A progress report on the development of rehabilitation priorities for broad scale erosion within the World Heritage Area on the Central Plateau of Tasmania *2005-06*

Kathryn Storey and Michael Comfort

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Cover photograph: Broad scale sheet erosion at Wild Dog Tier, July 2005

Table of contents

Summary

The Central Plateau is a large, generally low relief alpine and subalpine area in central Tasmania. The higher parts of the Plateau in the west and north are largely either National Park or Conservation Area, and are included in the Tasmanian Wilderness World Heritage Area. Of this reserved area, some 11,000 ha or 7.5% has been mapped as suffering from some degree of erosion (Cullen, 1995). The bulk of this damage is broad scale sheet and stream erosion, and is thought to have been initiated by inappropriate burning and grazing regimes that have now ceased. The limited information available on vegetation changes since grazing ceased suggests that recovery is very slow. No measurements of the rate of ongoing soil erosion are available, but based on field observations significant erosion is still occurring in many areas. Rehabilitation efforts to date have had mixed results, from moderate success at some sites near Lake Augusta, to complete failure in a rehabilitation trial on sheet erosion near Bernacchi.

Recent fieldwork suggests that soil erosion is ongoing across much of the degraded area. Erosion is driven by a suite of processes including frost heave by needle ice, sheet flow, channelised flow, wind erosion, desiccation and animal grazing and digging. Vegetation recovery is impeded by the shallow degraded soils, but also by frost heave, animal trampling, grazing, digging and defecating, and by the short growing season constrained by winter cold and summer drought.

The rates of continuing soil erosion and vegetation recovery are presently unknown, but are likely to be variable in both space and time. It is usual to see signs of both recovery and erosion within one metre of each other. Many degraded areas appear to have the potential to either recover full vegetation cover and stable soil, or to continue to degrade until surface soil horizons are completely lost and replaced by either erosion pavement or bare rock. Without more knowledge of site trajectory (the relative rates of erosion and revegetation), it is not possible to say which of these is likely to occur.

This project aimed to review knowledge of the condition of the Plateau and the processes of degradation and recovery, and to update that knowledge where possible. It also aimed to identify areas that should be a priority for rehabilitation. Priority classes for rehabilitation works have been developed as follows. Note that action may never be recommended for the lower priority classes, as it is likely that conservation resources could be more productively used elsewhere in the state.

Priority One: Protection of large areas with high ecological integrity that have not suffered erosion, but are threatened by degradation in neighbouring environments.

Priority Two: Protection of areas that support significant soils, landforms, threatened species or communities, and that are threatened by erosion related disturbance.

Priority Three: Partially degraded areas that still retain some conservation value but are actively deteriorating or not recovering naturally.

Priority Four: Areas where rehabilitation is likely to fail because there is no known effective rehabilitation technique.

Priority Five: Areas where rehabilitation is likely to fail because of the extent of degradation.

Priority Six: Partially degraded areas that still retain some conservation value and are recovering naturally.

During fieldwork for this project, efforts were made to identify any areas that would fit the criteria for priority one. None were found. Fully vegetated sites that were close enough to eroding patches to be considered threatened typically show signs of past degradation.

Identifying other priority areas depends upon knowledge of site condition, conservation value, trajectory and the cost and probability of success of appropriate rehabilitation techniques. The present status of each of these points can be summarised as follows.

1. The present condition of the area.
In general, the present condition appears similar to the condition mapped by Cullen (1995). There are signs that some sites have improved their condition (as indicated by vegetation cover), whilst others have clearly deteriorated, but signs of ongoing soil erosion are common and widespread.

2. The conservation value of the area.
During fieldwork, efforts were made to identify large areas that have high conservation value because of their high degree of ecological integrity (ie never been impacted by soil erosion). None were found. No systematic search for special conservation values has yet been made.

3. The trajectory of the area.
With the exception of a few areas it is not possible to comment with any confidence on the trajectory of broad scale erosion on the Central Plateau. This is because the 1995 mapping by Cullen is not suitable for use as a benchmark. Also, the slow character of both erosion and recovery means assessments of trajectory must be made through carefully designed and targeted monitoring projects. The present poor state of knowledge means that it is not possible to say where active rehabilitation is required urgently, or where it is not required at all.

4. The cost and probability of success of rehabilitation.
Indications from existing trials indicate that presently known rehabilitation techniques have a high chance of failure in sheet eroded areas. Attempting to rehabilitate an area with techniques that are likely to fail is a waste of money and effort. New techniques that are more likely to succeed need to be identified. A review of techniques used interstate and internationally, and potentially the development of new techniques is required. This needs to be followed by scientifically and statistically sound trials on the Central Plateau.

In order to identify priority areas for rehabilitation, the following work program needs to be initiated. Much of this work should proceed concurrently. The results of the special values survey should inform the location of trajectory monitoring and rehabilitation trials. However, Monitoring and trial work will take a significant number of years, and so should commence as soon as possible.

Survey of special values potentially threatened by erosion

- Use fieldwork, aerial photography and desktop analysis of existing data to list and map special conservation values relating to geoconservation, threatened species and vulnerable communities. Particular emphasis should be placed on values that are potentially threatened by soil erosion because of either their location or their sensitivity.

Measurements of site trajectory.

- Develop a regionally based classification of eroding landscapes that can be used to structure measurements of site trajectory.
- Develop a robust and repeatable monitoring method that will allow accurate measurement of small rates of soil loss or gain and changes in vegetation cover over decade time spans. This may be based on remote sensing or on field surveys.
- Apply monitoring methods in a program designed to target different environments, including some of the special values identified above.
- Revisit existing vegetation monitoring sites and re-analyse data to identify patterns in control plots. Also, improve methods of marking quadrat sites so that monitoring can continue into the future.

Review and trialing of rehabilitation techniques.

- Review alpine and subalpine zone rehabilitation techniques used interstate and internationally.
- Continue monitoring existing experimental rehabilitation techniques.
- Within the context of the regionally based classification of eroding landscapes, develop a plan to extend rehabilitation trials to a broader range of environments and techniques.
- Make sure an appropriate robust and repeatable monitoring program is included in these experiments so that results can be clearly and scientifically evaluated.

Acknowledgments

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1. Introduction

The Central Plateau is a large, generally low relief alpine and subalpine area in central Tasmania (Figure 1). The higher parts of the Plateau in the west and north are largely either National Park or Conservation Area, and are included in the Tasmanian Wilderness World Heritage Area (TWWHA). Historical land management practices have resulted in widespread degradation of the vegetation and soils (Pemberton, 1986; Cullen, 1995). Some 11,000 ha or 7.5% of the reserved area of the Plateau has been mapped as suffering from some degree of erosion (Cullen, 1995). This damage is thought to have occurred because of inappropriate grazing by domestic and feral animals, burning both from wildfire and fires deliberately lit to promote green pick, road construction and the manipulation of lake levels for hydro schemes or to improve fishing opportunities (Mitchell, 1962; Pemberton, 1986; Bradbury, 1994; Cullen, 1995).

The eroded area of the Plateau considered in this report is primarily managed by the Tasmanian Parks and Wildlife Service (PWS), but also includes some land vested with Hydro Tasmania. Existing bare areas and ongoing soil erosion have had and are likely to continue to have a significant impact on the conservation values of the area. They may also affect the characteristics of the area as a water catchment, potentially effecting water quality, hydrology and capacity of water storages.

Over the last 15 years, PWS and the Department of Primary Industries and Water (DPIW) have put considerable effort into rehabilitation of some degraded sites on the Plateau, often with reasonable levels of success. This work has almost entirely been focussed on the small areas of mechanically disturbed ground created during road and dam construction, and in some cases by intense recreational pressures. The sheet and stream erosion that comprise the bulk of degraded areas have not been the target of any rehabilitation efforts, except for a few very small experimental treatments. This is partly because such broad eroded areas are difficult to define, access and treat, but also because the huge scale of the degradation dwarfs the resources that could presently be diverted to rehabilitation.

This project is a first step towards identifying rehabilitation priorities for protection of conservation values on degraded land on the Central Plateau. It builds on previous work, including the erosion mapping produced by Phil Cullen in 1995 (Cullen, 1995), the monitoring of vegetation recovery by Kerry Bridle and others (Bridle, 1997; Bridle, 2000; Bridle *et al*., 2001), and ongoing experimentation in rehabilitation techniques developed by Michael Comfort and others (unpublished data).

This study considers the portion of the Central Plateau that falls within the TWWHA. This includes 51,800 ha in the Walls of Jerusalem National Park and 89,070 ha in the Central Plateau Conservation Area. Pragmatically, this reflects the World Heritage Area funds that supported this project. However, this is also the area which is managed for conservation, and the area for which base line information exists in the form of Phil Cullen's mapping (Cullen, 1995). Within this area, there was a strong focus on those parts of the Plateau that Cullen identified as having significant erosion problems. For this reason, field work was strongly focused on areas north of the Great Pine Tier.

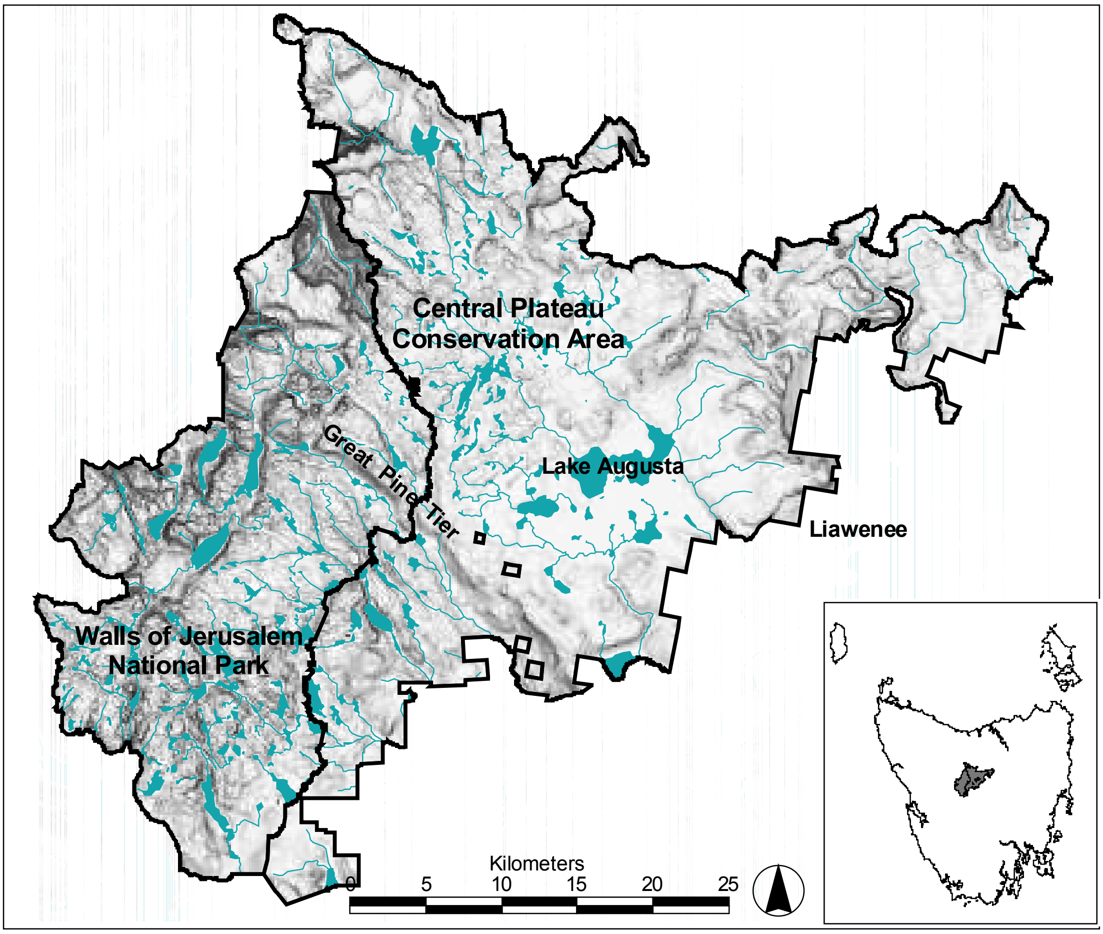

Figure 1. The Central Plateau study area.

1.1. Aims of this project

Rehabilitation of degraded areas on the Central Plateau should aim to prevent further damage to conservation values, and to eventually re-establish natural levels of soil stability across the Plateau. Achieving these goals will also have the effect of returning a more natural buffered hydrology than is likely to occur at present, improving water quality and reducing sedimentation rates in receiving water bodies. However, in a reflection of the WHA funding source, the immediate goals for this work are related to the protection of conservation values.

Conservation values on the Plateau are very diverse, and include features relating to soils, geomorphology, flora and fauna. They vary from discrete readily identifiable features such as lunettes (sand dunes on a lake margin) or a population of a threatened plant species, to less clearly defined areas that are valuable for their high degree of overall ecological integrity rather than for special features. Even areas that have suffered some degree of degradation will still have some values worth conserving in the remnants of soil and vegetation found between eroded patches.

Degradation caused by broad scale erosion on the Plateau takes a variety of forms, described in Sections 3.2.1 and 3.2.2. Forms of degradation vary from the loss of vegetation creating bare ground, through to the partial or complete loss of soil profiles. This results in an ecosystem that no longer maintains the full range of natural features and functions.

The rehabilitation of the Plateau is a very large and complex task, because of the scale of erosion, the remoteness of many degraded areas, and the difficultly of achieving revegetation in a very harsh environment. For this reason, an adaptive management strategy is needed that identifies priority areas for rehabilitation, specifies rehabilitation methods and identifies which organisations may be responsible for funding and completing the work. This report does not present such a strategy, but rather provides some of the information that will be required to do so.

This report has three broad aims. Firstly, we review the current status of the Plateau soils and sediments, in terms of existing information, present condition and ongoing causes of degradation. Secondly, we propose a prioritisation scheme that can be used to guide the intensity and direction of the rehabilitation effort. Thirdly, we consider how close we are to being able to apply that prioritisation scheme, and discuss what extra information is required to do so.

Underlying this work is a deliberate attempt to move the focus of rehabilitation away from small individual sites, to the broad scale forms of soil degradation. Unfortunately, the extent of erosion, the multitude of erosion processes and the generally harsh environment on the Central Plateau means that the rehabilitation of broad scale erosion is a very challenging problem. There are many unknowns, such as the trajectory of degraded and remnant patches, and the most appropriate rehabilitation techniques to use in different environments. It is probable that new, innovative rehabilitation techniques will need to be developed to suit the Plateau. This situation goes some way to explaining why very little has been done to address the degradation since the extent of the problem was first fully described in 1995.

The goals of this work were:

- Review the existing literature on erosion on the Plateau.
- Review through field assessments the present condition of degraded areas on the Plateau.
- Identify the processes that are causing ongoing erosion or preventing recovery of degraded areas.
- Make a reconnaissance style assessment of the trajectory of degraded sites, potentially using Cullen's 1995 mapping to do so.
- Develop criteria for identifying high priority sites for rehabilitation.

- Identify high rehabilitation priorities on the Central Plateau.
- Recommend future actions to most efficiently promote soil stability on the Central Plateau.

1.2. What can rehabilitation of degraded soils achieve?

The first goal of rehabilitation should be to prevent damage to areas that are not yet degraded, and to protect valuable features wherever they occur (Rutherfurd *et al*., 1999; Rutherfurd and Jerie, 2000). In many cases, this will be achieved by stabilising an area of degradation so that it cannot spread into adjoining intact areas. In other cases, restoring stability to a degraded area may be the primary goal. It is worth considering what can be achieved when working in such degraded areas.

The erosion on the Central Plateau involves damage to soils that formed over thousands or tens of thousands of years. In places, entire organic soil profiles have been burnt or eroded, resulting in a decrease in soil depth of up to 30 cm (Mitchell, 1962). In other areas, mineral soils have entirely lost the fertile A horizon and much of the B horizon, with soil depth decreasing by up to 45 cm (Cullen, 1995). The remaining soil is often very stony and lacking any organic content. In many cases, it is very shallow, and underlain by boulders or bedrock. In this situation, the return of a soil resembling the natural condition would require significant weathering of bedrock, or accumulation of tens of centimetres of organic material. Similarly, a lengthy and complex vegetation succession may be needed to convert largely bare ground to a community resembling the pre disturbance situation. These changes are clearly not possible within human timeframes, and as such, the recovery of the pre-European Central Plateau environment is not a practical management goal.

Rather than reconstruction of pre-disturbance conditions, the goal of rehabilitation here is to change the long term trajectory from deterioration to improvement. This means stopping further losses of soil and creating a stable environment where natural soil formation processes and vegetation succession can occur. This will also reduce off site impacts related to altered hydrology and increased sediment supply. This positive trajectory is reached when vegetation has stabilised the soil surface. Note that this simply requires a high vegetation cover, and does not necessarily mean the return of a vegetation community that resembles the natural state. Figure 2 is an example of the recovery of stability in a previously eroded area.

It should be acknowledged that this goal assumes that sites with close to 100% vegetation cover are in fact stable. This assumption should perhaps be tested, particularly on sites that have been badly eroded and have a very low biomass of vegetation despite the high cover value. These areas may still lack the robustness and resilience of undisturbed sites to natural disturbances such as drought, fire or intense frost. Similarly, achieving healthy re-vegetation does not necessarily mean that the site has regained a natural soil profile.

Figure 2. The difference between the return of full vegetation cover (left) and healthy vegetation (right), at New Year Lake.

1.3. The Central Plateau environment

1.3.1. Topography

The Central Plateau is an area of high elevation and generally low relief, bounded in the northwest, north and northeast by distinct escarpments. The Plateau boundary is less well defined to the south, where the land drops gradually down into the Derwent Valley. For this reason, the southern boundary of the Plateau is usually taken to be the 600 m contour (Pemberton, 1986).

Although the Plateau is characterised as having generally low relief, it does in fact include a large elevation range, from the 600 m at the southern boundary, to high peaks reaching over 1,600 m. The portion of the Plateau that falls within the study area has a elevation range between around 650 m in the Little Fisher River at the northwestern border of the park, and 1,490 m at St Davids Peak. Much of this elevation change occurs through a series of relatively distinct steps, described by Davies as erosion surfaces (Davies, 1959). The study area includes three erosion surfaces, as well as intermediate areas and lower surfaces. The three main surfaces are (Figure 3):

- the Lower Plateau Surface (roughly 915 to 1,065 m),
- the Higher Plateau Surface (roughly 1,190 to 1,340 m), and
- the High Monadnocks (remnant peaks and ridges between 1,340 and 1,614 m).

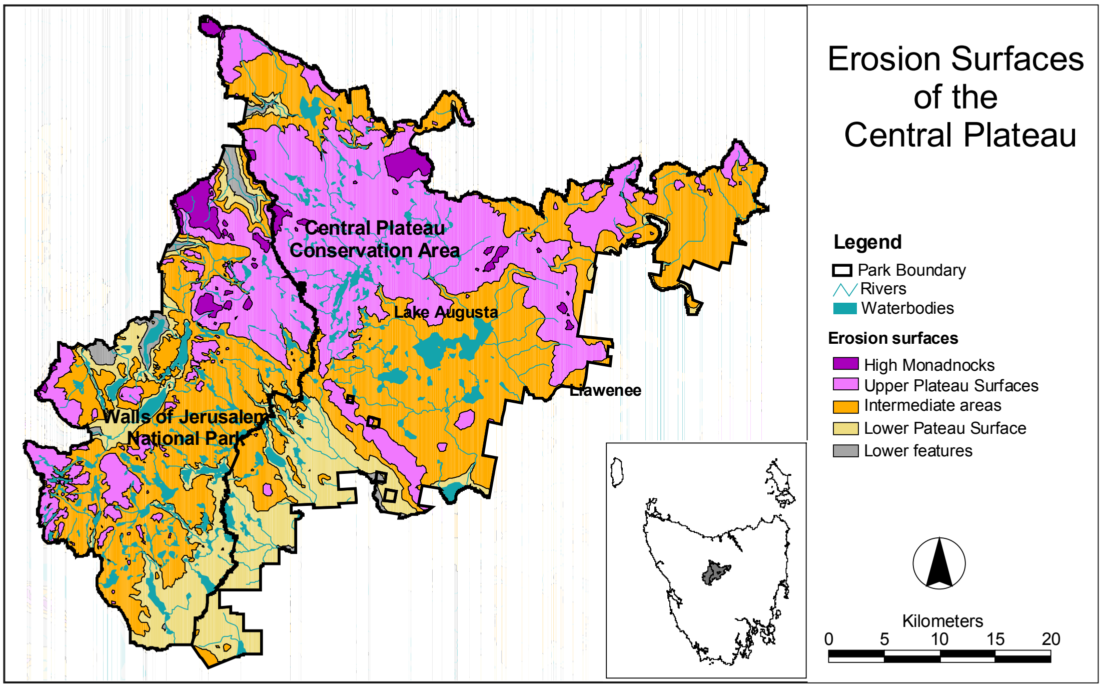

Figure 3. Davies' erosion surfaces on the Central Plateau (derived from Davies 1959).

1.3.2. Recent geomorphic history

The geomorphic history of the Plateau has influenced the local topography, geomorphology and soils. This has a strong effect on the intensity and form of erosion. The Plateau has been glaciated multiple times during the past two million years (Kiernan, 1990; Colhoun *et al.*, 1996). The extent of ice development has varied between glaciations, with the most recent ice cover, around nineteen thousand years ago, being considerably smaller than the maximum extent of ice (Colhoun *et al.*, 1996). However, even at its maximum extent, the ice appears to have been restricted to the western part of the study area, with areas to the east of Lake Augusta remaining free of permanent ice. As such, the Plateau can be roughly divided into periglacial and glaciated landscapes, according to which process dominated during the Last Glacial Maximum.

In areas not covered by ice, intense periglacial processes have operated. These are related to freezing and thawing processes, the effects of frost, and the development of ground ice, amongst others (Colhoun, 2002). There are also localised areas where aeolian processes (wind erosion and deposition) have operated (Bradbury, 1994).

The periglacial region forms a landscape of rolling hills, with wide valley flats, broad ridges and long gentle to moderate slopes (eg see Figure 4). Steeper slopes do occur on small escarpments and rocky ridges, particularly in the north of the study area and along Great Pine Tier. Steep slopes are often mantled by boulder fields. However, away from these block streams, large visible boulders are relatively uncommon in the periglacial areas. Broad wetlands are common in this area, with streams often braiding through swampy valley fills and boulders. Where lakes occur, they are typically large, well defined, and relatively shallow. Figure 4 shows an example of this landscape.

These lakes are often associated with lunettes, which are crescent shaped sand dunes on the downwind side of the lake. These are formed from sand blown from beaches on the lake shore, and potentially the lake bed during dry periods (Bradbury, 1994). These dunes may be several meters high, and at Lake Augusta are 5-6 m above lake level. Associated with the lunettes are often parabolic dunes and sand sheets formed from sand blown out of the initial dune. These form areas of distinct, sandy soils.

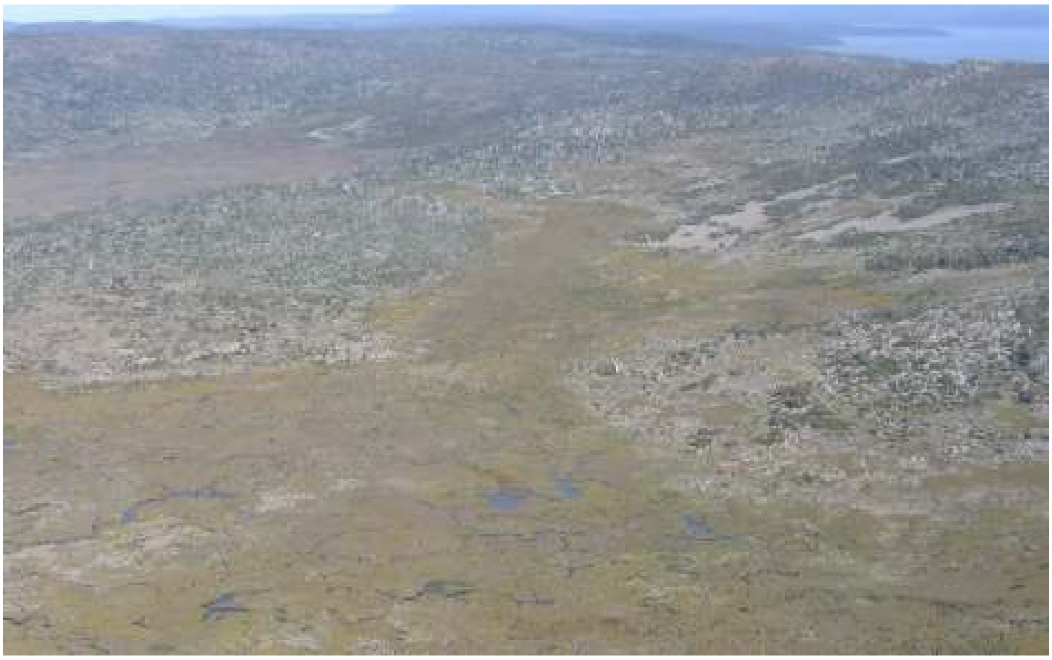

Figure 4. A periglacial landscape near Wild Dog Tier. Note the gently undulating terrain, the scree slopes and the swampy valley floor.

In contrast, the recently glaciated areas have a local topography that has a much rougher texture. Erosion and deposition by ice has in places exposed underlying bedrock features. In this part of the landscape, the structures in the dolerite can be clearly seen expressed in the surface topography, on top of which the ice has carved features such as roches moutonnees, whaleback ridges and rock basins (Colhoun *et al*., 1996). In other areas, the ice cap has deposited moraines that dominate the local topography, creating ridges and hummocks that can dam or divert watercourses. The topography in this ice cap area is very variable.

However, with the exception of some of the broad, bare bedrock areas, it is characterised by short, dissected slopes, hummocky terrain and disorganised and impeded drainage. Depending on the actions of the ice in the area, high points may be bedrock rises scraped clean by ice, or hummocky moraine deposited by the ice. Between these rises are hollows that are typically poorly drained, and contain small lakes or wetlands. Much of the region has a loose scatter of boulders deposited by the ice. The resulting landscape has few long slopes, but is highly dissected by the uneven topography and boulders (eg Figure 5). Soil depths can vary widely over short distances.

Within the recently glaciated area, stream and waterways are largely controlled by structural features in the rock, or glacial features including hummocky and ground moraines. The result is a dominant stream trend from north west to south east, with a secondary trend from nor-north east to sou-south west (Banks, 1973). There are a myriad of lakes and wetlands, ranging from tiny ponds through to big lakes such as Lake Pillans that have been dammed by large moraines.

Figure 5. Typical glaciated terrain near Lake Nutting. Note the undulating landscape, the frequent boulders and the many lakes.

1.3.3. Geology

The geology of the Central Plateau is dominated by Jurassic dolerite, which is mapped as covering some 98% percent of the area (Figure 6). Dolerite formed as an intrusive igneous rock, injected between layers of the flat lying sedimentary rocks of the Parmeener Supergroup to form relatively flat sheets and sills. Dolerite sheets can be hundreds of meters thick, and as it is a hard erosion resistant rock this may have had the effect of preserving the level surface of the Plateau. Dolerite cracks as it cools after emplacement, forming networks of joints. Near the edge of the dolerite body, these joints divide the rock into platey structures only centimetres thick. Deeper inside, where the rock cooled more slowly, the joints form the characteristic dolerite columns that are often meters thick (Burrett and Martin, 1989). The structures in the dolerite are exploited by weathering processes, and are evident in the landscape of the Plateau.

Parmeener Supergroup rocks are sedimentary rocks of Permian and Triassic age. Mudstones, siltstones and sandstones are common. These are the rocks into which molten dolerite was injected in the Jurassic. Outcrops of Parmeener occur beneath the dolerite around the margins of the Plateau, but are rare on the Plateau surface. Within the study area only very limited areas of Pameener outcrop have been mapped. These are chiefly restricted to some deep river valleys in the west of the Walls of Jerusalem National Park. On the Plateau itself, no outcrops have been mapped, but the occurrence of Parmeener sediments has been inferred in several places from the presence of quartz dominated lake shorelines and dunes that could not have been derived from dolerite (Bradbury, 1994; Cullen, 1995). These occur at Wadley's Lake, near Pine Lake, and at Carter Lakes.

Tertiary basalt flows of considerable size are evident on the eastern side of the Central Plateau, around Great Lake. However, for the most part these are outside the study area. Basalt is mapped within the study area west of Lake Augusta, along the Ouse River downstream of Lake Augusta, south of Double Lagoon and near Lake Flora.

Quaternary deposits include lake and river sediments, sand dunes, organic soils, moraines and glacial outwash, and periglacial slope deposits.

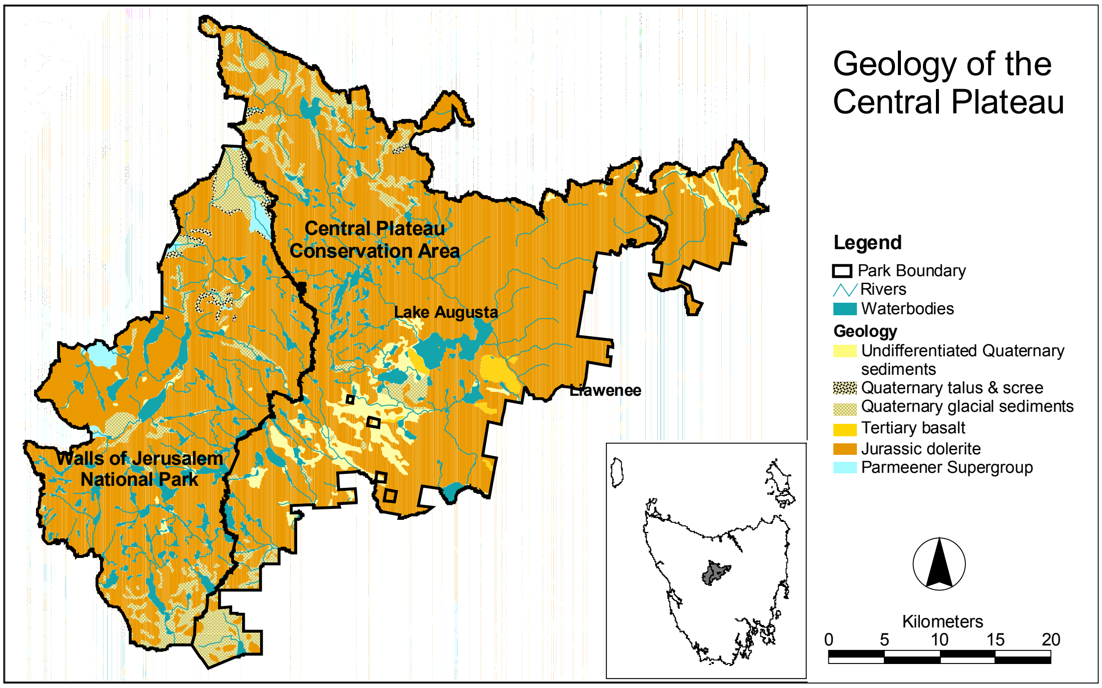

Figure 6. Geology of the study area. Based on 1:250,000 digital geology maps produced by Mineral Resources Tasmania in 1997, which in turn were derived from 1:63,360 scale mapping produced between 1956 and 1970.

1.3.4. Climate

The climate of the Central Plateau reflects its elevation and southern latitude, in that it is cold, windy and seasonally both wet and dry. The climate has a major role in driving ongoing erosion and determining the rates of vegetation recovery (see Section 3.2.1). In particular, frost is an important driver of erosion, and the short growing season limited by cold winter and spring and late summer drought limits the rate of vegetation recovery.

There is a strong precipitation gradient across the Plateau, due to a rain shadow effect from the western ranges (Pemberton, 1986). On average close to 3,000 mm falls at Lake Mackenzie in the north west (Jackson, 1973), and just over 1,000 mm at Liawenee to the east of the study area. This gradient is also present in modelled effective precipitation. Effective precipitation is the precipitation that remains once evaporation losses have occurred. This varies from just under 1,800 mm in the southwest to less than 600 mm in the east of the study area (see Figure 7). There is also a gradient in rainfall intensity, with falls of up to 80 mm in

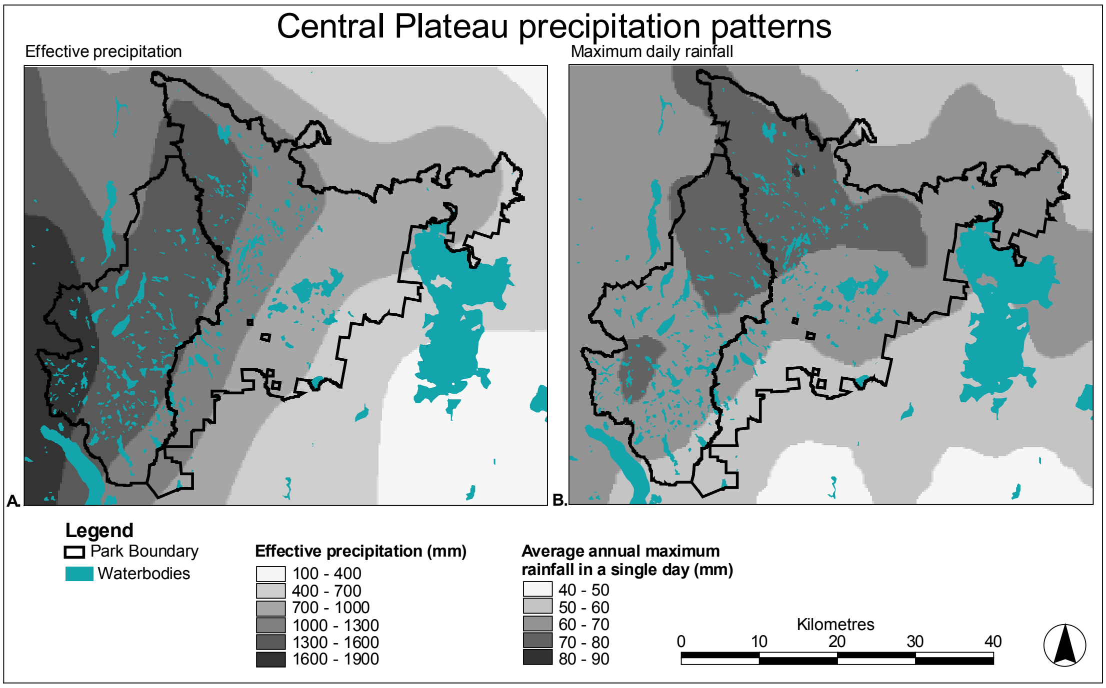

Figure 7. A. Average annual effective precipitation across the study area. B. Rainfall intensity (average annual maximum daily precipitation). Produced from data modelled by the Bureau of Meteorology in 2000 for Jerie *et al.* (2003).

a single day on the higher Plateau surface in the north of the study area, but a maximum of only 60 mm per day in the south east (see Figure 7).

The closest Bureau of Meteorology station to the study site is at Liawenee on the drier eastern side of the study area. This station is at 1,065 m asl which is several hundred meters lower than the Upper Plateau Surface where the bulk of erosion has occurred. Weather stations to the west and south are more distant and at lower elevations, eg Lake St Clair at 750 m and Cradle Valley at 900 m. The weather station data described here comes from the Bureau of Meteorology web site (BoM, 2004). There is a weather station maintained by Hydro Tasmania at Bernacchi, but this data was not obtained as part of this project.

At Liawenee, the average maximum daily temperature varies from 18.7 ºC in February to 5.5 ºC degrees in July. Temperatures occasionally exceed 30 ºC. Average minimum temperatures vary from 5.5 ºC in January and February, to almost –2 ºC in July and August. Frosts occur throughout the year, and are very common in winter. On average, 23 August nights drop below 0 ºC each year. It is common for frosts to build over several nights, as day time temperatures may not get high enough to melt ice. The Upper Plateau Surface, which covers roughly a third of the study area, is likely to get considerably colder than the Liawenee area as it is between 100 and 300 m higher.

On average, just over 1,000 mm of precipitation falls each year at Liawenee. Late winter and spring receive the most precipitation, averaging over 100 mm per month. Summer and early autumn months are drier, with February having an average of only 48 mm. There is a short record of summer evaporation rates. This shows average rates of evaporation exceed average rainfall between November and March, indicating summer drought. There is no data on winter evaporation rates, but these are likely to be very low, given that rain falls on average for more than 20 days each winter month.

Snow and hail can occur at any time of year, although it is most common in winter and spring. Falls may descend to quite low altitudes, but generally does not lie on the ground for long periods. Only in sheltered patches at higher altitudes is snow likely to remain for extended periods (Pemberton, 1986).

1.3.5. Soils

The character of soils obviously has a very direct impact on an area's susceptibility to different types of erosion, and the potential rates of recovery from disturbance. The soils of the Central Plateau have been surveyed by Pemberton (1986). This work showed that organic, gradational and uniform soils (Northcote, 1979) all occur in the study area.

Pemberton (1986) found that gradational soils cover over 90% of the Central Plateau. These soils typically grade from a sandy loam, loam or clay loam at the surface to a clay loam or light clay at depth. They are often very rocky, particularly where they have formed on dolerite, as is the case over the bulk of the study area. Rock fragments may be layered in the soil profile, although they are more commonly poorly sorted. Fragments vary in size depending on the location, from gravel to the extreme case of boulder deposits that have only small accumulations of soil between the rocks. The gradational soils are mostly shallow, with A horizon depths typically between 5 and 20 cm, and total soil depth typically between 20 and 50 cm.

Organic soils (peats) are common within the study area, occurring in waterlogged and cold areas. They are more widespread at higher altitudes and in the higher rainfall areas in the west of the Plateau. Pemberton (1986) found peaty soils where impeded drainage occur. They are common along drainage lines and swampy depressions. In higher altitude or wetter areas, organic soils may also be found on lower slopes, amongst boulderfields and in flat areas at any level in the landscape. The organic horizons were typically between 20 and 30 cm deep, and mostly underlain by loamy or clayey mineral soils, sometimes with rock fragments. In glaciated areas peat may overlie boulder clay or other glacial material. The only deep peats were found in the hummocky terrain of the glaciated area, and swamps in the Lake Augusta area.

Within the study area, uniform soils occur only on the lunettes in the Lake Augusta area, and potentially also some alluvial soils in the Gunns Lake land system (Pemberton, 1986). Lunettes are deposits of sand, eroded by wind from beaches or from lake beds during dry periods, and deposited as sand dunes on the downwind flanks of the lake. These dunes form deep uniform soils of undifferentiated sand. These soils are some of the deepest on the Plateau, and are typically greater than 1.5 m deep.

1.3.6. Stream geomorphology

Field reconnaissance and previous work suggests that there is considerable erosion on the Plateau associated with drainage lines. For this reason, it is important to consider the variation in stream character around the Plateau, in order to understand the past and present drivers of this erosion, and how rehabilitation might be attempted in such an environment. There is little existing work on stream character in this area, and time constraints have precluded any detailed analysis of stream geomorphology as part of this project. Therefore, a very superficial overview of stream geomorphology on the Plateau is presented below. The topic warrants a more detailed study, both for the information it could yield on broad scale erosion, and because these systems are themselves worthy of study.

Stream character is influenced by catchment size, local topography, the character of the sediment and substrate (includes combinations of bedrock, moraines, organic sediments and stream sediments). Several broad categories of waterway have been recognised, and are listed below. Note that this is by no means an exhaustive list.

- Steep streams tightly controlled by bedrock or boulders (eg Figure 8A). These streams are able to erode stream beds or valley bottoms only in small patches of sediment between rock controls. These basins are typically in the order of tens of meters long. Within such small basins, the stream often has multiple channels and may flow through tunnels. The potential for erosion in these zones is significant, but is limited by the regular rock controls. These streams are common on the higher Plateau surface, but occur throughout the study area.

- Broad gently sloping rocky valley bottoms with multiple channels (eg Figure 8B). These valleys are common in the periglacial areas of the Plateau. Boulders, probably of periglacial origin, are present across the valley floor. Stream deposits and peat are present between boulders, sometimes to significant depth. However, boulders are a major control on the development of drainage lines. Within the valley bottom zone, streams are highly disorganised and typically take the form of multiple channels braiding through the boulders. These streams have significant potential for bank erosion and the change in the number or dominance of channels over quite large areas.
- Low gradient rivers on deep erodible mineral sediments (eg Figure 8C). In these reaches sediment deposition has largely covered the underlying boulders. As a result, streams show relatively little control by bedrock or moraine, and are prone to lateral erosion. However, they appear to lack the power to erode vertically. In some areas distinct levees are present, which may influence patterns of lateral erosion. They are most common around the central parts of the study area, from north of Lake Augusta to the area around Lake Kay.
- Tributary streams on toe slopes of wide valleys (eg Figure 8D). Where steep, rock controlled streams reach broad valley bottoms they tend to deposit sediment as the water disperses across the valley floor. These areas are prone to lateral erosion and bed incision. The natural form of streams in this context has not been described, but is likely to involve multiple channels. These streams are common along the broad valleys of the periglacial areas of the Plateau.

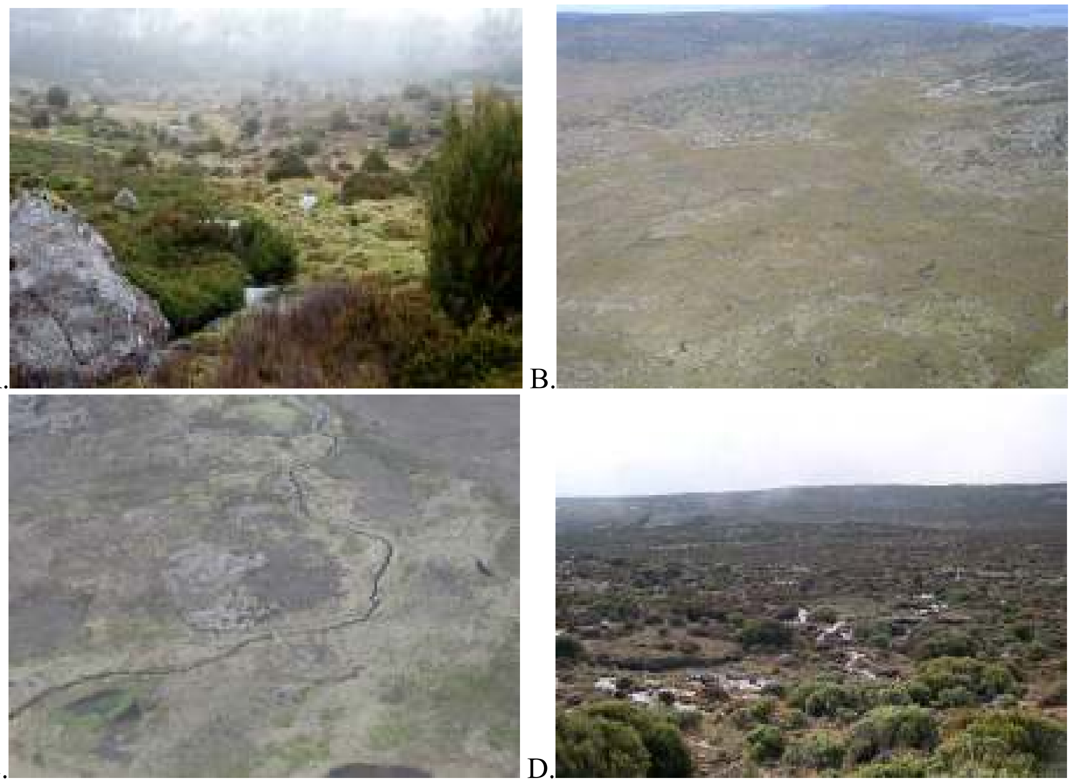

Figure 8. A. A small stream near Lake Fanny with regular boulder controls. B. A broad valley bottom near Wild Dog Tier with multiple stream channels. C. A low gradient stream near Devils Den, north of Lake Augusta. D. Eroded tributary streams on the toe slopes of Wild Dog Tier.

1.3.7. Vegetation

The vegetation of the Central Plateau has been described by many workers, most recently and thoroughly by Corbett (Corbett, 1996). The vegetation is diverse, including forest, woodland, shrubland, heathland grassland, sedgeland and herbfields (Pemberton, 1986). The controls on vegetation distribution include frequency of low temperatures and storms, soil, aspect, drainage and fire history (Jackson, 1973). Because the area, particularly the upper Plateau surface, is close to the tree line, small variations in site conditions cause major changes to the vegetation (Jackson, 1973; Corbett, 1996). Vegetation has also been extensively influenced by the history of landuse, which is discussed in the next section.

Eucalypt woodland is common on well drained rocky sites, and is more common on the lower Plateau surface. This vegetation type is dominant south of the Great Pine Tier. Woodlands of Pencil Pine are widespread north of the Tier, but are very sensitive to fire, and so are now restricted to areas that have not been burnt, including wetlands and on talus slopes.

The northern Plateau has large treeless areas, covered by wet alpine heaths, and *Sphagnum* bogs in poorly drained areas. In areas effected by fire, there is a mosaic of grassy heath and *Restio* swamps. Cushion moorlands and swamps occur in wet areas. Near Lake Ada and Augusta, distinctive grasslands occur in an area of deep soils. Fjaeldmark can be found in some locations where soils are shallow and dominated by rock fragments.

Wet forest and rainforest chiefly occur at lower altitude sites around the margins of the study area.

1.3.8. History of landuse on the Central Plateau

The landuse history of the Central Plateau is important to this study because it has a direct impact on soil stability. Cullen (1995), Pemberton (1986) and Mitchell (1962) all identified land use, in particular grazing and burning, as being largely responsible for initiating erosion in the area. Any process that creates bare ground leaves the soil open to erosion by frost, rain, flowing water, and wind, which then cause ongoing erosion. After the initial disturbance, factors such as grazing pressure, frost heave, summer drought and changes to soil character slow vegetation recovery and so extend the time span of that erosion. In this way, fire is very effective at promoting erosion, particularly when it is of sufficient intensity or frequency to destroy organic horizons. Similarly, overgrazing and trampling by stock, feral, or native animals can also cause erosion and prolong the recovery process.

Prior to European settlement, the Central Plateau was seasonally occupied by several Aboriginal bands (Cosgrove, 1984). Potential impacts on soil stability could have been through the use of fire, track development and soil disturbances caused by digging for foods. With the exception of fire which is discussed below, it appears unlikely that they caused widespread soil erosion.

Since European settlement, the Plateau has been used for grazing, hunting for the fur trade, fishing and other recreational activities and as a water catchment for hydro electricity generation.

Grazing began on the Plateau by 1825 (Cullen, 1995), and by the late 19th century there were around 350,000 sheep and 6,000 cattle grazed in the area over summer (Shepherd, 1973). Levels of stock dropped through the 20th century, in response to a variety of pressures including deterioration in the natural pastures. This deterioration has been linked to ‘frequent and severe burning of vegetation to promote green pick’ (Shepherd, 1973), and also to deliberate overstocking to produce hunger fine wool. Overgrazing was exacerbated by rabbits. These were reported to be in plague proportions between the 1920’s and 50’s, until numbers were reduced by the introduction of myxomatosis. In 1989 the study area was included in the Tasmanian Wilderness World Heritage Area, and grazing by domestic stock was stopped due to concerns over the impact on the conservation values of the area.

The Plateau is used for recreation, in particular for fishing, hunting, four wheel driving and walking. Trout were first introduced to Great Lake in 1870 (Jetson, 1987), and were in lakes in the central part of the study area by 1919 (Cubit and Murray, 1993). The impacts of these activities on soil stability is largely limited to localised effects of 4WD tracks, walking tracks and camp sites. The most significant impacts of recreational activities are related to the small scale raising of lake levels to improve fishing conditions, as has occurred at Lake Ada. These have resulted in shoreline erosion and destabilisation of some lunettes (Bradbury, 1994).

Professional hunting was popular on the Plateau, particularly during the early part of the 20th century. At times a significant income could be generated from selling skins, and hundreds of hunters worked in the area, with numbers decreasing after the Second World War (Cubit and Murray, 1993). Rabbits, wallaby and possum were commonly targeted. There are reports of hunters burning open plains in October and November to encourage fresh growth to attract animals for the hunting season the following winter.

Hydroelectric development of the Plateau within the study area is mainly centred around the damming of the Lake Augusta Impoundment in 1953, in the south east of the study area, and Lake Mackenzie in the north west, completed by 1973. These developments have had localised but significant impacts on soil stability on the Plateau, related to shoreline erosion, quarrying, and road construction. In particular, raising of the Lake Augusta is thought to have been responsible for significant erosion of the surrounding lunettes (Bradbury, 1994; Stone, 2001). As the enlarged Lake Augusta is empty for a significant portion of the year, there is also significant wind erosion from the exposed lake bed (Bradbury, 1994). It is interesting that 35 years ago, the large areas of un-vegetated ground on the Plateau were considered potentially useful for minimising evapotranspiration, and so maximising water yield to the hydro-electric schemes (Edwards, 1973b). However, it was also acknowledged that vegetation played an important role in increasing precipitation by trapping fine water droplets in mist at high altitude.

1.3.9. Fire history

Pre-European fire regimes on the Plateau are difficult to reconstruct (Cullen and Kirkpatrick, 1988). There are records of the indigenous people of the area burning large parts of the Central Plateau landscape, and this was thought by the settlers to be responsible for the presence of open grasslands (Cosgrove, 1984; Jetson, 1987). However, most records of burning come from the plains on the lower Plateau surface to the east of the study area (Cosgrove, 1984). It is not clear how frequent fire may have been in the higher areas of the Plateau. What is clear is that large areas of fire sensitive vegetation including coniferous heaths on the upper Plateau have been killed by wildfire in this area since European settlement (Cullen and Kirkpatrick, 1988). These vegetation types appear to be highly flammable, as only small areas of unburnt vegetation remain (Corbett, 1996). If Aboriginal burning did occur, it must have had a very different impact to European burning.

Johnson and Marsden-Smedley (2001) constructed post-European fire history maps for the northern parts of the World Heritage Area from historical records and aerial photography. Within the study area, they identify several small fires prior to and including the 1930's, which burnt approximately 1,500 ha in the vicinity of the Walls of Jerusalem. Unfortunately, there are no records of many of the fires lit since European settlement by explorers, and by graziers or hunters to encourage green pick. These fires were not reported or mapped at the time (Mitchell, 1962). Some fire scars appear on the air photo record, but this record only begins in the late 1940's or early 50's, and early photos are often of poor quality within the study area (Johnson and Marsden-Smedley, 2001). This means that the extent, frequency or intensity of fires cannot be determined.

In 1961/62 a major group of fires burnt over 84,000 ha of the study area (Johnson and Marsden-Smedley, 2001). These fires burnt for around six months, and destroyed many vegetation types and organic soils (Edwards 1973 in Pemberton, 1986). Mitchell (1962) writing soon after these fires, reported areas where peats had been burnt completely, leaving ash and sand some 30 cm lower than the original soil surface. Writing in 1986, Pemberton (1986) reported that "the burnt areas have a semi-desert appearance due to lack of vegetation, soil and severe sheet erosion". This is still true of some areas today (see Figure 9).

Several smaller fires have occurred since 1962. These include fires in the vicinity of Nells Bluff, Pine River, Parsons Track, Double Lagoon, Dunnings Rivulet, Sales Lake, Gowan Brae, and Doctors Point. Information on most of these is summarised in Johnson and Marsden-Smedley (2001).

Impacts of fire are likely to be particularly intense when repeated fires occur within 35 years (Corbett, 1996). This can result in the combustion of the organic soil horizons, as dead stems and roots from plants killed in earlier burns lead the fire into the soil profile.

Figure 9. Broad scale erosion at Wild Dog Tier - a very cold wet desert.

1.4. Previous research on Central Plateau erosion and vegetation

1.4.1. Soil erosion

Soil erosion on the Central Plateau has been noted by many authors, including (Mitchell, 1962; Edwards, 1973b; Shepherd, 1973; Pemberton, 1986; Cullen, 1995). Of these, the most systematic assessment of erosion has been work by Phil Cullen (Cullen, 1995). Combining mapping from 1990 1:25,000 scale aerial photography with considerable fieldwork, Cullen produced maps of erosion intensity and distribution. He mapped erosion in three intensity categories: moderate, severe and extreme (see Table 1). He identified around 10,890 ha of eroded ground, and estimated that this represented the loss of some nine million cubic metres of soil lost as a result of European land management. The erosion occurs mainly as small to medium sized patches across the Upper Plateau Surface and slightly lower elevations. The map of eroded areas is reproduced in Figure 10.

Table 1. Characteristics of erosion classes mapped by Cullen (1995)

Erosion intensity	Percent bare ground	Soil depth lost (cm)	No. patches mapped	Average patch size (ha)
Moderate	10 – 40	2 – 45	3,882	2.0
Severe	40 – 70	4 – 35	804	3.7
Extreme	70 – 100	7 – 28	151	1.1

As well as mapping erosion, Cullen investigated the causes of soil erosion. He found evidence of fire at 87% of eroded sites, and evidence of rabbits at 62% of eroded sites (eg see Figure 11). He concluded that these were dominant causes of soil erosion. He also established permanent quadrats to monitor rates of vegetation recovery and soil loss with and without grazing by native mammals and rabbits. Since establishment, these sites have been monitored by Kerry Bridle and others (Bridle, 1997; Bridle, 2000; Bridle *et al*., 2001). Unfortunately, the erosion pins intended to measure soil loss are thought to have been disturbed by frost heave to such an extent as to render any measurements meaningless, and only vegetation measurements have been made.

1.4.2. Recovery of native vegetation

Information on rates of vegetation change over time comes from monitoring permanent quadrats, a PhD project and trials of the effects of trampling.

Kerry Bridle and others (Bridle, 1997; Bridle, 2000; Bridle *et al*., 2001) have monitored vegetation changes in permanent quadrats on the Plateau, including those established by Cullen (1995) in 1991, and two other sets of plots established in 1973. The monitoring and analysis of these plots measured changes in vegetation cover over time, and investigated the influence of grazing and the initial proportion of bare ground on that rate of recovery. Analysis of the older quadrats also examined which life forms colonised bare ground.

Across all sites and treatments over a 5 – 23 year period, there was an average increase in vegetation cover of just over 1% per year (Bridle *et al*., 2001). Rates were slightly higher in the older quadrats (around 1.3%), but it is not clear to what extent this may be a real trend, an effect of climatic fluctuations over time (Bridle *et al*., 2001) or even sampling error. The study detected no significant effect of the grazing treatments, but noted that rates of increase in vegetation cover were lowest (only 0.65% per year) when grazers where present.

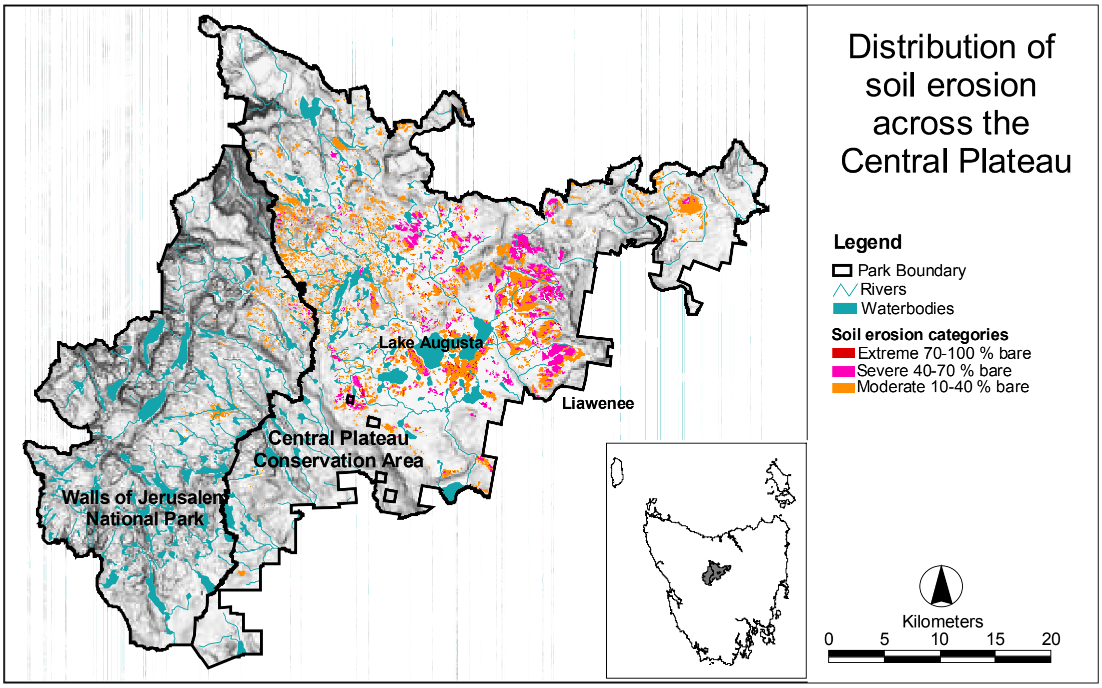

Figure 10. The distribution of the three erosion classes mapped by Cullen (1995).

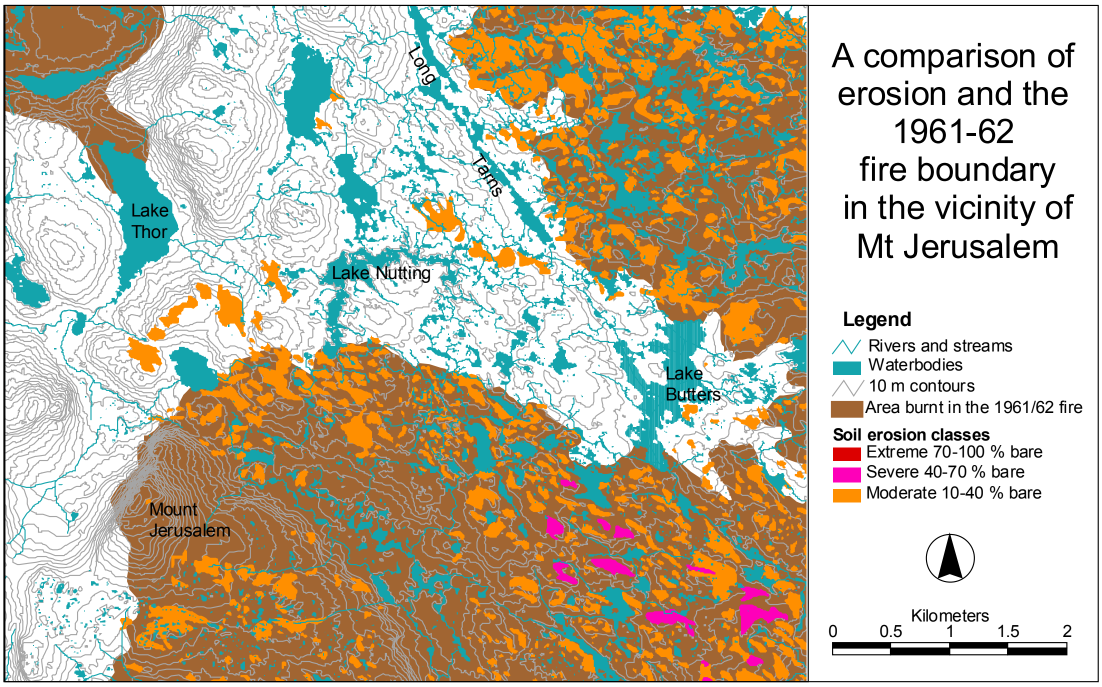

Figure 11. The relationship between erosion (Cullen, 1995) and the fire boundaries from Johnson and Marsden-Smedley (2001) in the Mt Jerusalem area.

Extrapolation of these measured vegetation recovery rates across the Plateau is difficult. These quadrats sample a limited range of environments. Also, the intention of Cullen's study was to monitor the effect of grazing on vegetation cover, so the recovery rates observed reflect the unnatural situation where some or all vertebrate grazers are excluded. As such, it is only the unfenced control plots that can be used as a measure of the present revegetation rates. Finally, the variability in the data adds to difficulties in interpretation.

Examination of the data presented in (Bridle, 1997) shows that in unfenced quadrats the changes in vegetation cover were highly variable. Although the overall rate of vegetation cover increase was 1% per year, 22.5% of the plots set up by Cullen had increased their proportion of bare ground after five years. Where quadrats initially had a very high proportion of bare ground rates of recovery were slower. In contrast, only 7% of the 23 year old plots showed an increase in bare ground over the whole period of monitoring.

Generally, shrubs were the most important colonisers of bare ground (Bridle *et al* (2001). The quadrats at Wild Dog Tier were an exception to this pattern, possibly because of the exposure of the site to harsh climatic conditions.

A PhD student (School of Plant Science, University of Tasmania) studying the impediments to revegetation on the eastern Plateau is almost complete. Wieslawa Misiak has studied seed production, dispersal and predation, seedling germination rates and survival in different micro-environments, the frequency and intensity of frost heave, and how that is effected by plant cover, and by laying jute or slash. She has found that although seed production varies between seasons, in general, plentiful seed is produced by remnant vegetation. Post dispersal seed predation by invertebrates is unlikely to limit seed availability. Seed harvesting species do not occur in the area, and no seeds were removed from seed bait stations by ground dwelling invertebrates. Large numbers of seedlings germinate across a range of micro-environments. However, in bare ground these are killed by frost heave, summer drought or exposure to temperature extremes. Seedling survival rates are significantly higher where some vegetation cover exists, particularly *Grevillea australis*, which has a prostrate form on the Plateau. Laying jute and slash does have a positive effect on the microclimate of eroded sites, increasing minimum temperatures and humidity, and reducing the frequency and intensity of frost heave events. However, Michael Comfort's work at Bernacchi (described below) suggests that this amelioration is not sufficient to increase revegetation rates.

Whinam and others have looked at the effect on vegetation of trampling by horses (Whinam *et al*., 1994) and by walkers (Whinam and Chilcott, 1999). Their work has found further evidence for increasing bare ground over time since disturbance. This work has also found that the prostrate shrub *Grevillea australis* is very prone to damage by trampling, which can result in the death of part or all of the prostrate shrub. This has important implications given the potential nursery role of *Grevillea* described above.

1.4.3. Rehabilitation work

In the last decade the Parks and Wildlife Service, and the Department of Primary Industries and Water have established ongoing rehabilitation works and several trials of rehabilitation techniques at several sites on the eastern Plateau. In general, these efforts have had a primary goal of improving a local problem, rather than being part of a systematic approach to improving the condition of the Plateau as a whole.

Rehabilitation works to date have been concentrated on intense but localised degraded areas. These include mechanically disturbed sites along the Lake Augusta Road (quarries, borrow pits and other areas disturbed during road or dam construction) and on eroding areas on the lunettes at Lake Augusta, Lake Ada and Double Lagoon, caused by trampling, vehicle access and the effects of artificially raised lake levels. These sites were considered high priority because of the high conservation value of the eroding feature, in the case of the lunettes, or because of the potential for further environmental damage in the form of vehicle access and weed invasion in the mechanically disturbed areas.

Rehabilitation works have taken the form of combinations of earthworks such as ripping or spreading imported soil material, fertilising, seeding with locally collected seed, planting tube stock, applications of jute or slash, and fencing to exclude grazing, digging and trampling by rabbits, native mammals and humans (eg Figure 12). Works have occurred at intervals over the last decade, and most have required maintenance. Most of these sites have been informally monitored by observation and photographs. Results have varied between highly successful and negligible improvement in site conditions. Table 2 below summarises this information.

Figure 12. Jute and slash sausages as sand fences (foreground) and jute layed over bare sand (background) at the Lake Ada Lunette.

Table 2. Rehabilitation efforts on the eastern Central Plateau to date.

Site name and type	Date	Works conducted	Comments
Lake Highway			
Roadside disturbances, quarries and dumps	1992	Various sites direct seeded, fertilised and slash laid.	No monitoring details available, though many sites have subsequently been retreated indicating initial works may have had limited success.
Halfmoon spoil dump	1996	Following the dumping of spoil from roadside works, the site was direct seeded (*Hakea, Leptospermum, Poa*, and *Eucalyptus* species) and fertilised.	*Poa* now dominates the site with the odd *Eucalyptus* and other species slowly appearing.
	2004	Limited slash placed on bare area previously untreated.	Limited seedling germination to date under slash.

Mickeys Creek scrapes and others	2004	Small sites treated with: Jute Jute slash sausages Placement of slash Fertilised and weed control works.	Good self-seeding occurring, especially where seedlings protected from browsing under slash.
	2006	Low fencing erected around a number of sites by DIER.	*Poa* growing well in fenced areas, weeds however are of potential concern.
Liffey diversion canal			
Disturbances associated with canal construction	1992 1993	Removal of clay spoil heaps. Seeded and fertilised.	*Poa* established with few additional species. There is little recruitment of heath species from the surrounding area.
Lake Augusta Road			
Bare roadside areas	1992 1993 1994	Soil from road widening was spread and *Poa* seedlings (11,000) planted.	*Poa* tussocks established, however few additional species have become established in treated areas.
Mechanically disturbed sites adjacent to and along the Lake Augusta Road including: Lake Ada boat ramp and closed track, Lake Augusta west quarry and levee, Carter Levee, large scrapes and quarries (see Comfort 1999)	1999 2000	Works conducted included: Minor earth works, ripping, spreading of windrowed material and imported soil Spreading slash Direct seeding Planting of tubestock Fertilising Fencing and Rubbish collection.	Earth works conducted in 1999 utilising a 20 tonne excavator and 10 tonne trucks, teams of volunteers under supervision used for much of the manual work. Recovery is occurring at most sites treated with a range of revegetation rates, though it is quite slow at many sites. Planted tubestock was heavily browsed and if not protected often pulled out. Small rocks were found to be useful in protecting tubestock.
Lunettes			
Lake Ada lunette (see Comfort 2006)	1994 1995 1996	This was the first lunette to attempt rehabilitation works on with a number of treatments trialed including: Jute slash sausages Various geo-fabrics including, jute, jute-master, coconut matting, wool mulch mats Timber water bars and Jute sand fences.	Of the various geo-fabrics trialed, jute matting was the longest lasting. Wombats were found to interfere with some treatments. Jute sand fences proved ineffective. Trial demonstrated need for ongoing maintenance works for many years in this environment with recovery extremely slow.

Lake Augusta, Double Lagoon and Lake Ada (continuing) lunettes maintenance works (see Comfort 1999, 2000 and 2006)	1999 2000 2001 2004 2005	Following on from the above initial works, a more extensive program of rehabilitation works was instigated with ongoing maintenance activities. Works included: Jute laying Fertilising Use of slash and jute sausages Laying of slash Fencing Direct seeding and Planting of tubestock.	Recovery on the degraded lunettes has been slow but there is now evidence that the sites are stabilising and revegetation is occurring. Isolated sections of dune face collapse still occur and require on going maintenance.
Sheet eroded country			
Second Bar Lake, Wild Dog Tier, Talinah Lagoon and Lake Flora (see Comfort 2000)	2000	A number of sites were treated by laying double thickness of jute, fertilising and the placement of limited slash.	Areas of severe sheet erosoin were targeted under this program after succuss with similar treatments on the lunettes, however results to date have shown little recovery on the severe sheet eroded country.

1.4.4. Rehabilitation trials

The lunettes and mechanically disturbed ground where rehabilitation efforts have been successful are very specific environments that are not typical of the areas where broad scale erosion occurs on the Plateau. With this in mind, several experiments have been established to test the suitability of these techniques for other areas of the Plateau. These include DPIW initiated works including Phil Cullen's exclosure quadrats described above, a trial of a variety of techniques at Talinah Lagoon, and a second trial at Bernacchi, and a trial developed by Jim Yates of the University of Tasmania School of Agriculture in the early 1970's. These are summarised in Table 3 below.

The rehabilitation treatments that have been trialed included various combinations of excluding some or all grazers, planting cutting or tubestock of several different species, laying jute or slash and fertilising. Cullen's quadrats and the Bernacchi trial have been carefully monitored with a series of before and after measurements of vegetation cover. At Bernacchi, these measurements have been made seasonally, allowing an assessment to be made of what processes may be limiting seedling establishment. In contrast, the Talinah Lagoon trial has no established monitoring program, greatly restricting the amount of information that can be gained from the trial. Yates' quadrats were monitored regularly for the first fifteen years and once more in 2003.

The only rehabilitation treatment applied to Cullen's quadrats was to exclude some or all grazing animals. The results to date have been described above, and can be summarised as a slight but not significant increase in the rate of vegetation growth in the absence of grazing (Bridle *et al*., 2001).

The Bernacchi trial involved various combinations of fertiliser (0, 1 or 2 applications), jute and slash. The trial has now been running for six years. The results have not yet been published but preliminary data analysis has shown that regardless of the treatments revegetation of these quadrats is extremely slow, typically in the order of 0.04% per year.

The most successful treatment appears to have been slash, however, even the most successful quadrat has only developed 4% veg cover, or 0.7% increase in cover per year. It must be acknowledged that these sites are representative of some of the harshest conditions on the Plateau, with no remnant vegetation present prior to the study and very disturbed gravelly soils typically between 10 and 20 cm deep underlain by bedrock and totally lacking any remnant A horizon. Unfortunately, such conditions are not rare.

The Talinah Lagoon trial has now been running for 11 years. Unfortunately, poorly established monitoring means that little can be concluded, other than the death of *Grevillea australis* cuttings and seedlings, and the survival of *Poa gunnii* and *Eucalyptus coccifera* seedlings. There is some observational evidence for erosion continuing around the established seedlings.

Yates' trial of pasture establishment on eroding ground involved repeated applications of fertiliser, sowing pasture grasses and a variety of clover species, mulching and fencing to exclude sheep and wild animals (Yates, 2005). Very high rates of fertiliser were applied, initially a 690 kg/ha of a mix of superphosphate, potash, urea and trace elements. A further 625 kg/ha of dolomite was added to some areas. Fertiliser applications continued annually at a variety of lower rates until the mind 1980s. Initial responses to treatment were the development of 'almost complete ground cover' of the introduced species in fertilised areas within three and a half years. After 35 years, fertilised areas have retained full vegetation cover, in marked contrast to neighbouring untreated areas. Introduced species remain at the site but are a relatively minor component of the cover. Some native species, in particular members of the Proteaceae family, are conspicuously absent from the treated areas. Unfortunately, quantitative measurements of the cover of different species under the different treatments is not available. A careful analysis should be undertaken to assess whether this intense fertiliser application resulted in a net benefit or loss to the conservation value of the site.

Table 3. Rehabilitation trial and monitoring sites on the eastern Central Plateau.

Site name and type	**Date**	**Works conducted**	**Comments**
Yates pasture establishment sites			
Trial site near Lake Augusta (Yates, 2005)	1971	Trial established on sheet eroded site to monitor effect of following treatments: Fertiliser Mulch Grazing exclusion Sowing introduced pasture species in various combinations	Response to the combination of fertiliser and sowing pasture species has resulted in close to 100% cover, regardless of degree of protection from grazing. Exotic species are still present at the site, and some native species are absent.
Cullen's browsing exclosure trials			
Established at Wild Dog Tier, Bernacchi, Double Lagoon and Lake Botsford (see Cullen 1995 and Bridle 1997)	1991	Long term monitoring sites with paired plots of: Rabbit & marsupial exclosures Marsupial only exclosures and control sites, established at four sites on sheet eroded country.	Recovery at all sites is slow and variable, with revegetation rate averaging only 1% per year across all treatments. Last monitored in 1996.

Talinah Lagoon			
Trial site on sheet eroded country east of lagoon	1995	The trial included a number of treatments: Fencing Fertilising Jute (single & double layers) Slash *Grevillia australis* planted direct from local cuttings and cuttings propagated in a nursery then planted out *Poa gunnii* seedlings *Eucalyptus coccifera* seedlings.	*Poa* and *Eucalyptus* seedlings have survived, however other species establishment has been limited. *Grevillia* cuttings did not survive. *Poa* responded favourably to fertiliser and exclusion from grazing. There is still evidence of ongoing erosion despite healthy *Poa* tussocks. Due to trial design it is only possible to obtain qualitative results from the different techniques trialed.
Bernacchi trial site			
Trial site on sheet eroded country	2000	Trial established on shallow soils in the extreme sheet eroded class to monitor effectiveness of following treatments: Jute Slash Fertiliser in various combinations.	Recovery under all treatments has been extremely slow with the best-recorded revegetation rate in one of the monitored quadrats after 6 years of 4%, though for most it was less than ¼%. Seedlings continue to germinate however nearly all do not survive the winter being physically forced up by frost heave.

1.4.5. Conclusions to be drawn from previous research

Some general conclusions can be drawn from this body of work. The common themes relate to slow rates of change, variability of features and processes and uncertainty. It is also worth mentioning that there is a bias in the existing experimental work to studying areas that are easily reached from Hobart, namely those parts of the eastern Plateau that are close to the Lake Augusta Road.

The work of Phil Cullen has shown clearly that the existing damage to soil and vegetation is widespread across the higher areas of the Plateau. However, there is considerable variability in erosion intensity at many scales.

Ongoing rates of change of both ongoing soil loss or gain and vegetation cover recovery have proved difficult to measure. In particular, rates of ongoing soil loss have not been successfully measured and are presently unknown. Rates of change in vegetation cover have been easier to measure, but again, the results that are available suggest rates are slow and variable. Both increases and decreases in vegetation cover have been observed. Vegetation recovery tends to be slowest where there was a very large initial proportion of bare ground. The effects of frost heave, summer drought, and temperature extremes appear to limit rates of vegetation recovery. It is possible that low soil fertility may also be important but at present there is insufficient data to say this with any confidence.

The response to rehabiltiation works and trials has generally been slow and variable, and appear to be specific to the local environment. All rehabilitation works have required and still require significant ongoing monitoring and maintenance. No rehabilitation technique has been clearly and consistently successful across all environments where it has been applied, although the reasons for this variability are typically unknown.

The only dramatic success in existing rehabilitation works or trials has been the fertiliser and pasture species trials of Jim Yates. These have resulted in almost complete vegetation cover that was reportedly reached only a few years after first treatment, and has been maintained over the following thirty years. However this has been at the expense of the local introduction of weeds and the loss of some native species. This work has not been repeated at any other locations within the study area.

More recently, rehabilitation efforts have had limited initial success on sandy areas of the lunettes, and in mechanically disturbed sites. It is possible that the reason for this success relates to the depth and fertility of soils still present at these sites. At most of these sites the rehabilitation still require ongoing maintenance. None of these sites has yet reached a stage where soil stability has been fully recovered.

In areas of severely sheet eroded ground, none of the rehabilitation methods trialed to date have been successful. The reasons for this are unclear, but probably relate to shallow soil depth, intense disturbance by frost heave and low soil fertility.

It is clear that at this stage, we do not have a good understanding of the controls on ongoing soil loss and vegetation recovery. There are likely to be critical thresholds in variables such as temperature extremes and the frequency and intensity of frost heave. These are presently unknown. We have no clear understanding of what governs the success or failure of rehabilitation works. This means that we have no ability to predict the outcomes of any intervention. Because none of the rehabilitation methods trialed on sheet eroded areas have been successful, new techniques need to be identified and trialed.