose to near its present level at around 1850 m. By 10,000 years ago the climate was broadly similar to that of today. Earth science phenomena in the Holocene are intimately interlinked with the development of soils and vegetation.

Holocene land-forming processes in the park include solifluction (less intense than during the Pleistocene), erosion, nivation, frost heaving of soil (Costin and Wimbush 1973), stone movement by snow pressure (Costin et al. 1973) and the formation of string bogs (narrow turf contour ridges separating elongated ponds).

At high altitudes, solifluction of frost-shattered debris and soil on the Ordovician sedimentary rocks has created non-sorted steps, lobes and terraces on slopes. These features are now largely inactive but a slight decrease in mean temperature could reactivate them (Costin et al. 1967).

Erosion of soils and other fine-textured surface materials has been significant in the Holocene. At least 7 m of sediment has been washed into Blue Lake since the ice disappeared 15,000 years ago. This process is still active today and substantial soil erosion control works have been necessary as discussed in Chapter 6 of this report.
Nivation is most active today on the upper slopes overlooking glacial cirques and in other south- and east-facing hollows where thick snow drifts accumulate in winter and survive through spring into summer. Effects of nivation include mass movement of wet unconsolidated material, movement of boulders by snow pressure, frost heaving of soils and accelerated surface wash.

**Condition**

Over most of the park, Holocene processes and deposits are generally in reasonably good condition but there are limited areas of concern such as the heavily impacted summit of Mount Kosciuszko and parts of ski concessions. It has been feared that ‘snow farming’ in ski concessions could lead to unwanted surface changes. While this may be true for vegetation and soil (Pickering and Hill in press) the depths of snow involved are substantially less than would be required for full nivation to occur (Galloway et al. 1998). Active stream bank erosion around Blue Lake is cutting away sediments with potential value for dating.

**Trend in condition**

In the last century and a half stock grazing, road construction, mining and engineering works have had major impacts on the area of the park. The completion of the Snowy Mountains Hydro Electric Scheme, soil conservation efforts and walkway construction have now helped to re-establish more natural, gradual Holocene processes. On the other hand, the increasing tourism in the park and the growth of skiing have inevitably added new pressures. The effects of the 2003 fires and the associated fire-fighting measures such as bulldozing access tracks will also adversely affect the condition for years to come. In future, nivation may be reduced if snowfall decreases as a result of climatic warming. However, no significant change in snow fall is yet apparent even though there has been some warming (Osborne et al. 1998).

**Significance**

In the park surface processes such as soil erosion, frost heaving and solifluction can be observed under the present climate in a great variety of situations. The park can thus serve as a benchmark for processes in more heavily impacted regions elsewhere giving it state level significance. In particular, it offers comparison with alpine areas in Victoria that are subject to more stock grazing although the advent of horses in the Kosciuszko alpine zone is now tending to reduce this contrast. The pollen evidence for past vegetation and climate is of state and even national significance.

**Pressures**

Pressures on Holocene phenomena are inevitably linked to changes in park usage with some pressures concentrated in heavily used areas such as Perisher and the Kosciuszko summit. Pressures from bushfires, on the other hand, can occur almost anywhere. These pressures will be apparent through their effect on vegetation and soils.

**Opportunities**

Study of the depositional history of alluvial fans might throw light on the possibility of flood damage after exceptionally heavy rain. This is a problem in Swiss ski areas and may arise here if more intense rain results from the greenhouse effect. The evolution of alluvial flats over the last six decades could be studied using successive generations of air photographs. This air photo record could also provide a useful picture of the park not long after the great 1939 fires for comparison with what is happening after the 2003 fires.

Climate studies and observations are relevant to Holocene earth sciences. Re-establishment of the Spencers Creek climate station at the same site as in the 1950s and 1960s might be possible using solar-powered, unmanned equipment. This would enable climate change in the mountains to be tracked more effectively. It is important that the existing snow courses are maintained; their value as records of snow history increases year by year.

**Knowledge gaps**

Topics worth investigating include what effect will the use of artificial snow have on stream processes? How much erosion and other effects might occur in a 100 year flood? Will significant climatic change occur and, if so, what will be its effects on earth processes?

**Indicators**

A good cover of native vegetation and soil indicates good condition while bare earth and soil erosion indicate bad, and probably deteriorating condition. Monitoring at 10 year intervals of sediment accumulation in lakes and dams throughout the park could provide useful indication of current soil loss rates for comparison with the high rates recorded for parts of the Main Range (see Chapter 6) and with the long record of sediment accumulation in Blue Lake.

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Introduction

Soils are very complex physical, chemical and biological systems. They provide the life-sustaining pathways of air and water from the atmosphere, through the vegetation, into and through the ground below. In the reverse direction, soils transmit some of the air and water back into the atmosphere. Because soils are mostly out of sight beneath plants, their values tend to be overlooked among other natural values. Kosciuszko National Park differs greatly from other alpine areas in that deep organic soils dominate, whereas in most other alpine areas around the world soil formation is limited. This characteristic has led to the Australian Alps being described as ‘mountains of soil’ (Costin 1989). It also points to the area’s sensitivity to disturbance.

The soils of Kosciuszko National Park are of great scientific interest in themselves. They have attracted international attention as outstanding examples of some of the great soil groups, both individually (the alpine humus soils) and in association with each other (e.g. the alpine sequence of lithosols, snow patch soils, alpine humus soils, bog and fen peats and silty bog soils), and for the associated studies of the pedogenic factors and processes controlling their formation and maintenance (Costin 1989, Good 1992). The scientific value is enhanced further by the large degree of ‘naturalness’ of the soils, which are relatively unaffected by the centuries of human occupation and associated uses of most mountains elsewhere in the world. Hence they are important natural ‘standards’, like above-ground reference areas of vegetation (Costin 1954, Costin et al. 2000).

In addition to their scientific interest, soils have vital ‘service functions’ such as the supply of clean water for domestic and industrial uses, irrigation, hydroelectric power and a wide range of recreational activities. The alpine and subalpine soils of Kosciuszko National Park receive, store, process and supply a larger quantity of high-quality water than any other group of soils on the continent. The soils of the surrounding mountain forests in the park also have valuable hydrological functions. Map 6.1 illustrates broad soil group distributions in the park.

Basis for management

A major objective of the New South Wales (NSW) National Parks and Wildlife Act 1974 and the biodiversity strategy is the conservation of natural ecosystems, including (i) habitat, ecosystems and ecosystem processes and (ii) biological diversity at the community, species and genetic levels. Soils are an important part of most ecosystems, and are the medium through which many conservation management measures operate. Soils as part of ecological integrity are therefore well protected legally in national parks in NSW.

Because of the importance of the soils of Kosciuszko National Park for catchment protection and water yield, they are safeguarded further by the Soil Conservation Act 1938 and the Protection of the Environment Operations Act 1997. In fact, it was the soil conservation legislation that played an important role in the establishment of Kosciusko State Park in 1944, and in its subsequent protection and rehabilitation.

Significance

In parallel with the wide representation of plant communities in Kosciuszko National Park, the soils vary characteristically on the semi-continental scale in response to the major pedogenic factors of climate, geology and physiography, down to local aspect and catenary levels (Costin 1954, 1989, Costin et al. 1969, Good 1992). The recognition and understanding of these variations are facilitated in Kosciuszko National Park by its large size and persistence as a relatively undissected uplifted paleoplain, its wide altitudinal (225–2228 m) and climatic range, and the occurrence of soil parent materials as diverse as basic limestone and basalt, acid granites and metasediments.

Because soils are mostly out of sight beneath plants, their values tend to be overlooked among other natural values.”
Thus, the dominance of the alpine and subalpine climate on soil formation is seen in the development of one and the same soil group, the alpine humus soils, on all parent materials, in contrast to the increasing dominance of parent material on soil formation at lower levels. On a given parent material over a wide range of altitude, characteristic sequences of soils are developed: for example, alpine humus soils and various podsolics on granites and metasediments; alpine humus soils, krasnozems and chocolate soils (not in Kosciuszko National Park) on basalt; and alpine humus soils, rendzinas and terra rossas on limestone (Costin 1954, 1989).

The importance of the topographic factor (through drainage) also varies with altitude and parent material as expressed in soil catenas: in the alpine–subalpine environment, the lower–catenary soils (bog peats) are the most acid and oligotrophic, whereas at lower elevations the lower–catenary soils (meadow soils) are relatively eutrophic, reflecting the accumulation, rather than dilution and loss, of nutrients. Whilst many native plant species in Kosciuszko National Park are not particularly sensitive to soil nutrient levels, other species, and even whole communities, are nutrient-sensitive, a fact not fully appreciated in park management.

In Kosciuszko National Park the alpine humus soils of the alpine and subalpine tracts are particularly well developed. Important soil processes that have been studied, albeit inadequately, include weathering, soil moisture movement, colloid and nutrient cycling, solifluction, aeolian deposition, soil faunal and mycorrhizal activity and various types of soil erosion and remediation techniques (Costin 1954; Costin et al. 1959, 1960, 1961, 1964; Walker and Costin 1971; Johnston and Ryan 2000).

A notable feature of the alpine humus soils in Kosciuszko National Park is the absence of the podsolisation process normally found in cold wet climates on acid rocks with low-nutrient vegetation. In fact, the reverse situation occurs, with accumulation of soil colloids and nutrients in the surface soil. These soil-building processes involve recycling by the deep-rooted snow grasses and other major herbs, possibly in association with soil mycorrhiza (Johnston and Ryan 2000), accretion of windblown dusts, and vigorous decomposition and redistribution of plant remains by soil organisms, particularly invertebrates, including the mountain earthworm (affin. Megascolex sp) (Costin 1954, Good 1992). One of the main conditions under which these organisms can operate is the deep continuous cover of winter–spring snow insulating the underlying soil and its inhabitants. The below-snow surface soil is thus maintained at favourable soil moisture levels at temperatures above freezing. These conditions are not found in mountain areas with colder autumns and early winters and/or subsequent light snow cover (Costin et al. 1969).

The abundant alpine–subalpine insect fauna in Kosciuszko National Park of some 850 recorded species (Good 1992) may also depend on these soil conditions, because eggs, larvae and pupae can overwinter without damage, with an almost explosive emergence of adults soon after the spring thaw.

Kosciuszko National Park encompasses the foremost water catchments in Australia. Historically, appreciation of this significance by the first Soil Conservation Commissioner, Commissioner Clayton, and Premier McKell led to the establishment of Kosciuszko State Park in 1944, and appreciation of the importance of nature conservation in the park has continued.

The significance for catchment performance of soil conditions, including surface cover, cannot be overestimated. Surface soil conditions have a controlling role in the balance between non-erosive infiltration of precipitation and erosive surface run-off. Depending on site conditions, surface cover of 70–100% at rates of at least 10 tonnes per hectare (oven dry weight) is necessary for soil protection from frost, wind and storm rains (Costin et al. 1980, Costin 1980, Good 1976). Reduction of surface cover below these levels by former burning practices and livestock grazing led to widespread catchment erosion, especially in the alpine and subalpine tracts. Subsequent protection from these practices has been followed by recovery of ground cover and soil stability in most areas, although some erosion ‘hot spots’ remain (see below). In the lower elevation sclerophyll forests, current prescribed burning programs frequently reduce cover to below these limits, as well as preventing forest successions from proceeding towards old-growth stages. More attention should be given to a fundamental conservation equation: fuel = catchment cover = habitat.

Along drainage lines within a catchment, groundwater soils have a further controlling role in spreading and filtering catchment run-off before it enters streams. The groundwater soils have to carry a heavy ‘water load’; they can function successfully only if they retain their almost level even surface. Incision by gullying and deeper entrenchment impairs these functions, a situation still present in parts of Kosciuszko National Park even though there has been general catchment improvement.

Dependence

Kosciuszko National Park is the only part of southeast Australia that protects such a wide range of mountain soils still in their largely natural condition and in one and the same geographic location. This applies particularly to the snow patch soils, alpine humus soils, bog and fen peats and silty bog soils of the alpine and subalpine areas. They are represented in high mountain parks in Victoria but are still subject to livestock disturbance and erosion there.
**Condition and trend in condition**

Surveys of the snow leases and permissive occupancies in Kosciusko State Park, carried out in the 1940s and 1950s by the Soil Conservation Service of NSW, documented widespread soil erosion attributed to the destruction of soil cover by fires and grazing (Costin 1954; Durham 1956; Morland 1949, 1951, 1958ab, 1959, 1960; Newman 1953, 1954abc, 1955abc; Taylor 1956, 1957, 1958ab). Improved fire management and progressive removal of grazing from 1944 to 1958 have been followed by natural stabilisation of most soils in the park, associated with an increase in the soil surface cover on a catchment scale to the previously mentioned levels of 70–100% in amounts of at least 10 tonnes per hectare. Other associated soil measurements in some subalpine areas over a 20-year period show a reduction in the bulk density (ie increased porosity and infiltration of moisture) and an increase in soil organic matter (Costin et al. 1959, 1960, 1961; Wimbush and Costin 1979a). In general, the recovery trend of the last 40–50 years has reached a plateau of relative stability, but not always in the original condition. Near-original conditions have been achieved where sufficient organo-mineral topsoil remained, but not where topsoil loss proceeded to the residual stony erosion–pavement stage (Johnston and Ryan 2000, Wimbush and Costin 1979abc). This stage will persist for a long time, probably centuries; fortunately shrub regeneration on these stony sites is stabilising most of them. In the alpine zone these stony pavements have reached stability as ‘erosion’ fieldmarks (Good 1976, 1992).

On the Kosciuszko Main Range, and Gungartan and Bulls peaks area to the north, some of these erosion ‘hot spots’ involved losses of up to half a metre of organo-mineral topsoil over a total area of about 1500 hectares (Good 1976, 1992). Soil losses from the Main Range between Mount Kosciuszko and Mount Twynam were recorded by the Soil Conservation Service of NSW to be in the order of 1.2 million tonnes. Patient, hands-on soil reclamation work by the Soil Conservation Service between 1954 and 1980 eventually stabilised most sites, but there remain eroding edges and run-off/run-on erosion problems requiring future attention.

The problem of incising and eroding peats and other groundwater soils elsewhere in Kosciuszko National Park also requires attention. Measurements over a 20-year period show continuing erosion of stream-bank and stream-bed profiles in subalpine valleys, even though the initial disturbing agents are no longer present. Where incision is less severe, simple water-spreading measures in valley headwaters may halt further degradation. Where there has been only minor incision, a slow upward trend is apparent (Wimbush and Costin 1979c, 1983).

As well as the already mentioned disturbances and trends in the catchment soils of Kosciuszko National Park as a whole, localised soil damage has occurred in many areas, such as that arising from former engineering operations of the Snowy Mountains Hydro-Electric Authority (SMHEA); along transmission lines, roads and management tracks, four-wheel drive tracks, horse riding route pads and walking tracks; and in development sites such as resort areas. Much of the former damage has been repaired, but continuous maintenance work will be required.

**Pressures**

The most widespread pressure on the soils in Kosciuszko National Park is that of fire, as it destroys or reduces the protective ground cover, thereby mobilising surface soil and nutrients, and potentially leading to erosion (Brown 1972, Good 1973).

During the last 50 years, there has been a reduction in the number and extent of wildfires, and in recent years there has been a reduction in the number and area of prescribed fires, with a subsequent improvement in cover and soil stability. A policy of no burning now applies in the alpine zone, much of the subalpine zone and the lower Snowy rain shadow area, where the protection of severely eroded soils on steep slopes requires the further build-up and maintenance of ground cover. In most of the remaining forest areas ‘hazard reduction’ or ‘prescribed’ burning is part of their management, but widespread prescribed burning is not practised. Wildfires are less frequent, but they have the potential to initiate extensive soil damage if the burnt areas are subject to fire of high intensity (Brown 1972, Good 1973).

On the assumption that prescribed burning will minimise the risk of future wildfires, there is a perceived need for the periodic reduction of ground cover to below 10 tonnes per hectare. However, this is not necessarily consistent with the needs of catchment protection or nature conservation. Frequent prescribed burning in the ‘safe’ winter period increases the potential for soil nutrient losses, as fire-mobilised nutrients are exposed to several months of erosion and leaching until there is sufficient recovery of vegetation to reabsorb them during the following summer. Such losses are likely to be cumulative and are always downhill. Fire managers in Kosciuszko National Park have a difficult task to get the balance right (see Chapter 12).

Recreational activities present significant, if localised, pressures on soils. As well as soil erosion, surface compaction may result from slope grooming and the use of vehicles on a shallow snow pack. Where pore space in soils is related to many years of previous soil development - as in alpine humus soils - compaction effects may last for a long time. Then there is the problem of slow ‘nutrient leakage’, as of calcium from paved tracks made with concrete or concrete blocks, onto nutrient-susceptible bogs and peats. Such leakage is associated with an increase in less oligotrophic native species and an invasion by weeds. Alternatives to paved tracks are raised walkways, provided any steel that is used is ungalvanised and hence free from toxic zinc that may remain in soils for years (Johnston and Good 1995).
The ability of soils to absorb nutrients and sediment to the benefit of catchment water supply does not necessarily benefit other park values. Nutrients in human urine and faeces, especially phosphorus, can persist for years in recipient soils, as around the many huts in Kosciuszko National Park and on long-abandoned SMHEA campsites, which are now unidentifiable except for their persistent populations of thistles and other eutrophic weeds. Even where there is tertiary treatment of sewage from resort areas, the discharge of the effluent is likely to cause localised soil fixation and subsequent remobilisation of nutrients, with the potential for changes in the natural ecosystems affected. There is an ecological case for the complete removal of sewage wastes from Kosciuszko National Park.

There are also problems of localised soil disturbance and erosion from the activities of feral animals. In the less elevated cold air plains, such as Snowy Plains, rabbit control is an ongoing requirement. Rooting by pigs, with partial destruction of native vegetation and mobilisation of soil nutrients, facilitates weed invasion. The several thousand wild horses in Kosciuszko National Park, apart from their selective grazing effects on native vegetation, selectively frequent mountain valleys that are sensitive to trampling because meadow soils and bog peats are easily incised and gullied. Such effects are seen in the south of Kosciuszko National Park in the Ingegoodbee headwaters. With wild horses there is an obvious conflict between the conservation of natural and recently identified cultural values.

Knowledge gaps

As stated earlier, the soils of Kosciuszko National Park have been little studied compared with most other natural features. As one of the starting points for future work, detailed soil mapping could be considered. Among the attributes mapped would be soil cover, depth, and moisture characteristics, including infiltration capacity. Knowledge of these attributes is relevant to the management of vegetation, fauna and other ecosystem components, and would assist fire planning and resort area management.

Further research is required on the relationship of soils, vegetation and ground cover at different altitudes and aspects of erosion potential (see Chapter 12).

There is a knowledge gap in terms of appreciation and quantification of the thresholds between acceptable and unacceptable levels of vegetation and soil degradation in high-use recreational areas.

Opportunities

Although much has been achieved in the control and management of soil erosion in Kosciuszko National Park, the erosion control programs started many years ago must be continued and accepted as a part of routine resource maintenance works. Specific achievable objectives include the further stabilisation of erosion ‘hot spots’ on the Main Range and control of their accelerated run-off effects; the rehabilitation of eroding groundwater areas, especially valley bogs, in the alpine and subalpine zones; and the control of soil degradation and erosion in all infrastructure development projects. In view of the rapidly increasing use of walking tracks, especially in the alpine area, the effects of different track systems on associated soils and vegetation should be reviewed and the most appropriate systems more widely applied.

Indicators and monitoring

The long-term vegetation transects in the alpine and subalpine zones should be continued not only for the information they provide on vegetation trends but also for information on the soils. These have been documented by Roger Good and by the Alps Liaison Committee (R Good, National Parks and Wildlife Service, pers. comm., 2002) and a selection of transects for further monitoring could be made.

There are also various photographic records of soil conditions made many years ago by former officers of the Soil Conservation Service of NSW (e.g. Morland 1949, Newman 1953, Taylor 1957). These records should be located, some of the sites should be identified in the field and repeat photographs should be taken at regular intervals (e.g. Main Range, Kiandra, along roads and around construction sites). There is a good case for a professional ‘ecological archivist’ on the park’s staff to coordinate such work.

Addendum on fossil soils

Kosciuszko National Park also contains fossil soils and remnants of fossil soils. Their persistence in parts of the park reflects its relatively subdued terrain and the limited glacial and other types of natural erosion activity. Some of the older soil materials have been able to persist, with present-day soils developed within or over them. They are of high scientific value and practical importance (Costin 1972, 1989).

At the scientific level, the ages of various fossil soils contribute to the evidence of general contemporaneity of Ice Age and subsequent climatic changes at Kosciuszko and mountains in other parts of the world. Certain fossil soil features, notably the non-sorted steps, are among the best examples of their kind; their study has also shown how alpine humus soils developed (Costin et al. 1967, 1969). At the practical level, the depth and extent of slope deposits enhance catchment storage of water, but they present construction problems for engineers and are erosion hazards if disturbed.
The oldest features are topsoil remnants in extensive slope deposits formed by solifluction during previous periglacial conditions. They occur on gentle to moderate slopes on both sides of the mountains, as in the upper Murray Valley between Geehi and Tom Groggin, along the Thredbo Valley and the Snowy Valley at Munyang and below Island Bend. On sites steeper than the angle of repose of unconsolidated materials, slope materials would also have moved downhill but could not accumulate. The age of the buried topsoils, about 30,000 years, indicates when the Ice Age cooling off started (Costin and Polach 1971, Costin 1972).

At higher altitudes in the Snowy headwaters, the age of the fossil peats and sediments overlying surfaces that would have been covered by ice and snow during the Ice Age indicates that this long cold period was on the wane by 15,000 years ago. Identification of pollen grains in the peats and sediments reveals how the vegetation has changed during postglacial time to the present day (Martin 1986ab, 1999).

Solifluction terraces and non-sorted steps record more recent changes in climate, including a cold phase between about 3000 and 1500 years ago (Costin et al. 1967). The stratigraphy and surface soil and vegetation patterns of the steps also show how alpine humus soils at Kosciuszko have originated and developed, including rates of formation of various soil properties.

The peats beneath long lasting snow patches preserve remains of the specialised plants that formed them, together with varying amounts of dust blown in from the west (Walker and Costin 1971, Johnston 2001). Their further study could provide an ‘aridity index’ for inland Australia during the last several thousand years.

Many of these fossil features are in the Kosciuszko summit area that is now attracting increasing numbers of walkers. Some re-siting of tracks and/or replacement by raised walkways may be needed to minimise trampling damage.