Natural Values of the Public Lands Along the Broken, Boosey and Nine Mile Creeks of Northeastern Victoria

A report to the Australian Heritage Commission
on the natural values, human uses and threatening processes found along the creeks with recommendations for listing and future management.

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To the Yorta Yorta people, traditional owners of all of the lands
and waters along the creeks.

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SUMMARY

In 1994, the Goulburn Valley Environment Group applied for funding from the Australian Heritage Commission to survey the natural values of the Broken, Boosey and Nine Mile Creeks system in northern Victoria (Fig. 1). The survey was undertaken because of the paucity of information about the natural environment in the eastern Northern Plains, because the creeks system represented the single largest remnant of woodland vegetation in the eastern Northern Plains and because much of the creeks system is bordered by public frontage, making changes in land management relatively straightforward.

This report documents the results of that biological survey along the 360 km of creek which was fronted primarily by public land. In brief, we found that the remnant vegetation along the Broken, Boosey and Nine Mile Creeks system provides a connected habitat network that:

- links many of the larger conservation reserves in the region
- represents the largest remaining example of grassy woodland in the eastern Northern Plains
- is of historical significance as one of the few surviving remnants of native vegetation of the Northern Plains landscape as it once was
- is of cultural significance for its many aboriginal artifacts and other cultural sites
- includes the largest patches of remnant vegetation in the region
- traverses a steep environmental gradient from southeast to northwest
- is ecologically distinguishable from most other Victorian creeks and rivers because of its riparian Grey Box vegetation
- is relatively intact, albeit simplified, because of a prescription in 1874 which prohibited timber cutting and cultivation
- provides habitat connectivity along the length of the creeks system for dispersing animals on land and in water
- contains a significantly higher proportion of old-growth woodland than most other remnants in the Northern Plains
- contains approximately one tenth of Victoria's native vascular flora
- contains 27 species of threatened plants and more than 100 species of regionally significant plant
- is the only known area in Victoria in which three plant species occur; Fat Spectacles, Pepper Grass and Spiny Saltbush
- provides habitat for 9 species of threatened bird, 16 species of declining bird and 7 species of waterbird with restricted or colonial breeding sites
- provides habitat for 1 threatened mammal (Squirrel Glider), 1 threatened frog (Barking Marsh Frog) and four species of regionally uncommon reptile
- provides habitat for 13 species of native fish, nine of which are listed as threatened and
- is one of the most important stream systems in the State for Murray Cod and Freshwater Catfish.

On the basis of these natural and cultural values, GVEG believes that the Broken, Boosey and Nine Mile Creeks system provides a special opportunity within the mostly cleared landscape of the eastern Northern Plains to expand the existing conservation reserve system in the Northern Plains and to create a significant conservation reserve for two of the most endangered ecosystems in Victoria and southeastern Australia - native grasslands and grassy woodlands (Frood & Calder 1987; LCC 1988; Foreman 1995; Ross 1994).

Currently however, the natural values and ecosystem future of nearly the entire creeks system are threatened by a range of short-term and long-term threats, notably: adjoining land-use activities, modification of the creek environment for industrial use; clearing of nearly all native vegetation from the surrounding landscape; over-grazing of the dryland environment, soil disturbance of the dryland and aquatic environments; and inundation and physical modification of the aquatic environment. Because of these many threats, 86% of the area surveyed was classified as being under moderate to severe environmental threat and only 0.4% of the survey areas was considered to be intact and not threatened.

Consequently, unless the remnant woodlands along the creeks system frontage and the associated creek waters are promptly accorded their true value as nationally significant remnants of the Northern Plains' natural heritage and managed for nature conservation, the natural and cultural values of the creek environment will inexorably decline.

The Goulburn Valley Environment Group consequently recommends that:

1. The dryland and aquatic environments along the entire Broken, Boosey and Nine Mile Creeks system should be managed primarily for conservation.

2. The most significant natural elements of the creeks system should be incorporated into a State Park.

3. Management within the State Park may vary in different sections, but the unifying objective should be to increase the habitat values and conservation values of the whole creeks system.

4. Use of the creeks system as a conduit for industrial water use should cease in the future and a new infrastructure should be developed to carry water around the region.

5. There should be unified management of the creeks system and adjoining land by the different land managers to ensure that recommendation 1 is achieved.

6. There should be an active program of habitat restoration along the creeks system to increase its ecological viability and value as wildlife habitat.

7. There should be an education program throughout the Goulburn-Broken catchment to highlight the significance of the Broken, Boosey and Nine Mile Creeks ecosystem as a fundamental part of our natural and cultural heritage in a landscape in which 99.97% of the natural environment has disappeared.

8. All current land-use and water-use activities should be done in accordance with the legal requirements of the various acts or regulations governing the management of the creeks' land, water and wildlife. In particular, all activities listed as potentially threatening processes under the *Flora and Fauna Guarantee Act* (1988) must cease or be modified in accordance with the conservation and management objectives of the Act.

Changes to text in relation to information previously published in the report 'Site-specific environmental values and threats of the land along the Broken, Boosey and Nine Mile Creeks system' (D. Robinson & S. Mann 1996).

1. Because of recent changes in classification status, the number of threatened plants found along the creeks increased from 25 to 27 species, the two additions being the Flat-sedge *Cyperus bifax* and Water ribbons *Triglochin dubium*.

2. Pale Poverty-bush *Sclerolaena divaricata*, a plant listed as regionally significant in the earlier report, was misidentified. All records of *Sclerolaena* are referrable to Five-spined Bassia *Sclerolaena muricata*.

3. Further analyses of the effects of grazing and earthworks on the natural environment revealed additional significant impacts. These are indicated in Tables 22 and 23.

4. More detailed recommendations have been provided for the future management of the creeks system by different authorities in Chapter 5.

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INTRODUCTION

In the 1870s, the Grey Box *Eucalyptus microcarpa* woodland along the Nine Mile and Broken Creeks between Drumanure and Numurkah was so dense that '*Mr Brenion ploughed a furrow for his children to follow...*' and other parents blazed trees along the way to mark the route from their selections at Drumanure to the schools at Numurkah so that their children wouldn't get lost (Bossence 1979, p.300). Further west along the Broken Creek, selectors in the Barwo and Yalca districts likewise blazed trails through the dense forests of White Cypress-pine *Callitris glaucophylla* to avoid becoming lost and local farmers were paid one pound to guide visitors through the dense groves of cypress-pine (Hibbins 1978, pp. 78-80). One hundred and twenty years later, only 1% of the former tree cover of these pine and box forests still survives in the eastern part of the Northern Plains (DNRE 1996) and the woodlands found on the public estate along the Broken, Boosey and Nine Mile Creeks represent the single largest remnant of this ecosystem in northern Victoria (Fig. 2).

Because of the near total loss of tree cover from the Northern Plains of Victoria and the complete modification of the native vegetation which still does remain (e.g. Bennett *et al.* 1994; Robinson & Traill 1996), nearly all vegetation types found on the Northern Plains are considered endangered (Frood 1983; Frood & Calder 1987; SAC 1992a; Foreman 1995; Robinson & Traill 1996) and many species of associated plants and animals are likewise endangered or under threat (Robinson 1991, 1993a; Brown & Bennett 1995; Foreman 1995; Robinson & Traill 1996; Bennett *et al*. in prep.). The protection and appropriate management of <u>all</u> remnants of native vegetation on the Northern Plains is consequently critical if we are to conserve any viable populations of grassland and woodland plants and animals on the Northern Plains.

Currently, the paucity of specific information on the current status of native plants and animals in northern Victoria (LCC 1988; OCE 1992, p. 267) has limited our ability to comprehend the severity of the changes to the natural environment following European occupation and consequently to make the conservation of remnant native vegetation in the Northern Plains a priority for action. This difficulty is exacerbated in the eastern part of the Northern Plains (east of the Campaspe River) because most previous ecological descriptions of the Northern Plains have concentrated on the flora and fauna of the western Northern Plains and particularly on the flora and fauna of the grassland communities, rather than the grassy woodland communities (e.g. SAC 1992a; Maher & Baker-Gabb 1993; McDougall *et al*. 1993; Ross 1994). The grassy vegetation communities of the eastern Northern Plains have consequently tended to be ignored by most studies on nature conservation needs for grassy vegetation in the Northern Plains (e.g. SAC 1992a; McDougall *et al*. 1993, but see Foreman 1995), even though the endangered status of <u>all</u> grassy vegetation types throughout <u>all</u> of the Northern Plains has long been known (e.g. Willis 1935; Frankenberg 1971; LCC 1983; Frood & Calder 1987).

To redress the lack of knowledge about nature conservation in the eastern Northern Plains, Goulburn Valley Environment Group applied for funding from the National Estates Program of the Australian Heritage Commission to survey the distribution and status of native vegetation and fauna along the entire length of the Broken, Boosey and Nine Mile Creeks (a combined distance of approximately 450 km). The survey is unique within Australia because:
(1) it is the only known wildlife survey in which the condition and status of all of the remnant vegetation has been assessed along a continuous transect through the landscape at a regional scale;
(2) it is one of few wildlife or habitat assessment surveys in which the condition and status of all of the remnant vegetation in a region has been assessed;
(3) in a landscape in which there is only 1% remnant tree cover, the survey examines the one and only remnant of that native vegetation that traverses the entire breadth of the eastern Northern Plains from east to west. The study thus provides a comprehensive assessment of the current distribution and status of native plants and animals in this predominantly agricultural environment.

Specifically, the study aimed to provide detailed and comprehensive information on:

- the distribution and condition of the natural vegetation communities on public land along the Broken, Boosey and Nine Mile Creeks;
- the habitat condition of the creeks themselves;
- the distribution and status of native plants, mammals, birds, reptiles, frogs, fish and some invertebrate groups found along the creeks system;
- human uses of the public land along the creeks;
- immediate and long-term threats to the habitat and wildlife;
- the appropriate future management of the public land adjoining the creeks and the creeks themselves; and
- the identification of sites with high natural values which should be nominated to the Register of the National Estate.

With support from the Yorta Yorta Clan, the traditional owners of the land along the creeks, we also identified sites with readily recognisable aboriginal values (e.g. scarred trees and charcoal mounds).

This report summarises the results of that study. More detailed information about the values and threats present at every site is contained in a separate report to Goulburn Murray Water and DNRE (Robinson & Mann 1996). A third report analysing the relationships between current management practices, natural values and degrading processes is envisaged.

The report is divided into six major chapters:
(1) Methodology;

(2) a Background which provides broad information on the study area, its geomorphology, develoment history and tenure;
(3) a chapter on the Values of the creek system, at both a landscape scale and for specific sites;
(4) a chapter on Threats to the existing natural and cultural values along the creeks;
(5) a chapter with Recommendations for conservation and management; and
(6) a final chapter describing the values of all sites to be nominated to the Register of the National Estate.

1 METHODS

1.1 GENERAL SURVEY METHODS

The major objectives of the project were to report on the distribution and status of the vegetation and wildlife along the creeks and to make appropriate management recommendations for the public estate. We therefore decided that we should survey the entire length of the creeks system and all of the public land. The natural values of different sites along the creeks could then be compared with one another, and the significance of a site determined within the broader context of the whole system. Additionally, sampling of the entire public land estate along the creeks enabled us provide an absolute measure of the status and condition of remnant native vegetation in the eastern Northern Plains.

The basic sampling unit consisted of a length of frontage on one side of as creek which we called a 'section'. Section boundaries were annotated as left bank, Right bank and Off-creek sections. Section boundaries were determined by changes in land tenure along the creeks (e.g. private, Crown land frontage or Crown land reserve), changes in management (e.g. fenced or not, next to a road or not), changes in management of the land abutting the creek (e.g. irrigated or dryland, urban or rural), changes in the natural character of the remnant vegetation (e.g. old-growth or regrowth), or by changes in the creeks (e.g. narrow or wide, channelised or not). Because land management tended to differ on each side of the creek, we seaparately surveyed the left and right banks of the creeks. When land management was identical on both sides of the creek, and management on one side was likely to affect management on the other (e.g. where stock could cross from one side to the other), sections on both sides of the creek were surveyed together. This happened most often in the upper reaches of the creeks system.

For every section surveyed, information was collected in the field on

- width of the frontage or reserve;
- adjoining land use;
- tenure and management;
- evident Yorta Yorta values;
- vegetation types, their condition and their distribution across the section;
- density and structure of the vegetation;
- shrub and tree species present;
- dominant species of native and introduced groundcover plants;
- plant species of special interest;
- creek condition (e.g. irrigated, channelised);
- grazing by domestic stock;
- earthworks and soil-disturbance;
- cropping;
- industrial structures (e.g. drains, channels, fences, weirs);

- recreation-related uses (e.g. fishing, firewood collecting, rubbish dumping);
- pest animals and noxious weeds;
- site-specific threats; and
- site-specific values.

Some additional variables were ascertained from aerial photographs, Parish Plans and land-tenure records at the DNRE office at Benalla, notably: area, grazing-licence status of every section, Crown land width and total width of tree cover, including tree cover extending beyond the Crown land boundary. A full list of variables sampled and their definitions is given in Appendix 1.

Surveying of creek sections began in late September 1994, and ended in early June, 1995. Altogether we sampled 473 sections along the creeks system which comprised 340 sections on Crown land frontage, 91 sections in streamside reserve or bushland reserve, 5 sections in wildlife reserves, 2 sections in State Forest, 10 sections on uncomitted Crown land and 21 sections on private land (Table 1).

Table 1. Number and total areas (ha) of sampled sections for different tenures

Land tenure category	Number of sections	% of all sections	Total Area	% of all sections
Crown land waterfrontage	340	71.9	2141.3	52.4
Streamside/Bushland Reserve	91	19.2	827.7	20.2
Wildlife Reserve	5	1.1	860.0	21.0
State Forest	2	0.4	2.3	< 1
Uncommitted Crown land	10	2.1	175.1	4.3
Private land	21	4.5	54.3	1.3
Other	4	0.8	27.5	0.7
Total	**473**	**100.0**	**4088.2**	**100.0**

1.2 HISTORICAL VEGETATION MAPPING

We examined early survey maps and surveyors' field notes held at the Central Plan Office of the Department of Natural Resources and Environment for information on the original natural vegetation in every one of the twenty-seven parishes intersected by the Broken, Boosey or Nine Mile Creeks. A total of 120 maps was examined at the office, 39 of which contained some information on vegetation, the landscape or other environmental features. That information was transposed onto a county and parish plan for the County of Moira so that

all environmental features and annotations were located precisely as they were on the original drawings.

1.3 FLORA SURVEY

At every section surveyed, we made a list of all shrub and tree species, all groundcover dominants and any uncommon plant species present. For a further subset of sections (Fig. 3), we made rapid plant lists of all vascular plant species observed at the site, the minimum time spent on compiling all such lists being a ten-minute period. Lists were sometimes made for the entire section, regardless of vegetation community, and sometimes for specific vegetation communities. Lists included additional records supplied by local naturalists or botanists from DNRE.

Vegetation communities were defined in the field according to structural or floristic classifications previously made for the eastern Northern Plains by Frood (1983), Margules & Partners (1990), Foreman (1995) and Clark (1996).

Data collected were analysed in two different ways: the status of all native plant species for those sections for which we made detailed lists; and the status of all less common groundcover species and all shrub and tree species, using every available list.

Although the lists made were as comprehensive as possible, the caveat must be made that most surveying was done in the drought season of 1994/95 when many species of annual plant and many groups of plants such as lilies failed to make vegetative growth or failed to flower. Additionally, the fieldwork period covered several different seasons and some species may not have been recorded, or recorded rarely, because we sampled those sites at the wrong time of year. The results thus represent a minimum measure of the plant species richness present at every site and only a preliminary measure of the status of some herbaceous and some annual species of native plant.

Identification of plants largely depended on Willis (1970, 1972) and Jessop and Toelken (1986), with taxonomy following Ross (1993). Accordingly, some of the more recent taxonomic divisions mentioned by Foreman (1995) as being significant with regard to the Northern Plains flora were not recognised during the survey. Additionally, some of the taxonomic changes made in the Flora of Victoria and Flora of New South Wales (e.g. *Craspedia*) were made after our field survey had been completed. In these cases, the old names are used.

1.4 GRASS SPECIES COMPOSITION

Moore (1970) has suggested that, historically, the Northern Plains grassland flora was dominated by a suite of tall, perennial native grass species such as Plains Spear-grass *Stipa aristiglumis*, Kangaroo Grass *Themeda triandra*,

Common Wallaby-grass *Danthonia caespitosa* and Silky Blue-grass *Dicantheum sericeum*. As a result of persistent grazing by cattle and sheep, and the addition of superphosphates, these species have become less common and have been replaced by short, cool-season growing perennial grasses (e.g. Bristly Wallaby-grass *D. setacea*, Rough Spear-grass *S. scabra*) and introduced annuals (e.g. *Hordeum* spp, *Vulpia* spp., *Lolium* spp., *Bromus* spp.). At the most heavily grazed sites, the short, cool season natives become less common and only tough species of sedge and rush (e.g. *Juncus* spp., Knob Sedge *Carex inversa*, Small Spike-rush *Eleocharis pusilla*) or introduced annuals survive (pers. obs).

Using this model of grass species succession, we identified the dominant grass and sedge species at a site as belonging to one of the following nine groups, as a means of sampling the ecological intactness of the groundlayer. Groups 1, 2 and 3 were considered to be indicative of an intact grassy groundcover. The remainder were considered to represent various stages of modification.

1. Tall warm-season perennials (*Stipa aristiglumis*, *Themeda triandra*, *Dicantheum sericeum*, Silky Browntop *Eulalia fulva*);
2. Short warm-season perennials (Spider-grass *Enteropogon acicularis*, Umbrella Grasses *Digitaria* spp.);
3. Medium-tall cool-season perennials (*Danthonia caespitosa*, Common Wheat-grass *Elymus scaber*, Rigid panic *Homopholis proluta*, Tussock Grass *Poa sieberana*, Yanganbil *Stipa bigeniculata*, Crested Spear-grass *S. blackii*, Feather Spear-grass *S. elegantissima*);
4. A combination of groups 1 or 2, and 3.
5. A combination of groups 8, and 1 or 2;
6. A combination of groups 8 and 3;
7. Volunteer warm-season perennials (Windmill-grass *Chloris truncata*, Red-leg Grass *Bothriochloa macra*, Brush Wire-grass *Aristida behriana*);
8. Short cool-season perennials (e.g. *Danthonia caespitosa*, *D. setacea*, Brown-back Wallaby-grass *D. duttoniana*, Rough Spear-grass *Stipa scabra*);
9. Sedges or rushes (*Juncus* spp., *Carex inversa*, *Eleocharis pusilla*);

1.5 FAUNA SURVEY

We recorded the mammal, bird, frog, reptile and butterfly species present at a range of sites along the creeks (Fig. 3). Additional wildlife records were also obtained from local naturalists, biologists at DNRE and the Atlas of Victorian Wildlife.

Sites were searched for a minimum ten-minute period, the searches including the turning over of at least five logs or sheets of iron to look for sheltering reptiles and frogs. At a small number of sites (n = 19), 20-minute spotlight searches were done for nocturnal wildlife. Some sites were specifically visited during spring and summer rainfalls to search for frogs.

As for the flora survey, the same caveats apply to the interpretation of the results and the data should be taken as indicative only.

1.6 CREEK WATERS SURVEY

At the same set of sites for which we made fauna lists (Fig. 3), information was recorded on the habitat values of the creek waters themselves. Variables measured comprised: creek width; abundance of logs in the stream (many, some, none); abundance of aquatic vegetation (much, some, none) and amount of overhanging vegetation (much, some, none). We also recorded the presence or absence of yabbies and freshwater mussels. Although searches for the latter two groups of animals were only cursory (i.e. a walk along the creekbank to search for burrows, pieces of shell or claws), they provide some indication of the status of both the groups.

Fish were not sampled as part of the survey. However, information on the presence or absence of freshwater fish species was obtained from DNRE's Victorian Freshwater Database.

1.7 DETERMINATION OF CONSERVATION VALUE OF SECTIONS

Overall ratings of conservation value and threats were given for every section. Rating procedures broadly followed those developed for the National Parks Service (NPS) of DNRE (NPS 1995) and Clark (1996) to ensure that the information collected was compatible with that of NPS, the main potential manager of land identified as having conservation value along the creeks.

The NPS procedure for rating reserves consists of definitions of the categories 'Very High', 'High', 'Medium', 'Low' or 'Very Low' for a range of ecological or management criteria (e.g. the size of the reserve, the structural diversity of the vegetation, adjacent land use, the level of disturbance). Sites are then rated independently for values and threats according to which category of significance they fit best overall.

Our procedure was similar and differed only in the selection of certain criteria. In particular, we used different criteria for ranking threats since we were surveying a linear strip of habitat within a broader rural landscape. Consequently, we did not think it appropriate to use reserve shape or adjacent land use as measures of threats (nearly all of our sites were equally threatened in these two ways).

Our conservation rankings were defined as follows, with sections being ranked according to which set of conservation-ranking criteria their values most closely resembled:

6. Excellent:

- known populations of any endangered species
- three or more threatened species of plants or animals
- five or more regionally significant species of plants or animals
- creek natural
- large area - reserve more than 100 m wide or total tree cover on both sides of the creek more than 100 m wide
- three or more vegetation communities present
- more than 50 species of native plants present
- intact example of any vegetation community with predominantly old-growth habitat, regeneration, shrubs and a predominantly native groundcover layer (> 75% native)
- high potential for restoration (i.e. no soil disturbance).

5. High

- no endangered species but one or more vulnerable or rare species
- five or more regionally significant species of plants or animals
- moderately large area - at least one side of creek wider than 50 m
- three or more vegetation communities present
- more than 30 species of native plants
- basic elements of environment intact - mostly old-growth habitat, mostly native ground layer (>75%), some shrubs and regeneration
- potential for restoration high (i.e. little soil disturbance).

4. Moderate-High

- one or more rare or threatened species but no endangered or vulnerable species
- two or more regionally significant species
- basic elements of environment intact in at least one vegetation community if two communities present
- predominantly native ground layer (>50%)
- predominantly old-growth woodland
- high potential for restoration (i.e. little soil disturbance)
- section width variable.

3. Moderate

- if threatened species present, only in the category 'depleted' (see Gullan *et al*., 1990)
- not necessarily any regionally significant species
- site less than 50 m wide
- basic elements of environment present but modified by persistent grazing and human use
- ground cover predominantly native(> 50%)
- predominantly old-growth habitat but sometimes including regrowth

- moderate potential for restoration (i.e. little soil disturbance)

2. Moderate-Low
- no threatened species or regionally significant species
- tree cover intact but not the habitat (i.e. mostly regrowth rather than old-growth habitat)
- some native species but ground cover predominantly weedy
- some to much soil disturbance at site

1. Low
- site highly modified by tree clearing and/or cultivation and disturbance
- site< 25m wide.

Threat rankings were defined as:

1. Very Low
- site securely protected
- no grazing, no weed invasion or soil disturbance

2. Low
- site intact and securely protected
- some weed or pest problems, or occasional grazing by stock

3. Moderate
- basic elements of site intact
- some human use, some-much weed/pest levels
- some modification of site by earthworks and grazing occurring.

4. Moderate-severe.
- site currently intact but extensive modification and use by stock and/or humans occurring

5. Severe

- site actively deteriorating as a consequence of threatening processes (e.g. tree clearing, extensive soil disturbance, weed invasion, etc.).

1.8 Selection of sites for nomination to the Register of the National Estate

Nearly all sections classified as having Excellent or High conservation values are considered to merit nomination to the Australian Heritage Commission's Register of the National Estate. To ensure compatibility with the AHC's own criteria for nomination, we also reviewed the proposed sections to be nominated with regard to the criteria specifically set out by Ross (1995) for the nomination of grassy woodland or grassland sites in Victoria to the AHC's Register of the National Estate. These criteria are summarised in Appendix 2.

2 BACKGROUND

2.1 STUDY AREA

The Broken, Boosey and Nine Mile Creeks form part of that portion of the Riverine Plain referred to in Victoria as the Northern Plains. At a national scale, the Riverine Plain is a distinctive biogeographic region covering an area of approximately 69,000 square kilometres in New South Wales and 21,500 square kilometres in Victoria (Fig. 4) (Thackway & Cresswell 1995). Within Victoria, the Northern Plains region is also recognised as a distinctive biogeographic unit (Hills 1946; Conn 1993) which spans northern Victoria between about Wangaratta and Wodonga in the east and Charlton and Swan Hill in the west. To the north it is bounded by the Murray River and to the south by the hills of the Great Dividing Range (Foreman 1995).

Within Victoria, the Northern Plains biogeographic region comprises two major sub-regions, each of which may be further subdivided on the basis of vegetation (Foreman 1995). These two sub-regions are physically separated by the Calivil Fault, the Colbinabbin Range and the Campaspe River (Butler *et al*. 1973; Tickell 1977). They are also distinct climatically. East of the Campaspe (hereafter called the eastern Northern Plains) the Northern Plains has an average annual rainfall of between 400 and 700 mm and the climate is decribed as 'temperate hot summer'. West of the Campaspe (western Northern Plains), average annual rainfall diminishes from 400 mm in the east to less than 350 mm in the west (Fig. 4), average monthly minimum and maximum temperatures are warmer than in the eastern Northern Plains and the climate is described as 'semi-arid' (LCC 1983; Foreman 1995).

The Broken, Boosey and Nine Mile Creeks are in the eastern Northern Plains. However, the three creeks traverse a significant proportion of the Northern Plain's climatic gradient, flowing from foothills in the southeast with an annual rainfall of more than 600 mm to semi-arid woodlands in the northwest with an annual rainfall of less than 400 mm (Fig. 4). The creeks thus provide a unique sample of the remnant vegetation found across a broad environmental gradient in the Northern Plains.

2.2 THE CREEKS

The three creeks and their associated tributaries form part of the Broken River catchment in northeastern Victoria. They extend from near Benalla and the Killawarras in the southeast to Barmah and the Murray River in the northwest (Figs 1, 2). Altogether the creeks drain a sub-catchment of some 3,700 square kilometres (CMPS & F 1993), the catchment boundary extending from near the Murray River between Cobram and Yarrawonga in the north, between Yarrawonga and the Warby Ranges in the east, along the northern edge of the Broken River between Goomalibee and Pine Lodge in the south and along the

western and southern edges of Pine Lodge Creek and the Broken Creek in the west (Hydrotechnology 1994).

Each of the three creeks represents an ancient (prior) course of the Broken River and all of them originate today in what is termed the Broken River Palaeovalley (Tickell 1989). This valley began to be formed approximately 100 million years ago by a river much larger than the Broken River of today, following the uplift of the central and eastern highlands (Hills 1946; Tickell 1989). As a result of subsequent erosion and sedimentary deposition, the Broken River Palaeovalley gradually backfilled with alluvial material and the river correspondingly changed its course in response to changing landforms (Tickell 1989). In relatively recent times, the Broken River established its present-day course between Benalla and Kialla and the three creeks of concern to this study took up three of its prior routes.

The Broken Creek is the most direct descendant of the Broken River. It is described as an effluent of the Broken River (Hills 1946) and flows out of the Broken River along one of the River's former courses at a point about ten kilometres west of Benalla near Goomalibee. Along its natural course it merges with the Boosey Creek near Katamatite and the Nine Mile Creek near Dunbulbalane and then near Mundoona, finally flowing into the Murray River at the Moira Lakes in Barmah Forest. Its total length is estimated to be 210 km, of which we sampled 200 km. Downstream of its final junction with the Nine Mile Creek, the present-day course of the Broken Creek follows one of the prior streamcourses of the Goulburn River, a streamcourse known as the Bunbartha Prior Stream which was flowing until about 21,000 years ago (Tickell 1991). This part of the Broken Creek is clearly distinguishable from the remainder of the creeks system because of its meanders and sandy levees (Johnston 1952; Butler *et al*. 1973; LCC 1983).

Historically, the Nine Mile Creek was an anabranch of the Broken Creek, flowing out of it west of Goorambat, rejoining near Dunbulbalane, flowing out again immediately and then rejoining once more at Mundoona (Fig. 3). Because of changes to drainage patterns across the Major Plains and Invergordon Plains, however, the original creek channel from the Broken Creek has been cut off and the remainder of this part of the Nine Mile Creek re-directed or channelised. The upstream section of the Nine Mile Creek between Dunbulbalane and Goorambat consequently now exists just as small, fragmented parcels of public water frontage (Fig. 2). The total length of the Nine Mile Creek is estimated to be 120 km, of which we sampled the approximately 90 km which was bordered by public land.

In contrast to the other two creeks, Boosey Creek is not an effluent stream but has natural headwaters in the sedimentary hills of the Killawarras and the granitic hills around Thoona, Mokoan and Bungeet. From these hills, it flows consistently northwest along one of the prior routes of the Broken River and merges with theBroken Creek west of Katamatite. The total length of the

Boosey Creek and its tributaries is approximately 120 km, of which we sampled the 75 km bordered predominantly by public land.

2.3 THE PLAINS

The eastern Northern Plains began to be formed about 65 million years ago following the uplift of the eastern and central highlands, the consequent formation of the Murray Basin and the subsequent deposition of alluvial materials by mighty ancestors of the present-day Murray, Ovens, Goulburn and Broken Rivers (Butler *et al*. 1973) and the ancestors of the Broken, Boosey and Nine Mile Creeks (Butler *et al*. 1973; Tickell 1989). These sediments now form a series of layers which are, altogether, as much as 250 metres thick (Tickell 1977; LCC 1983). The most recent sedimentary layers of alluvial material (known as the Shepparton Formation and the Coonambidgal Formation) were deposited between about 35,000 and 1600 years ago (Tickell 1977). Subsequently, a superficial layer of wind-borne, calcareous clay sediments (parna) is hypothesised to have been deposited on top of those alluvial sediments as a result of erosion of the Murray Basin region to the west of the Riverine Plains during an arid, climatic period (Skene & Poutsma 1962; Butler *et al*. 1973). Together with the underlying alluvial sediments, these sedimentary deposits now comprise the physical fabric of the eastern Northern Plains.

Although the plains appear almost uniformly flat and undifferentiated at a glance (they fall to the northwest at a gradient of 0.7 m/km), their geological and geomorphological history have determined the creation of a complex and diverse physical environment. The most apparent landforms in the eastern Northern Plains are flat plains, occasional hills (e.g. near Dookie, Katandra, Waggarandall, Tungamah), depressions and swamps caused by impeded drainage of recent streams, sand-dunes, lunettes, raised plains and, of course, the current creeks systems (Skene & Poutsma 1962; Cockcroft 1965; Butler *et al*. 1973). Meandering just beneath the surface of these contemporary landscape features, however, are many subterranean prior streams and their associated sandy levees (Johnston 1952; Cockcroft 1965; Butler *et al*. 1973). Close to these prior streams, soils tend to be sandy or loamy. Further away, on the floodplains of these prior streams, clay content rises. In addition to the current landforms, therefore, there is a sequence of underlying sands and clays (Johnston 1952; Skene & Poutsma 1962; Foreman 1995) which represents the prior streams, their levees and their associated floodplains.

Each of these landforms has an influence on soil type, vegetation and wildlife (Johnston 1952; Butler *et al*. 1973; Foreman 1995) and early European accounts make it clear that the woodlands, red gum forests, swamps and rivers of the eastern Northern Plains were once diverse and rich in native wildlife.

2.4 THE NATURAL ENVIRONMENT

2.4.1 Historical natural environment at Barmah

Halting near the junction of the Broken Creek and the Murray River in 1840, Edward Curr (1883) reported *'Looking around, on one side of us, we saw extensive reed-beds intersected by the Murray...The other half of the circle was occupied by open, grassy, forest land, which extended we did not know how far. The grass under foot, as yet undefiled by flock or herd, was as green and fresh as Eden, and the landscape generally bathed in a soft, hazy, sunlight, such as Monsieur Buvelot would love to depict.*' (Curr 1883). Magpie Geese (now extinct inVictoria), ibis and other waterfowl nested in vast numbers in the reed beds (Chesterfield *et al*. 1984) while along the creek and river, fish, water rats, platypus, Murray River crayfish, freshwater mussels and tortoises were common (Cadwallader & Lawrence 1990; Geddes 1990; Walker 1990; Hibbins 1991).

In 1853, Sir Henry Young, the then Lietenant Governor of South Australia, noted of the Murray River near Barmah that it '*abounds in fish of several kinds of which the Murray Cod, weighing sometimes seventy pounds, is not only the biggest but the best. The malloway, a species of cod, furnishes useful isinglass and good oil. The lagoons and backwaters of the river teem with crayfish and are the resort of innumerable wildfowl'* (Bossence 1979, P.41). In 1889, another observer similarly commented that '*on many occasions I have seen three and four hundred-weight of fish drawn from lagoons at single hauls, consisting of cod, perch, blackfish and turtle'* (Cadwallader & Lawrence 1990). Such was the abundance of fish along the creek and river, indeed, that, every week in the early 1900s, an average of 15 buckets containing about 100 pounds of fish each, left the Nathalia and Echuca railway stations for the Melbourne markets (Hibbins 1978, p. 137).

In the dryland areas of Barmah Forest, dingos, 'wallabies', 'bandicoots', 'native cats', 'kangaroo rats', 'field rats' and perhaps stick-nest rats all once occurred but have since disappeared (Curr 1883; Chesterfield *et al*. 1984; Hibbins 1991, p. 82). Charles Sturt's 1838 description of aboriginal burial places in Barmah being 'perforated by rats...' (Hibbins 1991, p. 8) hints that another species of native rodent was also present but has since likewise gone. On the grassy plains described by Sturt as '*...splendid and open flats of rich light loam'* (Hibbins 1978), Brolgas sometimes occurred in their hundreds (Hibbins 1991, p. 111, 132) and emus were common. The sandy box ridges in the forest not only supported Grey Box and Yellow Box but until as recently as 1936, supported a rich understorey of Buloke *Allocasuarina luehmannii*, Gold-dust Wattle *Acacia acinacea*, Lightwood *A. implexa*, Yarran *A. omallophylla*, Silver Wattle *A. dealbata*, Early Black Wattle *A. decurrens*, Weeping Pittosporum *Pittosporum phillyreoides*, River Bottlebrush *Callistemon sieberi*, Honeysuckle *Banksia marginata*, Broom Ballart *Exocarpos sparteus* and Pale-fruit Ballart *E. strictus* (Chesterfield *et al*. 1984). Of these plants, the

Honeysuckle is now extinct across the entire Northern Plains (Beauglehole 1986), there is just one known Yarran left in the Forest (DCE 1992) and Broom Ballart, Early Black Wattle and River Bottlerbrush are locally extinct (Chesterfield *et al*. 1984). Twenty years after settling at Barmah, Curr (1883) commented that 'reeds, blacks and bellbirds had gone' from the area. Previous works have suggested that the bellbird was the Crested Bellbird *Oreoica gutturalis* (Chesterfield *et al*. 1984). We suggest instead that the bellbird was the Bell Miner *Manorina melanophrys*, a species historically noted from other inland rivers (e.g. Walker 1838; Batey 1907) bordered by River Red Gums and tall shrubs. Once the shrubs disappeared, it seems likely that so too did the birds.

2.4.2 Historical natural environment along the lower Broken Creek

Travelling between the Murray River and Broken Creek in 1856, Clement Hodgkinson noted that '*...there is an extensive tract of low level country, wooded by the box variety of Eucalyptus, with occasional appearance of Banksia, Callitris Pyramidalis, Casuarina Torulosa, Casuarina Paludosa, Exocarpus Cupressiformis, and some of the Acacia tribe. The western portion of this level forest country is, however, diversified by many open grassy plains varying in extent from about one hundred acres to several thousands of acres. Some of these plains are very beautiful, their irregular but well-defined margins being fringed by the graceful Callitris and Casuarina'* (Hodgkinson 1856; Fig. 4). Further west, along the western edge of the Goulburn River, he reported a similarly rich flora, noting *that 'Beyond the river the land was very flat except for isolated hillocks, or ridges of sand, maybe three hundred yards wide and rising to forty feet above the surrounding land. Many of these supported dense groves of Murray Pine, and between the Murray and Goulburn grew forests of box eucalypts, banksia, buloke, sweet quandong, grey mulga, cherry ballart and wattles'* (Hibbins 1978).

In the Broken Creek, Murray Cod and other fish were abundant (Hibbins 1978, p. 137) and Azure Kingfishers were common (Willis 1935), even though all of these animals had to endure long periods when the creek regularly dried up until all that remained was a series of waterholes (e.g. Hibbins 1978, p. 58, 73, 95, 97); hence the name 'broken'.

Along the sandy banks of the Broken Creek, now endangered or threatened species of herbaceous peas such as Australian Trefoil *Lotus australis*, Red Bird's-foot Trefoil *Lotus cruentus*, Tough Psoralea *Psoralea tenax* and Small Psoralea *P. parva* would have been common and as many as 15 different species of shrubs may have grown together at some of the sites (Hodgkinson 1856; Willis 1935; Chesterfield *et al*. 1984; Beauglehole 1986). An entire suite of herbs, grasses, lilies, saltbushes and their associated fauna lived only on the sandiest parts of the creekbank and on sandhills, but most of these species have long since disappeared (Willis 1935) or now remain at just one or two sites (e.g. Woolly-head Mat-rush *Lomandra leucocephala*, Small-leaf Clematis

Clematis microphylla Beauglehole 1986, pers. obs). Wombats once lived in the sandhills (Bossence 1979, p. 215; I. Davidson, pers. comm.) and now threatened birds such as Superb Parrot Grey-crowned Babbler and Apostlebird lived in the clumps of cypress-pine. The heavier-soil plains away from the creeks were *'carpeted with native everlastings...*' (Willis 1935) and interspersed with sandy ridges that carried cypress-pine, Yellow Box (Fig. 4) and the now threatened Hooked Needlewood *Hakea tephrosperma* (Johnston 1952).

As an indicator of the rate of loss of these woodland habitats, it is instructive to compare Hodgkinson's 1856 list of shrubs and trees for the eastern Northern Plains with Willis' list for the eastern Northern Plains in the early 1900s (Willis 1935) and with those known now. Hodgkinson mentions Cypress-pine (*Callitris glaucophylla*), evidently two species of casuarina (probably Buloke and Drooping She-oak *Allocasuarina verticillata*), Sweet Quandong *Santalum acuminatum*, Grey Mulga *Acacia brachybotrya*, Cherry Ballart and Honeysuckle as being widespread. By the 1930s, Honeysuckle and perhaps one species of casuarina had become extinct and Cherry Ballart and Sweet Quandong were very rare. Additionally, Willis refers to Hedge Wattle *A. paradoxa*, Golden Wattle *A. pycnantha*, Yarran, Lightwood, Weeping Pittosporum and Desert Cassia *Senna artemisioides* as rare or very rare, and Hooked Needlewood as '*becoming scarce'*. Since then, Golden Wattle may possibly have become more common but Hooked Needlewood, Yarran, Lightwood, Weeping Pittosporum and Desert Cassia have become rarer. Other shrubs such as Grey Mulga, Sugarwood *Myoporum platycarpum*, Wedge-leaf Hop-bush *Dodonaea viscosa*, Berrigan *Eremophila longifolia* and Waterbush *Myoporum montanum* have also become threatened regionally or across the State. Cherry Ballart and Sweet Quandong appear to have disappeared from all of the eastern Northern Plains, except Barmah Forest.

2.4.3 Historical natural environment of the middle sections of the Broken and Nine Mile Creeks (Wunghnu, Numurkah, Katamatite).

In 1877, the Broken Creek at the present-day site of Numurkah was just a series of muddy waterholes but with some clear springs (Bossence 1979, p. 65). Murray Cod, catfish and perch were still found this far up the creeks system and continued to be recorded east of Katamatite as recently as 1950 (W. O'Connor, A. Rudd, in litts.). The first selector at Numurkah, arriving in 1873, described the site as '*a nice circular plain, well-grassed, the creek having a nice flow of water which abounded with all species of water-fowl'* (Bossence 1979, p. 63).

Further south, the Nine Mile Creek west of Wunghnu was described in 1878 as being '*full of clear water about three feet deep'* (Bossence 1979, p. 59), although in some other years the creeks failed to run at all (Bossence 1979, pp. 63, 124). Emus and kangaroos were widespread in the district and Brolgas occurred in big flocks which reportedly devoured '*a large percentage of sprouting grain'* in 1885 (Bossence 1979, p. 52). Wombats and spotted native cats still lived in the district at the turn of this century (Bossence 1979, p. 215).

Accounts of the wildlife near Katamatite likewise refer to the presence of native cats at Dunbulbalane in the early days of European settlement '*The country originally was very beautiful in the Spring. In the paddocks left in their original state there were Murray pines, black and golden wattles, other small wattle scrub, grey box and red gum trees, buttercups, harbingers of spring, rice flowers (Pimelea), swamp peas, brillian purple peas, which we called wild violets, everlastings, blue bells, chocolate flowers, billy buttons, and many orchids including spider, snake and sun orchids, greenhoods, blue and pink fairies. There were kangaroos, koalas, wallabies, possums, native cats, big goannas, with innumerable birds particularly water birds. It was indeed a lovely land in those early days'* (Rudd undated).

2.4.4 Historical natural environment of the upper reaches of the Broken, Boosey and Nine Mile Creeks (Katamatite to Lake Rowan, Benalla, Dookie)

The upper reaches of the Broken and Boosey Creeks flow through what was once mostly 'box forest' and some swampier parts consisting of River Red Gum or even 'crabhole plains' (Fig. 5). Close to the source of the Broken Creek, there were sandhills with Cypress-pine and Honeysuckle (see frontcover) and Silver Wattle and River Bottlebrush probably grew along the creek immediately downstream of its departure from the Broken River (where they can still be found). Along the sandy levees of the prior streams, Hooked Needlewood and Yarran were probably once widespread (Incoll 1936, in Chesterfield *et al*. 1984; Willis 1935; Johnston 1952; Butler *et al.* 1973). Now

they are confined to just a few sites in the one million hectares of the eastern Northern Plains.

Emus, Bustards and Brolgas were found on the plains around Tungamah, Stewarton, Benalla and Dookie (Pye 1920; Rudd undated) and old local residents on the Dookie Plains can recall seeing 'bandicoots' in the last 70 years. Murray Cod lived in the Boosey Creek as far upstream as Lake Rowan (P. Larkin, pers. comm.) and probably along the entire length of the Broken Creek. For example, an early description of the Broken River at Benalla in 1838 recorded that '*the broken river is not at present running but merely consists of a chain of ponds. The grass and trees are very luxuriant. The pools abound in cod Gristes Peelii, Eel fish, shrimps, and Emydes* [Turtle] *and a variety of fish which I know only from description. The ponds are full of duck, ornithorhynchi [platypus], hydromys or water rats, cranes (common blue) - and are covered with a beautiful confervia* [water milfoil?] *which covers the surface of all the rivers and ponds in this part of the country'* (Hobson 1838).

Such descriptions of bounteous nature by the European explorers and early settlers, and their comments on the '*excellent quality'* of the Plains' alluvial soils for grazing by stock (Fig. 5) encouraged rapid European colonisation of the Northern Plains. Destruction of the natural landscape quickly followed (Mitchell 1839; Curr 1883).

As a result, one hundred and fifty years later, Murray Cod no longer live upstream of about Nathalia, the waters of the various creeks are no longer clear or 'broken' now, the Emus have long since disappeared from the squatting run once named evocatively as 'Emu Plains', most of the orchids have not been recorded for many years (Willis 1935) and the wombats, honeysuckles, 'stick-nest rats', 'bandicoots', 'rat kangaroos', Magpie Geese, spotted cats, bustards and quandongs have all become extinct in the eastern Northern Plains.

2.5 EUROPEAN DEVELOPMENT HISTORY

Major Mitchell was the first European person to travel through the Northern Plains, doing so in the winter and spring of 1836 (Mitchell 1839). Within one year of his journey, the Northern Plains began to be occupied by other Europeans and their cattle and sheep, and by mid-1838, more than 5000 cattle and 140,000 sheep had been droved through the eastern Northern Plains (Hawdon 1838) in pursuit of pasture and land.

By 1840, squatting runs had been taken up by settlers at both ends of the Broken Creeks system (Hibbins 1978; Dunlop 1973). By 1850, squatting runs spanned the entire Broken Creeks system (Dunlop 1973; Billis & Kenyon 1974; Hibbins 1978; Bossence 1979) and more than 60,000 sheep and 4,500 cattle grazed along the creeks (Billis & Kenyon 1974; LCC 1983).

Although the environmental consequences of the squatting era were severe (most particularly because of the systematic destruction and displacement of local aboriginal clans and the consequent cessation of traditional techniques for tending the land), little clearing of the native vegetation occurred in this era. When the 1869 Land Act was introduced, however, the entire eastern Northern Plains region was rapidly taken up by selectors (Dunlop 1973; Hibbins 1978; Bossence 1979; Dobson 1980) and cleared of its native vegetation for pastures and crops. By 1885, a local Numurkah resident noted that '*The majority of trees, though killed, are still standing....We drove mile after mile through the flat, unchanging forest of dead trees...*' (Twitt 1974). Two years later, the editor of the Numurkah Standard wrote in an editorial that '*...paddocks have been denuded, and forests have been swept out of existence*.'.

So ended the first phase of European occupation. The speed of its environmental alteration can be judged by the fact that in 1884, just 12 years after the first selections, a proposal for a railway line between Nathalia and Numurkah stated that the railway line would serve a population of 5,300 Europeans, 41,182 horses, 13,403 cattle, 46,152 sheep, 2,938 pigs and nearly 60,000 acres of cultivated land (Bossence 1979). In just a decade, then, the dense forests of box and native pine that had forced selectors to blaze trails so that they could find their way had all but disappeared. The development of Victoria's agricultural heartland had well and truly begun.

2.6 CURRENT LAND AND WATER USE

Following the initial European land-use phases of grazing and timber-clearing, much of the eastern Northern Plains became a cropping region and various districts along the Broken Creeks system were specifically noted for their high crop yields, for example at Broken Creek Station near Goorambat, Stewarton, Major's Plains and Numurkah (Dunlop 1973, p. 73; Bossence, 1979, pp. 100-102). In the 1890s, farmers at the western end of the creeks system began to turn to dairy cattle and sheep (Hibbins 1978; Bossence 1979). As part of that change, local residents began to promote the concept of an irrigation industry and in the early 1890s, individual farmers began to irrigate their pastures using water pumped from the Broken Creek (Bossence 1979, p. 335; Dobson 1980). More formal irrigation of the region began in 1911 with the completion of the East Shepparton Channel which carried water north to the southern banks of the Nine Mile and Broken Creeks (Bossence 1979, p. 336). Subsequently, further irrigation programs began in the region surrounding the Broken Creeks system, following the completion of the Murray River-Narioka Channel in the 1930s (Hibbins 1978, p. 190), the proclamation and development of the Murray River Irrigation District in the late 1930s (Bossence 1979, p. 339) and the expansion of the irrigation region after World War 2 (Hibbins 1978, p. 203).

Today, the Broken, Boosey and Nine Mile Creeks flow through a highly modified landscape which consists almost equally of irrigated pasture land and dryland pasture (CMPS & F 1995). Within the Shires spanned by the creeks:

- more than 95% of land has been alienated and converted to agricultural land (DPUG 1990);
- there is only 6% remnant tree cover (DNRE 1996);
- there is more than 70,000 ha of cropland and more than 100,000 ha of irrigated pasture; and
- there are half a million sheep, approximately 60,000 beef cattle and 60,000 dairy cattle (CMPF & S 1995; Hydrotechnology 1995).

The public land adjoining the creeks is now the only continuous remnant of native vegetation surviving within the eastern Northern Plains (Fig. 2), and its persistence underlines the importance of having retained the creek frontages in public ownership.

2.7 THE PUBLIC WATERFRONTAGE RESERVE SYSTEM

When the first Europeans arrived in the eastern Northern Plains in search of land, the two pre-requisites for settlement consisted of a water supply and good grazing land (Dingle 1984). Given the speed of European colonisation of the region, it seems incredible, therefore, that land along the Broken, Boosey and Nine Mile Creeks remained in public ownership rather than being alienated as soon as possible, as was allowed to happen in some other states.

At the time of European colonisation of Victoria, however, there had been a long European tradition of providing fundamental physical resources such as water and pasture for people who did not own land (Wright 1989) and more broadly of providing for the public interest. By good luck, the early years of Victoria's development included a rare conjunction of circumstances in which there was a governing leader, La Trobe, who despised the political power of the squatters and was an ardent supporter of the public interest; there was a rapidly increasing population as a result of the gold rushes which led to political pressure for land subdivision as early as 1855; and there were specific Imperial edicts being issued which required that land be set aside along water frontages for public use (Cabena 1983; Wright 1989).

Initially, these public water frontages consisted only of frontages along the coastline and along major rivers (Cabena 1983). As the selection and alienation of Victoria's public land estate continued, it became increasingly clear that there must be public access to water in inland districts if districts away from creeks were to be settled. Accordingly, after 1857, Crown land frontages began to be retained along all navigable and potentially navigable streams in Victoria and water reserves were left along all minor streams at an average distance of about one mile apart. Following the 1869 Land Act, minimum frontages of one and a half chain's width were additionally set aside

along all permanent streams to ensure public rights of access and use (Cabena 1983). It was only land settled relatively early on, and particularly prior to the introduction of the 1860, 1862, 1865 and 1869 Land Acts, that evaded having public frontage along its permanent creeks.

But again by good luck, the land along the Broken, Boosey and Nine Mile Creeks was mostly made available for selection after the 1869 Land Act and following the issue of the 1874 Government order requiring that frontages be set aside along all permanent streams. Furthermore, the intermittent or 'broken' nature of the creeks' water supply made them relatively unappealing to the first generation of squatters who were granted pre-emptive rights to a chosen one square mile of land on their extensive squatting runs (LCC 1983; Dingle 1984). As a consequence, most of the creeks system is bordered by public frontage reserves which now constitute one of the largest areas of public land in the eastern Northern Plains.(Fig. 2).

In addition to the establishment of public waterfrontages along most permanent streams, the 1874 Government Order introduced regulations prohibiting cultivation or timber cutting on public frontages because of recognition that both activities caused destabilisation of river and creek banks and loss of soil. It was also recommended that frontages be fenced to ensure public access (Cabena 1983). But because insufficient personnel were employed to enforce these conditions, many landholders began to flout the law by clearing parts of waterfrontages for cultivation or by fencing frontages for their exclusive use (Cabena 1983). In the early 1880s, a licencing system was introduced in an attempt to respond to this situation, whereby landholders already in occupation of frontages were granted exclusive rights to graze a portion of Crown land frontage. As a consequence of the introduction of licencing, however, the initial purpose of retaining Crown land frontages for public use and public interest became much less clear and Crown land frontages came to be generally regarded as a special category of grazing land.

The private use of waterfrontages for grazing became entrenched following the introduction of the *Unused Roads and Water Frontages Act* (1903) and the establishment of a formalised licencing system for private grazing of these public lands (Cabena 1983). The framework of this Act is still retained today in the *Crown Lands Acts (Amendment) Act* 1994, which has granted five-year grazing licences on waterfrontages to the adjoining landholders with the undertaking that a review of the appropriate use of those frontages will be completed in the initial five-year period by the Goulburn-Broken Catchment and Land Protection Board (DCNR 1995).

2.8 CURRENT LAND TENURE

Of a total of 4034 ha of public land along the Broken, Boosey and Nine Mile Creeks, 2143 ha of Crown land is currently grazed under licence. Forty

percent of this is managed by Parks and 60% by Crown land and Assets (CLAD, DNRE). An additional 837 ha is managed for nature conservation and most of the remainder is unlicenced frontage which may or may not be grazed (Tables 1, 2)

Table 2. Crown land tenure and licence status along the Broken, Boosey and Nine Mile Creeks

Land tenure category	Total		Licenced for grazing		
	no. of sections	area (ha)	no. of sections	area (ha)	% of total
Waterfrontage	343	2168.8	163	1185	54.6
Streamside & Bushland Reserves	91	827.7	35	369	44.6
Wildlife Reserves	5	860.0	2	482	56.0
Uncommitted Crown land areas	10	175.1	4	107	60.9
State Forest	2	2.3	0	0.0	0.0
Totals	**448**	**4033.9**	**204**	**2143**	**53.1**

2.9 CURRENT MANAGEMENT ALONG THE CREEKS SYSTEM

Public land and water along the creeks system is presently managed quite disjunctly by four different sections of the Department of Natural Resources and Environment (DNRE), by Goulburn Murray Water (GMW), by the Lower Goulburn Waterway Management Authority and by local shires.

The Department of Natural Resources and Environment is primarily responsible for the management of all Crown land along the creeks system. However, depending on the Land Conservation Council's classification of that Crown land, part of the land is managed by Parks Victoria(notably Wildlife Reserves, Streamside Reserves, Bushland Reserves, Historic Reserves), part is managed by Forests and Fire and part is managed by Crown Land and Assets (CLAD).

At present, 41% of the Crown land adjoining the creeks system is managed by Parks Victoria for nature conservation (Table 1), 2% is managed by Forests and Fire and 29% is managed by CLAD as licenced frontage (Tables 1, 2). However, confusion exists as to which section of the Department (Parks Victoria or CLAD) manages the 28% or so of unlicenced frontage, which section is responsible for licenced frontages within Parks-managed reserves, and the respective responsibilities of DNRE and Shires in situations in which roads pass through Crown land (Appendix 6). Management of the public land along the creeks system for the public benefit is consequently hindered by the lack of clear direction from DNRE and the lack of co-ordination between the different DNRE sections and different authorities.

Management is similarly disjointed with regards to the creek waters. Legally, the creeks are included in the Crown land reserve and are under the jurisdiction of DNRE. Practically, GMW is the primary manager of the creek waters, responsible for water delivery along the creek waters, and for some of the channels and drains flowing into and out of the creeks. DNRE's Catchment and Land Management (CALM) section and the Lower Goulburn Waterway Management Authority also have some input into water-use issues along the creeks, particularly in the irrigation areas, but the chain of command currently appears to be unclear.

3 VALUES

3.1 OVERALL CONSERVATION VALUES OF THE PUBLIC LAND ALONG THE BROKEN, BOOSEY AND NINE MILE CREEKS SYSTEM

3.1.1 Significance of the remnant vegetation along the creeks in a landscape context

Throughout the two million hectares of land that comprises the Northern Plains, there is now just 6% of remnant tree cover - a 'massive decline from the estimated 76% tree cover in 1869' (Benett *et al*. in prep.). Likewise, throughout the one million hectares of the eastern Northern Plains, just 6% of the original tree cover has been retained overall and only 1% tree cover of the former box woodlands which once covered the Plains remains (DNRE 1996). Most of the surviving woodland remnants are small and isolated (Kelly 1994; Figs. 6, 7), and generally consist of no more than a clump of paddock trees on private land that have been subjected to grazing, cropping and timber-cutting for more than one hundred years (Bennett *et al*. 1994). Consequently, there is generally no tree regeneration in most patches of remnant vegetation (Bennett *et al*. 1994) and native understorey is usually absent. Overall, a miniscule 0.03% of the one million hectares of land in the eastern Northern Plains is estimated to still retain both tree cover and an abundant understorey (see 3.2.1.5).

Within this depauperate region, the public land along the Broken, Boosey and Nine Mile Creeks provides an extensive linear system of remnant native vegetation that totals more than 4000 ha in area and includes some areas with native understorey (see 3.2.1.5). Even though the area of vegetation left along the creeks is so small that it does not show up on statewide maps of treecover (e.g. Woodgate & Black 1988), it is the largest and broadest area of remnant woodland vegetation found in the eastern Northern Plains.

At the district scale, the remnant vegetation found along the Broken, Boosey and Nine Mile Creeks is frequently the largest area of remnant native vegetation (Table 3) and nearly always the only example of remnant native vegetation which is connected to other remnants (Figs. 6, 7). Thus, the Broken, Boosey and Nine Mile Creeks system is the only remnant of native vegetation outside of Barmah Forest in the eastern Northern Plains which meets the fundamental criteria of nature conservation at a landscape scale, that is: large size, connectivity, ecosystem representativeness, large or multiple populations, ecological integrity (relative to the remainder of the landscape) and ecological diversity (Bennett 1990; Recher 1993; Safstrom 1995).

Table 3. Proportion of remnant tree cover found along the creeks in relation to total tree cover found in the 10 minute geographic grids spanning the creeks

Grid reference	Location	Total area of grid (ha)	Total tree cover area in grid (ha)	% tree cover along creeks
36 05'S, 145 05'E	Narioka	27,761	2,870	2.0
36 05'S, 145 15'E	Nathalia	27,761	882	14.2
36 05'S, 145 25'E	Wungnhu	27,763	455	74.6
36 05'S, 145 35'E	Dunbulbalane	27,763	257	86.3
36 05'S, 145 45'E	Katamatite	27,764	225	85.4
36 15'S, 145 45'E	Waggarandall	27,706	71	71.8
36 15'S, 145 55'E	Lake Rowan	27,708	346	50.0

3.1.2 Significance of the remnant vegetation and habitat along the creeks in an historical context

It is estimated that about 88% of the area of the eastern Northern Plains originally consisted of grassy woodlands dominated by Grey Box, Yellow Box, Buloke and White Cypress-pine, while the remaining 12% comprised forests, woodlands and swamps of River Red Gum, notably along the Murray, Goulburn, Broken and Ovens Rivers (DNRE 1996; Fig. 5). As already noted, however, there is now only 6% total tree cover left in the eastern Northern Plains. Of that remaining tree cover, 80% now consists of River Red Gum forests, woodlands and swamps and only 20% consists of the formerly more extensive woodlands of box, Buloke and cypress-pine (DNRE 1996).

Native vegetation in the eastern Northern Plains has thus been transformed from a landscape in which woodlands were once dominant to one in which 99% of the former woodland has been removed and most of the remaining woodland has been severely altered. It is consequently almost impossible to comprehend what the woodlands might have been like. All surviving woodland remnants in the Northern Plains are therefore justifiably precious and worthy of conservation because they provide us with the only opportunity to conserve part of the once dominant woodland ecosystem, as well as providing us with an insight into what the flora and fauna of the woodlands was once like. As the single largest area of woodland vegetation surviving in the eastern Northern Plains, the woodlands growing along the public frontages of the Broken, Boosey and Nine Mile Creeks have extremely high significance for nature conservation.

3.1.3 Significance of remnant vegetation along the creeks in an ecological context

3.1.3.1 Ecological distinctiveness of the creeks' Grey Box woodlands

At approximately 60% of sections surveyed along the creeks, the dominant tree species were box eucalypts, in particular Grey Box (Table 4). This preponderance of box eucalypts along the creek margins distinguishes the riparian (creekbank) vegetation along the Broken, Boosey and Nine Mile Creeks from that found growing along nearly all other creek and river systems in the Northern Plains and, indeed, all other lowland plains in Victoria.

Table 4. Comparative tree-species composition of mature eucalypts and young trees (< 2 m high) along the Broken, Boosey and Nine Mile Creeks. 'n' and '%' refer respectively to the number and proportion of sections at which each species of eucalypt or eucalypt category was listed as the most common of the species categories present. The figures in brackets are revised percentage frequencies of the comparative abundance of young trees of different species categories, having excluding sections without any regeneration

Tree species	Mature Trees		Young trees	
	n	%	n	%
Grey Box	211	45.1	43	9.2 (12.4)
Yellow Box	9	1.9	1	0.2 (0.3)
Black Box	6	1.3	2	0.4 (0.6)
Mixed box species	22	4.7	2	0.4 (0.6)
Mixed box/River Red Gum	34	7.3	41	8.8 (11.8)
River Red Gum	185	39.5	258	55.4 (74.3)
None	1	0.2	119	25.6 (0.0)

The preponderance of box eucalypts rather than River Red Gum along the creek margins also emphasises the formerly characteristic 'broken', or intermittent nature of the creeks system (see 2.4). River Red Gums depend on a water supply greater than that which they receive from annual rainfall alone (Parsons *et al*. 1991). As a consequence, River Red Gums only survived along the 'broken' creeks system in those parts of the creek bed where the water table was high, whereas box, especially Grey Box, were able to grow in drier situations along the creek banks and elsewhere. Along all of the major rivers in the eastern Northern Plains, by contrast, there is a permanent water supply

and riparian plants such as River Red Gum, Silver Wattle, River Bottlebrush and River Tea-tree *Leptospermum obovatum* are able to survive. Along the creeks further south in the eastern Northern Plains, the higher rainfall (Fig. 4) likewise means that there is sufficient water in the creeks to support a riparian vegetation community of River Red Gum, Silver Wattle and River Bottlebrush rather than Grey Box and associated understorey species. In the western Northern Plains, average annual rainfall decreases and not only River Red Gums but also Grey Box disappear from watercourses and Black Box becomes the dominant riparian tree along the creeks (Fig. 8). Throughout all of Victoria, therefore, it is just a few creeks in the 400-550 mm annual rainfall range whose riparian vegetation consists primarily of Grey Box or Yellow Box woodland rather than River Red Gum or Black Box.

3.1.3.2 Environmental gradient

The Broken, Boosey and Nine Mile Creeks traverse a significant proportion of the Northern Plain's climatic gradient, flowing from foothills in the southeast with an annual rainfall of more than 600 mm to semi-arid, Black Box woodlands in the northwest with an annual rainfall of less than 400 mm (Fig. 4). As a result, the species composition of plants and animals found along the creeks changes as the environment became suitable or unsuitable for particular species of wildlife. A detailed study of the vegetation on the Northern Plains, for example, shows the woodland vegetation along the creeks system changing from a vegetation type described as 'Western Grassy Woodland' in the lower sections to 'Eastern Grassy Woodland' further east and finally to Eastern Wet Grassland in the highest rainfall areas in the southeast (Foreman 1995). As a whole, therefore, the remnant woodland vegetation found along the creeks provides a much richer sample of the range of natural environments found in the eastern Northern Plains than any other solitary and isolated remnant of woodland can.

3.1.3.3 Connectivity

The continuity of the different woodland environments along the environmental gradient of the creeks system further means that, as the climate or local environment changes in response to global warming, rising water tables or other environmental events, some animals and plants might be able to colonise or recolonise different parts of the creeks system relatively easily. This is because, in the event of climatic change, there is some likelihood of populations living at the extremity of their current range surviving, individuals of which can then move along the connected habitat provided by the creeks system to occupy suitable habitat wherever it now occurs. By contrast, surviving individuals may not be able to cross open farmland to recolonise an isolated remnant, even if it now provides suitable habitat for them. Conservation of the remnant vegetation along the entire creeks system is consequently critical if we are to conserve wildlife in the Northern Plains in the longer term (Bennett 1990; Bennett *et al*. 1991; Recher 1993).

Even without future change, the continuity of remnant vegetation along the creek frontages is already critical to the daily and seasonal movements or habitat use of some species of animal. At various sites along the creek, we observed roving groups of Black-chinned Honeyeater and Brown-headed Honeyeater moving along the streamside vegetation in short bursts, feeding intermittently and daily covering distances of more than one kilometre. The two pairs of Azure Kingfishers recorded during the survey were similarly observed moving more than one kilometre along Broken Creek in search of food. Two species of parrot mostly restricted to the River Red Gum forests along the Murray, Goulburn and Ovens Rivers - Superb Parrot and Yellow Rosella - used remnant habitat along the lower Broken Creek as far upstream as Nathalia. Superb Parrots also use the creek as a wildlife corridor connecting their nesting grounds in Barmah Forest with feeding habitat along the creek and on the surrounding plains (J. Chandler, I. Davidson, pers. comms).

In the spring, Noisy Friarbirds and Little Friarbirds moved upstream along the creeks, presumably migrating from the larger riverine forests along the Murray River towards the foothills and box-ironbark forests near Benalla and Wangaratta (Fig. 2). In autumn and spring, many different species of birds from the foothills and box-ironbark forests migrated down along the creeks to winter in woodland remnants on the plains and the riverine forests along the Murray, for example Red Wattlebird, White-naped Honeyeater, Fuscous Honeyeater, Spotted Pardalote and Golden Whistler. One endangered species of migratory bird that depends on woodland vegetation, the Regent Honeyeater has also been recorded from along the creeks.

The creeks thus provide a crucial habitat corridor for wildlife movement between the only two other large areas of remant native vegetation in the eastern Northern Plains - the River Red Gum forests at Barmah and along the Murray, and the box-ironbark forests at Killawarra and in the Warby Ranges (see Fig. 2). At a broader scale, the Broken, Boosey and Nine Mile Creeks system forms part of the network of creeks and rivers that connect the southeastern highlands with the woodlands and semi-arid woodlands out on the plains and allow for the seasonal migrations of a large number of birds (Robinson & Traill 1996).

Historically, the creeks provided important habitat for native fish species such as Murray Cod, Golden Perch and Macquarie Perch, all of which moved seasonally or opportunistically along the creeks system to breed (Koehn & O'Connor 1990a) and lived at least as far upstream as Lake Rowan and Benalla (see 2.4.4). Because of fundamental changes to the creeks, in particular the construction of weirs and other barriers, such movement is no longer possible and most of the native fish species once present in the creeks are now restricted to the lower Broken Creek below Nathalia (see 3.2.4.5). Nonetheless, suitable habitat for these threatened species of fish does still occur upstream of Nathalia (W. O'Connor, DNRE, in litt.) and highlights the need to maintain habitat connectivity along the entire creeks system, not just on the dryland but within the creeks themselves.

3.1.3.4 Ecosystem intactness

Because of the enlightened Government order of 1874 which prohibited timber-cutting on water frontages, the tree-cover along the creeks system includes a much larger proportion of old trees than is found in remnants of native vegetation on private land or in large blocks of public land in most other parts of the Northern Plains (see 3.2.1.4). The remnant habitat along the creeks system is therefore critical to the survival of animals such as Tree Goanna, Squirrel Glider, Crested Shrike-tit, Barking Owl and Southern Boobook which require older trees to provide them with necessary ecological requirements; for instance, food, hollows or roosting sites. The composition of the remnant tree cover at the least altered sites further provides us with a glimpse of what the box woodlands might have looked like prior to European occupation, with relatively large numbers of box with trunk diameters of more than one metre, high densities of hollow-dwelling mammals, reptiles and birds, and many scarred trees.

The same Government order of 1874 additionally ensured that most of the public land along the creeks was not cultivated, so as to minimise the risks of streambank erosion (Cabena 1983). As a result, the groundlayer beneath the canopy of mature and old-growth trees is predominantly native (see 3.2.1.6), albeit highly simplified in comparison with the wealth of plants recorded here in the early days of European settlement (2.4). Accordingly, the opportunities for restoration of a more diverse groundlayer along many parts of the creeks system are high, provided that there is a decrease in current grazing levels by stock.

Already at some sites along the creeks, however, levels of grazing have been restricted by various historical events such as the placing of public roads alongside the creek, the establishment of water reserves along the creeks for the watering of stock but not for licenced grazing, the establishment of churches or schools in whose grounds grazing was only intermittent, the establishment of recreation reserves, parts of which were left unmaintained and the establishment of town commons, as at Wunghnu, where grazing was only permitted under certain conditions (Hibbins 1978; Bossence 1979; Wright 1989). As a result, there are places in the public land estate along the creeks where understorey vegetation has remained, providing one with a fragment of the Northern Plains landscape as it once was and enhancing the local biodiversity of those given sites (see 3.2.1.5).

3.2 NATURE CONSERVATION VALUES OF SPECIFIC SITES ALONG THE BROKEN, BOOSEY AND NINE MILE CREEKS SYSTEM

3.2.1 Environmental attributes of the land along the creeks

3.2.1.1 Section width and tree cover width

Site width and area are the singlemost important predictors of species diversity and abundance of birds and mammals in temperate Australia, particularly for those species which need patches of tree cover or understorey in order to survive (Kitchener *et al*. 1982; Loyn 1985a; Arnold & Weeldenburg 1990; Bennett 1990; Lynch & Saunders 1991). Site width is also a significant predictor of plant-species diversity. For example, along the three creeks, wider frontages tended to support significantly more vegetation communities than narrower frontages (correlation = 0.197, $P < 0.05$) because of the changes in landform and soil type in relation to distance from the creek. Thus, along the lower meandering reaches of the Broken Creek, and in other sections where the creekbank formed a sandy levee, wider frontages were more likely to contain portions of the surrounding, low-lying floodplain vegetation than were narrow frontages. Conversely,in the other parts of the creeks system where the creek was the lowest point in the landscape, wider frontages were more likely to support dryland vegetation communities than were narrow frontages and consequently tended to have a more diverse fauna.

Along the creeks, 58% of sections had a width of less than 50 m and only 8% of sections were more than 200 m wide (Table 5). Total treecover widths varied in a similar way to crown land widths. The majority of sections had total treecover widths of less than 50 m, and treecover at 75% of all sections surveyed was less than 100 m wide (Table 5).

Table 5. Crown land widths and total treecover widths of surveyed sections along the Broken, Boosey and Nine Mile Creeks system

Width category	Crown land width		Total treecover width	
	no. of sections	%	no. of sections	%
> 200 m wide	39	8.3	64	13.6
150-200 m wide	16	3.4	18	3.8
100-150 m wide	26	5.5	35	7.4
75-100 m wide	43	9.1	56	11.9
50-75 m wide	75	15.9	85	18.0
30-50 m wide	139	29.4	111	23.5
<30 m wide	134	28.4	103	21.8

Despite these small widths, many sections of the creek represented the broadest areas of tree cover remaining in the local landscape (Figs. 6, 7). Furthermore, many parts of the creeks system, particularly those remnants more than 200 m

wide, were the only remnants in the local landscape which were able to support some species of woodland-dependent bird (see 3.2.4.1). They also tended to contain more vegetation communities than did narrow frontages (see above) and thus provided potential habitat for more species of native wildlife (Bennett 1990). At the district scale, therefore, the remnant vegetation along the creeks system is crucial for the survival of many species of native wildlife.

3.2.1.2 Vegetation communities present

Wildlife diversity is closely related to the diversity of vegetation types present in a given area as different vegetation types tend to support different species of wildlife (e.g. Bennett 1990), may provide different habitat elements such as food types or nest sites for the same species of wildlife (e.g. Superb Parrots nesting in River Red Gum forest but feeding in nearby box woodlands), or else may provide different habitat elements for the same species of wildlife in different seasons (e.g. nectar-feeding birds changing tree species in response to their flowering).

Along the creeks, we recorded thirteen different natural vegetation communities (Table 6), although most sections only contained two distinct vegetation types. The communities identified were as follows:

Riverine Red Gum Forest is a vegetation community restricted to the regularly inundated parts of the Murray River floodplain (Margules & Partners 1990). We recorded it during the survey only from the sections close to the junction of Broken Creek and the Murray River, although many of the groundcover species were also recorded from a low lying area near Dip Bridge. The vegetation consisted of an overstorey of River Red Gum and a groundlayer dominated by species such as Warrego Grass *Paspalidium jubiflorum*, River Bluebell *Wahlenbergia fluminalis*, River Buttercup *Ranunculus inundatus*, Common Sneezeweed *Centipeda cunninghamii* and Poong'ort *Carex tereticaulis*.

River Red Gum Swamp Woodland occurred in lowlying areas of the landscape away from Barmah Forest that were regularly but shallowly inundated. The vegetation thus consisted of species associated with the damp margins of wetlands, such asCommon Nardoo *Marsilea drummondii*, Poong'ort and Small Spike-rush *Eleocharis pusilla*, rather than aquatic plants.

Riparian Red Gum Forest/Woodland was a vegetation community characterised as growing in less frequently inundated sites than the Riverine Red Gum or River Red Gum Swampland communities. It typically occurred as a narrow fringe of vegetation along the creekbank along almost the entire length of the creeks system. Common groundcover plants growing beneath the Red Gum overstorey were Poong'ort, rushes *Juncus* spp, Common Spike-rush *Eleocharis acuta*, Small Spike-rush and wallaby grasses *Danthonia* spp. Tangled Lignum *Muehlenbeckia florulenta* also occurred in this community.

River Red Gum/Damp Grey Box Open Forest/Woodland represented a transitional community between the River Red Gum and Grey Box communities. It occurred commonly along much of the lower and middle parts of the creeks system but was rarer in the higher reaches. Common groundcover plants comprised Forde Poa *Poa fordeana*, Joyweeds *Alternanthera* spp., Raspworts *Haloragis* spp., Small Spike-rush and Native Penyroyal *Mentha satureoides*. Tangled Lignum was often moderately common in this community and some dryland species of shrubs such as Weeping Pittosporum, Sweet Bursaria *Bursaria spinosa*, Spreading Eutaxia *Eutaxia diffusa* and Gold-dust Wattle also began to appear.

Damp Grey Box Open Forest/Woodland occurred intermittently through most of the creeks system, growing on heavy soils in low-lying sites in the landscape, for example at Drumanure, Dunbulbalane and Rowan's Swamp. Understorey and groundcover plants typically included those mentioned above and the grasses Plains Spear-grass, Spider Grass and Rigid Panic.

Dry Grey Box Woodland occurred commonly along almost the entire length of the creeks system upstream of about Narioka. It typically was found on sites with clay loams and generally consisted of no more than an overstorey of Grey Box and groundcover of wallaby grasses, spear-grasses and sedges. As shown by lightly grazed sites, however, (e.g. Wunghnu Bushland Reserve), this community should include a rich understorey of many different species of shrubs and a groundcover of saltbushes, mat-rushes, flax lilies, bluebushes and many native herbs.

Dry Grey Box/Yellow Box Woodland usually grew on lighter soils than Grey Box woodland and tended to have a weedy groundcover of annual grasses. Where there were native plants present they usually included those found in Dry Grey Box woodland as well as some sandy-soil species such as Sweet Hound's-tongue *Cynoglossum suaveolens*, Pale Flax-lily *Dianella longifolia* and Variable Glycine *Glycine tabacina*.

Yellow Box-White Cypress-pine Woodland occurred very rarely throughout the creeks system at sites where there were sandy soils. Because of clearing of nearly the entire vegetation community for cropping, however, few intact examples of this vegetation type were found. At the few intact sites, the understorey vegetation typically included Desert Cassia, Grey Mulga and Wedge-leaf Hopbush. Groundcover plants characteristically included Sweet-scented Mat-rush *Lomandra effusa*, Annual New Holland daisy *Vittadinia cervicularis*, Sweet Hound's-tongue, Variable Glycine and other soft peas.

Black Box Woodland is near the eastern limits of its range in the eastern Northern Plains (Fig. 8) and only occurred in the lowest rainfall portions of the creeks system, downstream of Nathalia. It occurred most commonly along the Broken Creek in Barmah Forest. By contrast with other vegetation

communities recorded along the creeks, Black Box Woodland is characteristic of semi-arid rather than temperate environments. Its groundcover vegetation consequently included a large proportion of chenopods (saltbushes, bluebushes) rather than grasses or sedges.

White Box Woodland typically grows on coarse gravel soils derived from volcanic rocks or alluvium in those parts of the Northern Plains where average annual rainfall is higher than about 450 mm. Although it occurs relatively commonly on granitic hills in the North East, lowland examples of this vegetation type are rare. We twice recorded this vegetation community along the creeks: on the Broken Creek at Wagarandall and at Boxwood Historic Reserve. At both sites the canopy consisted of White Box interspersed with Grey Box and Yellow Box and the groundcover consisted of a range of native grasses.

Blakely's Red Gum Woodland also grows on gravel or sandy soils derived from volcanic rocks or alluvium and is a common vegetation community along the edge of the foothills in the North East. Along the creeks, it was recorded only once as a community (Table 6), at Bushland Reserve H91 on the Boosey Creek, although scattered trees were recorded at a few other sites, for example: Moodie Swamp, Rowan Swamp and Boxwood Historic Reserve. At H91, the overstorey consisted of Blakely's Red Gum and the understorey consisted of a mixture of native and introduced grasses.

Wetlands were treated as a conglomerate of different vegetation types and not distinguished from one another. They were broadly defined as vegetation types found in regularly inundated sites which were deep enough to support aquatic plants, for example Pacific Azolla *Azolla filiculoides*, Water Ribbon *Triglochin procerum* and milfoils *Myriophyllum* spp. Along the creeks system, there were relatively few natural wetlands, the most important comprising Tungamah Swamp, Moodie Swamp and Rowan Swamp.

Native Grassland was broadly characterised as a conglomerate of the different grassland communities defined by Foreman (1995). However, all grassland sites were characterised as being treeless or nearly-treeless areas dominated by a range of native grasses, native herbs and chenopods (Foreman 1995). Of the five native grassland sites recorded along the creeks, four occurred at or west of Numurkah and included at least three species of chenopods. The fifth site was at Tungamah Wildlife Reserve and comprised a distinctive damp, gilgai grassland type which contained no chenopods.

Table 6. The relative abundance of different native vegetation communities along the Broken, Boosey and Nine Mile Creeks

Vegetation community	No. of sections	% of sections

Riparian River Red Gum Open Forest/Woodland	252	53.4
Dry Grey Box Woodland	177	37.5
River Red Gum/Damp Grey Box Open Forest	176	37.3
Dry Grey Box/Yellow Box Woodland	67	14.2
River Red Gum Swamp Woodland	54	11.4
Cleared Woodland	67	14.2
Damp Grey Box Open Forest/Woodland	64	13.6
Yellow Box/White Cypress-pine Woodland	23	4.9
Black Box Woodland	18	3.8
Wetlands	8	1.7
Riverine River Red Gum Open Forest/Woodland	6	1.3
Native Grassland	5	1.1
Other	4	0.8
White Box Woodland	2	0.4
Blakely's Red Gum Woodland	1	0.2

The total area of these communities amounted to 3901 ha of land. An additional 187 ha of land along the creeks, most of which was previously Grey Box woodland, had been cleared and cultivated and no longer provided any habitat for woodland wildlife

As outlined earlier (3.1.1), all remnants of native vegetation are ecologically significant within a landscape in which 99% of the tree cover has been removed. Because of selective alienation and initial clearing of those soil types most suitable for agriculture, however, the extent of loss has been different for different vegetation communities (Pressey 1995; Robinson & Traill 1996). Within the eastern Northern Plains, a disproportionately high percentage of regularly flooded River Red Gum forest has been retained, much of it in the public estate, whereas a disproportionately high percentage of the grassy woodland has been destroyed (3.1.2). At a finer scale of resolution, those grassland or grassy woodland communities that grew on arable soils were alienated and cleared preferentially to woodlands growing on heavy soils. As a result, all sandy soil woodland communities are now extremely rare (Tables 6, 15).

The remnant vegetation along the creeks system is therefore highly significant for nature conservation as it provides representation of these now endangered vegetation communities which were once common on arable soils (Fig. 5) but have all but disappeared from the eastern Northern Plains.

3.2.1.3 Tree species present

Just as wildlife diversity is related to the diversity of vegetation types present at a given site (3.2.1.2), so it is related at a finer scale to the diversity of plant species present. For example, some species of native mistletoes grow only on eucalypts, others only on Buloke or allied species of *Allocasuarina*, and others only on wattles (Cunningham *et al*. 1992). The abundance of different tree species can therefore influence the abundance of different mistletoe species

present at a site. In turn, different mistletoes provide seasonal habitat for different butterfly species (Fisher 1978) and different birds (Robinson 1994a), and the biodiversity of the site increases.

Along the creeks,we recorded ten species of indigenous tree, although only three of these were common. River Red Gum was present at 88% of sites (n = 520 sites), Grey Box at 85% of sites and Yellow Box at 25% of sites. The remaining species occurred at fewer than 12% of all sampled sites. They comprised Buloke (11%), Black Box (5%), White Cypress-pine (5%), Lightwood (1.5%), White Box (1%), Blakely's Red Gum (1%) and Drooping She-oak (0.2%).

Historical descriptions make it clear that there was once a much more diverse array of trees growing in the Northern Plains (see 2.4). Cypress-pine and Buloke were common and now-extinct tree species such as Silver Banksia and Cherry Ballart were also interspersed through the plains. In addition, some species which now persist in the landscape only as shrubs, formerly grew to the size of trees. In 1935, Jim Willis noted Waterbush, Weeping Pittosporum, Berrigan and Sweet Bursaria growing as small trees in the Nathalia district. During the current survey, no tree-sized specimens of these plants were seen. The diversity and complexity of the tree layer in the eastern Northern Plains has thus diminished steadily over the past 140 years. In contrast to most of the Northern Plains landscape, however, there are at least some sites along the creeks which include mature stands of trees other than Grey Box or River Red Gum, so providing an opportunity to conserve particular species of wildlife that depend on those trees and to add to the overall biodiversity of the eastern Northern Plains.

3.2.1.4 Age structure of the tree overstorey

The presence of old-growth eucalypt habitat is critical to the survival of many species of native wildlife (Recher *et al*; 1987; Robinson 1994a, 1995). Approximately 37% of Victorian mammals and 39% of forest and woodland birds nest in tree-hollows (Robinson 1992). Other species of wildlife require older trees for specialised foraging habitat, roost sites or nest sites (Ford & Barrett 1995; Robinson 1995a). Accordingly, the abundance of old-growth habitat and large, old trees has been found to be one of the best predictors of the numbers of woodland birds at given sites (Ford & Barrett 1995).

Along the creeks, nearly 70% of sections contained at least some old-growth habitat (that is trees of greater than one metre diameter at breast height). Ninety-nine percent of sections contained at least some mature trees, as estimated by the abundance of trees more than 50 cm in diameter (Table 7).

These results contrast with those of a broader survey of tree size-class abundance undertaken across the Northern Plains (Bennett *et al.* 1994) in which it was found that only 8% of all trees surveyed were larger than 70 cm diameter at breast height (dbh) and that 50% of sites had few or no trees larger than 70 cm diameter (Bennett *et al*. 1994). However, that study also found that sites along creeks had the greatest density of mature and old-growth trees - a result due primarily to historical accident and the prevention of timber cutting or clearing on public frontages (see 2.7). Both studies thus emphasise the significance of the remant woodland habitat along the Broken, Boosey and Nine Mile Creeks as an important remnant of old-growth habitat in the Northern Plains.

Table 7. The abundance of different age-classes of trees. Definitions of terms are given in Appendix 1.

	Old-growth		**Mature**		**Young**		**Seedlings**	
Abundance	n	*%*	n	*%*	n	*%*	n	*%*
Many	37	*8.0*	219	*47.1*	218	*46.9*	60	*12.8*
Some	274	*58.9*	240	*51.6*	214	*46.0*	268	*57.1*
None	154	*33.1*	6	*1.3*	33	*7.1*	141	*30.1*

3.2.1.5 Shrub layer

Apart from the area of a given site, the number of different layers of vegetation present is often the next most important predictor of vertebrate distributions in

patches of native vegetation (e.g. Gilmore 1985; Arnold 1988; Arnold & Weeldenburg 1990; Cale 1990; Hadden & Westbrooke 1996). The presence of an understorey layer is also fundamental to the distribution of many species of invertebrates which need certain plant species in order to survive (e.g. Fisher 1978). More broadly, the presence of a shrub layer is fundamental to the ecosystem dynamics of eucalypt forests and woodlands: many shrub species fix nitrogen and enrich the soil and presumably the nitrogen content of the canopy trees (Recher 1985); shrubs provide habitat for predatory insects, mammals and birds which help to regulate numbers of defoliating herbivores in the tree canopy (Ford & Barrett 1995); and shrubs influence the microclimate of the groundlayer and soil. The presence of shrubs is consequently crucial to the maintenance of woodland environments.

Along the creeks system, however, indigenous dryland shrubs such as wattles, bush peas, hop bushes and cassias were the rarest plant form encountered. At 61% of sections, there were no dryland shrubs at all (Fig. 9). At a further 20% of sections, dryland shrubs were extremely scarce. And altogether, an extensive shrub layer was observed at only 15 of the 473 surveyed sections (Fig. 9) - a stark contrast to the early account of the vegetation by Clement Hodgkinson and others (see 2.4.1, 2.4.2). Even at those sites where some shrubs occurred, there were marked differences in the abundance of different species (Table 8). Of the 23 species of dryland shrubs recorded along the creeks, 13 were recorded at ten or fewer sites (i.e. 2% or less of all sites sampled) and no species was recorded at more than 21% of sites (Table 8); their rarity due primarily to persistent over-grazing (see 4.2.1).

Thus, whereas the 1874 government order prohibiting tree-felling and cultivation on crown land frontages helped to conserve the overstorey of trees and the native ground layer (see 2.7), the subsequent government decisions legitimising grazing on public frontages (section 2.7) resulted in the destruction of nearly all shrubs. Because of various historical events, however, (see 3.1.3.4), some sites along the creeks have retained their shrub cover and are critical for nature conservation in the eastern Northern Plains: as habitat for understorey-dependent animals; as fundamental elements of woodland ecosystems; as rare examples of what the environment may have been like prior to European occupation; and because nearly every shrub species found is so rare that multiple sites will need to be protected to ensure that they survive (Kirkpatrick 1983; Safstrom 1995).

The only wetland shrub recorded during the survey was Tangled Lignum *Muehlenbeckia florulenta*, a plant found growing along the wet margins of the creek and other waterbodies downstream of about Dookie, Tungamah and Yundool. Like other shrubs, Tangled Lignum was relatively scarce (Fig. 9), and was recorded in abundance at only 4.9% of sites. Overall it was absent from 59.3% of sites (Fig. 9).

Lignum is not mentioned in historical accounts of the region and it is possible that the species has become more common in recent years as a result of generally higher watertables and waterflows (Frood 1983; Margules & Partners 1990). If this is so, it is probable that current patterns of land and water use will cause the replacement of dryland box communities and dryland shrubs with a community of River Red Gum, sedges and lignum.

Table 8. Abundance of indigenous shrub species along the Broken, Boosey and Nine Mile Creeks. Data based on total sample of 520 sites. Asterisks indicate species listed as threatened in Victoria. Footnote 1: Silver Wattle was not recorded during formal survey but occurs along first one hundred metres of Broken Creek downstream from junction with Broken River. For scientific names and threatened status of plants see Appendix 3.

Shrub species	**No. of recorded sites**	**% of sites**
Gold-dust Wattle	106	20.4
Sweet Bursaria	100	19.2
Mallee Wattle	87	16.7
Golden Wattle	75	14.4
Weeping Pittosporum	26	5.0
Spreading Eutaxia*	24	4.6
Common Eutaxia	24	4.6
Grey Parrot-pea	17	3.3
Desert Cassia	11	2.1
Drooping Cassinea	11	2.1
Lightwood	8	1.5
Waterbush*	8	1.5
Twiggy Bush-pea	7	1.3
Wedge-leaf Hop-bush	5	1.0
Berrigan	5	1.0
Grey Mulga	4	0.8
Hakea Wattle	4	0.8
Wallowa	1	0.2
Silver Wattle[1]	1	0.2
Mallee Golden Wattle*	1	0.2
Varnish Wattle	1	0.2
Dogwood	1	0.2
Violet Kunzea	1	0.2

3.2.1.6 Groundcover

Despite their relative inconspicuousness in comparison to the canopy and shrub layers of vegetation, groundcover plants are the primary determinant of plant-species diversity in grassy woodland environments (Tremont & McIntyre 1994). Native plant-species diversity in turn influences the species diversity of invertebrate species present at a given site, since many invertebrates can only live on particular plants (e.g. Fisher 1978), and the species diversity of smaller vertebrates (Hadden & Westbrooke 1996). The open structure of the groundlayer vegetation of grassy woodlands, in association with the presence of a litter layer and logs, similarly exerts an important influence on the distribution of many species of ground-dwelling birds (Robinson 1994a; Ford & Barrett 1995), reptiles (Brown & Bennett 1995) and litter-dwelling invertebrates (Bromham 1994). Retention of a diverse groundlayer is thus fundamental to biodiversity conservation in the Northern Plains. More broadly, retention of an intact layer of groundlayer vegetation and tree litter is fundamental to ecological processes such as nutrient cycling, soil formation, water cycling and water quality in woodland environments (Scougall *et al*. 1993; Nicholas & Mack 1996).

At nearly one half of sections (46%) along the creeks, the groundcover vegetation consisted predominantly of native species. At one third of sections it was predominantly weedy. The remaining 20% of sections contained a mixture of weeds and native plants (Table 9). The extent of weedy groundcover was generally highest for sections adjoining roads, sections along which there had been creek works, sections that had been mostly cleared, narrow sections, sections on sandy soils, sections adjacent to irrigation properties and sections which had been cultivated.

Although the composition of the groundcover in many sections was mostly native, the quantity of groundcover material was generally low (Table 9). At only 6% of sections did groundcover plants cover 100% of the area and grow to a height of more than 20 cm. At 51% of sections there was groundcover vegetation on less than 20% of the site and/or the groundcover plants were less than 5 cm high (Table 9). The species composition of the native grasscover that was present along the creeks was highly modified, moreover. Only 3% of sections along the creeks were dominated by tall, warm-season perennials - the grass type considered to have dominated the Northern Plains environment prior to European arrival (Moore 1970). A further 12% was dominated by short warm-season perennials or medium cool-season perennials (Table 10). More commonly, the native groundcover species consisted mostly of short, cool-season perennials (26%) or short sedges and rushes (22%), as a consequence of severe grazing pressure over the past 140 years (see 4.2.1).

Associated with the scarcity of deep, dense groundcover or intact groundlayer vegetation, it was found that most sections had little tree litter and very few logs. At 79% of fauna survey sites, there were few or no logs and at 67% of all fauna sites there was only shallow or scattered leaf and twig litter. There was consequently little potential habitat for ground-dwelling fauna along the creeks.

Ground-dwelling animals have been identified as the next most likely group of animals in Australia to undergo a wave of extinctions (Recher & Lim 1990), primarily as a result of habitat loss and modification. Results obtained during this survey supported that view: we recorded very few reptiles overall, did not record widespread species of ground-dwelling animals such as Bearded

Table 9. Groundcover characteristics of sampled sections along the Broken, Boosey and Nine Mile Creeks system. See Appendix 1 for explanation of definitions.

Environmental Variable	**No. of sections**	**%**
Species composition of groundcover vegetation		
More than 90% native plant species	47	10.0
71-90% native plant species	100	21.2
56-70% native plant species	70	14.9
45-55% native plant species	95	20.2
56-90% introduced plant species	116	24.6
More than 90% introduced plant species	43	9.1
Biomass of groundcover vegetation		
Much	26	5.6
Some	212	45.3
Little	204	43.5
None	26	5.6

Table 10. Frequency occurrence of different categories of native grasses and other groundcover plants as the dominant groundcover species along the creeks. (see section 1.4 for explanation of categories).

Grass-species category	**No. of sites**	**%**
1. Tall warm-season perennials	9	2.8
2. Short warm-season perennials	18	5.6
3. Medium cool-season perennials	23	7.1
4 Combination of 1 or 2, and 3	40	12.4
5. Combination of 1 or 2, and 8	53	16.5
6. Combination of 8 and 3	20	6.2

7. Volunteer warm-season perennials	4	1.2
8. Short cool-season perennials	83	25.8
9. Juncus/sedges	72	22.4
Total	322	100

Dragon, Common Blue-tongue or Echidna at all; and recorded few ground-dwelling species of insectivorous woodland bird (see 3.2.4.1). Unless current grazing practices along the creeks are modified, therefore, further declines of the local native fauna can be expected. Furthermore, unless current grazing practices are modified to ensure that there is a well-vegetated strip of riparian vegetation along the creek banks, water quality and the aquatic environment will likewise decline even more (see Nicholas & Mack 1996 and section 3.2.2).

3.2.2 Environmental attributes of the creek waters

3.2.2.1 Naturalness

In common with nearly all lowland streams in Victoria (OCE 1988; LCC 1989; Mitchell 1990), the Broken, Boosey and Nine Mile Creeks are highly modified as a result of channelisation works, the installation of barriers such as weirs and fords, the construction of bridges and nearby roads, the removal of fallen timber (snags), changes to natural water flows, increases in sediment loads, increases in nutrient loads, increases in salinity, the clearing of streamside vegetation, the over-grazing and pugging of banks by domestic stock, and over-fishing (OCE 1988; LCC 1989; Koehn & O'Connor 1990a, 1990b; Mitchell 1990; Koehn 1993).

These problems are exacerbated further because of the poor environmental condition of the whole Broken River catchment. Within the catchment:

- there is just 15% of former treecover (OCE 1988);
- no sub-catchments with 'high naturalness values' exist (LCC 1989);
- 79% of the water available for diversion is already used by agriculture (OCE 1988);
- water quality on the plains is rated as 'degraded' (OCE 1988);
- water flows are the reverse of natural flows, particularly in the lower reaches (Fig. 10; Dexter *et al*. 1986), with peaks in summer and troughs in winter;
- extensive channelisation works have occurred (OCE 1988; CMPS & F 1993); and
- drinking-water quality at many towns on the plains (e.g. Dookie, Katunga, Numurkah, Nathalia) fails to meet the standards recommended by the World Health Organisation (OCE 1988).

Given this poor environmental record for the entire catchment, it is not surprising that nearly all creek sections along the Broken, Boosey and Nine Mile Creeks system were found to be highly modified.

Along the entire 360 km of sampled creek, only 2% of sections (9 sites) had wholly natural flows; most of them being located in the upper reaches of the Boosey and Nine Mile Creeks. Ninety-six percent of creek sections instead received irrigation water at least once every year (Table 11), causing the creeks

to be unnaturally full and wide. Whereas early settlers noted the creek channel as narrow, ill-defined and often dry (2.4; Hodgkinson 1856), we found sixty-two percent of sampled sections to be more than 10 m wide (Table 11) and 99% of sections to be full of water, despite sampling being done during summer.

A larger proportion of sampled sections (56%) had not been physically altered by dredging or channelisation works and had retained essentially natural streambed and streambank characteristics. Again however, most of these unmodified sections occurred in the middle and upper reaches of the creeks system.

Table 11. Streambed and waterflow characteristics of sampled sections along the Broken, Boosey and Nine Mile Creeks. See Appendix 1 for definitions of terms.

Stream character	No. of sections	%
Streambed character		
Channelised, frequently irrigated	121	26.8
Channelised, regularly irrigated	70	15.5
Channelised, rarely irrigated	5	1.1
Not channelised, frequently irrigated	111	24.5
Not channelised, regularly irrigated	131	29.0
Not channelised, rarely irrigated	5	1.1
Not channelised, natural flows	9	2.0
Creek width		
< 6 m	20	18.9
6-10 m	20	18.9
11-20 m	33	31.1
21-30 m	7	6.6
31-40 m	22	20.7
41-60 m	4	3.8

3.2.2.2 Instream habitat attributes

Apart from the physical attributes of the creek water (e.g. rate of flow, seasonality of flow, temperature, turbidity) and its substrates, four habitat

elements are considered critical to the distribution, abundance and survival of native fish: instream logs; instream detritus; aquatic vegetation; and overhanging vegetation (Koehn & O'Connor 1990a; Koehn 1993). The presence of live or dead trees in water is also a critical habitat component for many species of waterbird (Briggs & Thornton 1995).

Along the Broken, Boosey and Nine Mile Creeks system, all of these habitat elements were scarce (Table 12). Although there was some treecover along the creekbanks in at least 71% of sections, low overhanging vegetation was absent from 87% of sampled sections and was abundant at none. Within the stream, logs were absent from 38% of sections and uncommon at a further 54%, while clumps of organic material such as twigs and leaves were absent or uncommon at 97% of all sampled sections.

As noted in section 3.2.3.3, aquatic plant species were disproportionately rare along the creeks system. Overall aquatic plant cover was concomitantly rare. At 51% of sections, there was no emergent aquatic vegetation. At another 44% of sections, aquatic plants covered less than 20% of the water's surface (Table 12), in stark contrast to early descriptions of the Broken Creeks system in which it was noted that '...a beautiful *confervia* (probably a Water Milfoil species) ...covers the surface of all the rivers and ponds in this part of the country' (Hobson 1838).

The rarity of trees growing within the stream along the Broken, Boosey and Nine Mile Creeks was likewise in contrast to the testimony provided by the skeletons of dead River Red Gums of a once abundant woodland of River Red Gum within the streambed along the middle and lower sections of the creeks (Fig. 11). Now, few live trees survive within the streambed and few young trees are growing to replace them (Fig. 11).

Table 12. Instream habitat attributes along the Broken, Boosey and Nine Mile Creeks. For all variables measured, we defined 'common' as covering more than 20% of the water surface area in the section and 'uncommon' as covering 1-20% of the area. Figures in parentheses indicate the number of sampled sites. Figures in the body of table are percentage occurrence.

Habitat attribute	Abundance Ranking		
	Common	Uncommon	None
Overhanging vegetation (105)	0.0	13.3	86.7
Logs/snags (105)	7.6	54.3	38.1
Organic detritus (105)	2.8	24.8	72.4
Emergent aquatic vegetation (106)	4.7	44.3	51.0

3.2.3 Native plant species

3.2.3.1 Plant species richness

Nearly three hundred plant species (approximately one-tenth of all known species of vascular native plants found in Victoria) were recorded along the Broken, Boosey and Nine Mile Creeks during the course of the survey (Appendix 3). Several additional species had previously been found along the creeks system but were not found by us (Chesterfield *et al*. 1984; Beauglehole 1986), while additional species are likely to be found during future surveys in non-drought years or in different seasons.

At sites surveyed in detail (146 sites), there was an average of 34 native species of plants. For all sections surveyed, 7% contained more than 50 species (Table 13). The richest site for plants was the 17 hectare Bushland Reserve at Katamatite which contained 130 native species, including eleven species listed as threatened in Victoria and many which are regionally threatened.

That so many species can still be found in just 17 hectares testifies to the biological richness of the former box woodlands of the Northern Plains, especially when one recalls that whole families of plants such as orchids were once reported as abundant near Katamatite (section 2.4.3) but have since disappeared. The richness of the Katamatite site furthermore underlines that there is still a rich and varied flora surviving on the Northern Plains which depends on the conservation of all remnants of native vegetation for its survival.

3.2.3.2 Threatened plant species

Of the 300 native plant species found along the Broken, Boosey and Nine Mile Creeks, 27 (9%) are listed as threatened in Victoria or Australia wide. Three species moreover, are known in Victoria only from crown land frontage along the Boosey, Broken or Nine Mile Creeks, namely Fat Spectacles *Menkea crassa*, Spiny Saltbush *Atriplex spinibractea* and Pepper Grass *Panicum laevinode (*formerly *whitei*).

Species endangered in Australia

Psoralea parva (Small Psoralea). Previously recorded from three sites along the lower Broken Creek (James Bridge, Kempsters Bridge, Fairmans Bridge) by Howie Marshall (Beauglehole 1986), but no longer present at Fairmans Bridge. New population of more than 500 plants found in Yellow Box/Grey Box ecotone at the western edge of Rowan Swamp Wildlife Reserve. Another population also found on Unused Road UR0887526, running south from Rowan Swamp Wildlife Reserve.

Table 13. Species-rich sites for native plants along the Broken, Boosey and Nine Mile Creeks system. Note that most searches were done on just one day in one season of a dry year and that all lists are assumed to be minimum estimates of species richness. VROTS refers to plants that are listed as vulnerable, rare or threatened with extinction in Victoria by Gullan *et al*. (1990).

Site	No. of species	No. of VROTS	Area (ha)
1. Katamatite Bushland Reserve	130	10	17.0
2. Moodie Swamp Wildlife Reserve	108	3	198.0
3. Numurkah Rifle Range	103	3	10.2
4. Boosey Creek between Youarang Rd & Tungamah	91	5	192.5
5. Wunghnu Bushland Reserve	89	7	33.0
6. Bushland Reserve H44, Broken Creek, Waggarandall	86	2	20.0
7. Broken Creek, east of Folletts Bridge, Naringaningalook	86	2	15.2
8. Broken Creek, Galts Bridge, Mundoona	84	3	6.4
9. Streamside Reserve K12, Drumanure, sw of Gordons Rd	81	3	9.6
10. Rowan Swamp Wildlife Reserve	80	5	430.0
11. Streamside Reserve K12, Drumanure, ne of Gordons Rd	79	3	4.7
12. Boosey Creek, Hester Rd, west of Katamatite, north bank	72	2	17.0
13. Streamside Reserve K12, Drumanure, west of site 9	69	4	20.0
14. Streamside Reserve K10, Waaia, north bank	64		50.9
15. Broken Creek, Barmah Forest	63	2	8.7
16. Streamside Reserve K12, west of Harris Bridge, north bank	60+	5	5.9
17. Broken Creek, Hester Rd, west of Boosey Ck, nw bank	60	3	1.4
18. Broken Creek, east of Dip Bridge, se bank	60	2	10.4
19. James Bridge, Broken Creek, Narioka	60	2	5.0
20. Streamside Reserve K12, Brookfield, south bank	60	4	14.9
21. Streamside Reserve K12, Dunbulbalane, 102nd section	59	1	13.7
22. Broken Creek, east of Dip Bridge, west bank	59	2	14.7
23. Broken Creek, Follett's Bridge, east of Numurkah	58	3	2.5
24. Broken Creek, Dickies Rd, Youarang	57	2	2.9
25. Broken Creek, Fairmans Bridge, Picola	56	3	10.4
26. Broken Creek, Barmah Forest	55	3+	20.0
27. Boosey Creek, west of Pelly Rd, St James	55	1	7.0
28. Broken Creek, south of Carlands Bridge, west bank	53	1	10.9
29. Streamside Reserve K27, Lake Rowan	52	2	15.9
30. Streamside Reserve K12, Kelly Rd to Gordon Rd, n. bank	50+	2	39.0
31. Bourkes Bridge, Broken Creek, Barwo	50	2	6.8
32. Streamside Reserve K12, east of Black Swamp	50	2	15.1
33. Tungamah Wildlife Reserve	50	3	146.0
34. Boosey Creek east of junction with Broken Creek, s. bank	50	2	9.0

Species vulnerable in Australia

Eragrostis infecunda (Southern Cane-grass). Not listed as threatened in Victoria but listed as nationally vulnerable. Relatively widespread along the creeks system and the dominant species across the lakebed at Moodie Swamp Wildlife Reserve.

Species endangered in Victoria

Panicum laevinode (Pepper Grass). New record for Victoria. Recorded from one tiny section of the Boosey Creek on low-lying heavy clay soil to the east of Katamatite. Also found on Three Chain Road, east of the Boosey Creek at Tungamah. Both populations unprotected.

Atriplex spinibractea (Spiny Saltbush). Previously known from only two sites in Victoria, both in Grey Box woodland on the Nine Mile Creek between Wunghnu and Drumanure. Two new populations were found during the survey, one near Follett's Bridge, east of Numurkah, and the other at Katamatite Bushland Reserve. All populations consist of fewer than ten plants. The population at Drumanure is now protected. The others are not.

Psoralea tenax (Tough Psoralea). Known from approximately 25 sites in Victoria (VicFlora Database) but not known from the eastern Northern Plains until discovered on the Broken Creek near Bourke's Bridge at Barwo (H. Marshall, pers. comm.). The population there currently consists of two small sub-populations, both of which are unprotected and at threat from vehicle traffic and occasional grazing by stock.

Menkea crassa (Fat Spectacles). Not recorded during this survey. The only known locality in Victoria is from Black Box frontage adjoining the Broken Creek in Barmah Forest (R. Weber, pers. comm). The site is poorly protected at present and is open to grazing by stock.

Species vulnerable in Victoria

Cyperus bifax (Sedge). Previously known in Victoria only from the western Northern Plains (Walsh & Entwhistle 1994), *Cyperus bifax* was recorded once during the survey along the lower Broken Creek in Riverine Red Gum forest in Barmah Forest. The site at which it was found is currently unprotected.

Eleocharis pallens (Pale Spike-rush). Not previously known from the eastern Northern Plains (Beauglehole 1986; Gullan *et al*. 1990). During the survey, we found it to be relatively widespread on the heavier soil sites east and south of Katamatite, notably at Tungamah Wildlife Reserve, Three Chain Road, Tungamah, Rowan Swamp Wildlife Reserve and the Barnes Road site east of Katamatite where Pepper Grass was also found.

Acacia notabilis (Mallee Golden Wattle). Known in Victoria from only a small area in the Big Desert and Sunset country area, and from one very isolated stand of five or fewer plants next to the lower Broken Creek at Fairmans Bridge, Picola (Beauglehole 1986; Fig. 12). Previously found along the Broken Creek at James Bridge at Narioka but that population has since died

out (H. Marshall, pers. comm.). The Fairmans Bridge population is unprotected.

Sida fibulifera (Pin Sida). Previously known in Victoria from only a few sites along the Murray River floodplain between Mildura and Boundary Bend, and at one site in the Mallee (Fig. 12). A small population of 20-30 plants found in gilgai Grey Box woodland in Katamatite Bushland Reserve, with most plants living on the gilgai mounds. The reserve is now fenced but the population may need further actions to protect it (for instance, weed control).

Haloragis glauca (Grey Raspwort). Not previously known from the eastern Northern Plains (Beauglehole 1986; Gullan *et al*. 1990). Recorded during the survey from Black Box woodland next to Broken Creek in Barmah Forest, from scattered Grey Box sites on heavy soils along Streamside Reserve K12 between Dunbulbalane and Dip Bridge, at Katamatite Bushland Reserve, along the Boosey Creek frontage east of Katamatite and at Tungamah Wildlife Reserve.

Brachyscome chrysoglossa (Yellow-tongue Daisy). Recorded from only 11 sites in Victoria (VicFlora Database). Two populations found along the creeks: one on the Numurkah Rifle Range in an open, damp grassland; and one of about 100 plants along the north bank of the Nine Mile Creek west of Harris Bridge, in Grey Box woodland. The recent discovery of a large population on private land just north of Follett's Bridge suggests that further populations may be discovered on other creek frontage areas to the east of Numurkah. Both of the creek populations are unprotected.

Species rare in Victoria

Triglochin dubium (Water Ribbons). This species of Water Ribbons is restricted in Victoria to the Northern Plains and Murray Valley (Walsh & Entwhistle 1994) and has recently been listed as rare (VicFlora Database). It was recorded only once during the survey, along the southern part of the Nine Mile Creek near Youanmite. Sampling in wetter seasons may find it to be more widespread as it is known to grow in regularly inundated, native pastures near Nathalia and Barmah (H. Marshall, pers. comm.).

Stipa gibbosa (Spurred Spear-grass). Recorded at scattered sites along the Broken, Boosey and Nine Mile Creeks between Wugnhnu Bushland Reserve and Tungamah. Also recorded along the southern part of Nine Mile Creek on the Dookie Plains near Yabba South. Most common on heavier soil sites in open Grey Box woodland. Not known currently from any of the well protected reserves and populations need additional protection.

Panicum decompositum (Native Millet). Very rare along the creek. Present in small numbers at only two sites - Wunghnu Bushland Reserve and Rowan Swamp Wildlife Reserve. Within the district, the largest populations occur along the Benalla-Yarrawonga railway line.

Tragus australianus (Small Burr-grass). Not recorded during the survey but known to occur on Crown land frontage next to the lower Broken Creek in Carlands Bend (H. Marshall, pers. comm.).

Maireana aphylla (Leafless Bluebush). Not previously known from the eastern Northern Plains (Beauglehole 1986; Gullan *et al*. 1990). Two plants are known to survive - one on the Barmah Bridge Road next to the Broken Creek and one in Katamatite Bushland Reserve (Fig. 12). Both are unprotected and appear to be unable to reproduce.

Maireana humillima (Dwarf Bluebush). A relatively widespread species, it was recorded intermittently between James Bridge and Katamatite. It was most common at Katamatite Bushland Reserve, Numurkah Rifle Range and in open grassy woodland west of Galt's Bridge. Dwarf Blue-bush tended to be recorded most often in wide reserves where the soil type changed to include the heavier soils found away from the creeks on the plains.

Desmodium varians (Slender Tick-trefoil). Recorded from four sites during the survey, all on sandy soils: water frontage next to the Boosey Creek east of Coles Rd near Lake Rowan; the sand rise at the western edge of Rowan Swamp Wildlife Reserve; on Unused Road UR0887526 running south from Rowan Swamp Wildlife Reserve; and at Bushland Reserve H91 on the Boosey Creek near Thoona. It is also known from along the lower Broken Creek near Kempsters Bridge (H. Marshall, pers. comm). None of these sites is currently protected from grazing or other threats.

Eutaxia diffusa (Spreading Eutaxia). Listed as rare in Victoria, Spreading Eutaxia was found to be relatively widespread along the creeks system, with individual plants or small stands recorded on heavier soil sites in Damp Grey Box woodland along the Broken, Boosey and Nine Mile Creeks between Numurkah, Tungamah and Waggarandall. One individual is also known from the lower Broken Creek near Kempsters Bridge (H. Marshall, pers. comm.). Two large populations were found during the survey, one of 20 plus plants in Wunghnu Bushland Reserve (now fenced) and one of more than 100 plants in Streamside Reserve K12 at Drumanure (now fenced). Most of the other populations are not protected.

Myoporum montanum (Waterbush). Recorded at eight sites on a range of soil types along the Broken and Nine Mile Creeks between Barmah and Katamatite but at only one of these was there a large population: at every other site there were just one to three plants. The population at Wunghnu Bushland Reserve comprises more than 50 individual plants and is the second-largest known population of Waterbush in the eastern Northern Plains, after a population of more than 200 plants on Machonicies Ridge in Barmah Forest. The Wunghnu population is now securely fenced but most other populations are unprotected.

Minuria integerrima (Smooth Minuria). A relatively widespread species recorded from 15 sites on heavy soils beneath either Black Box or Grey Box woodland from between Barmah to Dunbulbalane and Yabba North. Four large populations were located during the survey: in Black Box woodland next to the Broken Creek in Barmah Forest; in Streamside Reserve K12 at Drumanure (more than 100 plants); next to the Broken Creek immediately west of Dip Bridge; and along Sailor's Plain Road adjoining the Nine Mile Creek channel, west of Youanmite. At other sites, the population consisted of just a few plants. All populations apart from the one at Drumanure, are unprotected.

Ixiolena sp. (Woolly Plover-daisy sp.). A very rare forb recorded from just four sites along the creeks: Wunghnu Bushland Reserve (more than 30 plants), Katamatite Bushland Reserve (more than 30 plants), the Broken Creek just west of Galts Bridge at Mundoona (one plant) and Numurkah Rifle Range (less than ten plants). Elsewhere in the eastern Northern Plains, the species is very rare and is mostly confined to roadsides. Its conservation status is therefore insecure. The larger populations at Katamatite and Wunghnu both occur outside the fenced parts of the reserve and need protection.

Species depleted in Victoria

Callitris glaucophylla (White Cypress-pine). Recorded intermittently along most of the length of the creeks system. At most sites, however, it occurred as just one or two young plants and stands of old trees were extremely rare (4 sites). The latter sites are all unprotected.

Allocasuarina luehmannii (Buloke). Like White Cypress-pine, Buloke occurred throughout the creeks system but was extremely rare at most sites where present. Very few sites contained examples of the original Grey Box/Buloke woodland as it once was and those which do still survive need urgent protection.

Lotus cruentus (Red-flowered Trefoil). Found at just one site during the survey, in Black Box woodland next to the Broken Creek in Barmah Forest. The single plant was growing on what appeared to be an aboriginal midden. Although previously known from Barmah Forest (DCE 1992) and several sand rises in the Nathalia-Yalca area (H. Marshall, pers. comm.), there appear to be only three recent records of the species from the eastern Northern Plains (VicFlora Database). The plant found growing along the Broken Creek is unprotected.

Templetonia stenophylla (Leafy Templetonia). A widespread species recorded intermittently along almost the entire length of the creeks system between Picola, Thoona, Yabba South and Waggarandall. Also known from box ridges in Barmah Forest. Although recorded from 29 sites, populations of Leafy Templetonia at most sites consisted of just one or two, heavily-grazed plants and nearly all require protection. The largest populations located during the survey were found at Fairmans Bridge, Picola; on Crown land frontage adjoining Thompsons Road and the Nathalia-Katamatite Road, east of Nathalia; in Katamatite Bushland Reserve on the north side of Boosey Creek, along the Boosey Creek north of Tungamah, next to Petit Road on the Boosey Creek north of St James and in Bushland Reserve H44 at Waggarandall.

3.2.3.3 Regionally significant species

The ecological processes that underpin the maintenance of ecosystems and biodiversity operate at a local scale rather than a statewide or national scale (Robinson 1993a). Any species of native animal plant that is regionally threatened or endangered therefore merits as much conservation effort regionally as species recognised as threatened statewide.

During the survey, 119 species of the native plants (or approximately 40% of the total native flora) recorded along the creeks (Table 14) were considered to be regionally threatened within the Broken, Boosey and Nine Mile Creeks system because of their restriction to just a few sites, their small population sizes or the lack of adequate protection measures for them. Even excluding annuals (which were extremely scarce because of the dry season), there were still more than 100 species of regionally significant plants along the creeks system.

These regionally significant plants occurred predominantly in four broad vegetation types - wetlands and swamp woodlands, native grasslands, sandy soil woodlands and Dry Grey Box woodlands (Table 15). They occurred disproportionately often in wetlands and swamp woodlands, native grasslands and sandy soil woodlands (Table 15), highlighting the almost complete loss or degradation of these three broad vegetation types in the eastern Northern Plains. Any remaining areas of intact wetlands, native grasslands, Yellow Box woodlands or White Cypress-pine Woodlands in the eastern Northern Plains must therefore be ranked as having extremely high significance for plant conservation.

Another notable group of regionally threatened plants comprised geographically disjunct populations of particular plants. Examples include a large population of Golden Billy Buttons *Pycnosaurus chrysantha* at Tungamah Wildlife Reserve (Fig. 12), the easternmost known population of Minnie Daisy *Minuria leptophylla* in Victoria at Katamatite Bushland Reserve, and isolated specimens of two species of foothills shrubs (Violet Kunzea *Kunzea parvifolia* and Dogwood *Cassinia aculeata*) and one western Victorian shrub (Wallowa *Acacia calamifolia*) out on the plains. In every case, the occurrence of these species outside of their previously known range helps with the ecological reconstruction of what the woodland landscape was like, contributes significantly to the local ecosystem and may represent biologically distinctive forms of the plant. Sites with such geographically isolated populations of plants are consequently recognised as having special conservation value (AHC 1990).

Table 14. Regionally significant or regionally threatened species of native plants along the Broken, Boosey and Nine Mile Creeks system. Species were considered regionally significant/threatened if they were recorded at less than 10% of sampled sites and less than 6% of all sites, or if all localities of the species were known and it was present at less than 6% of sites. For many annuals and soft herbs, it was impossible to ascertain their status because of the dry season. The following list is consequently preliminary. For comparison, species listed as threatened either nationally or statewide are also included here and shown in **bold**.

SPECIES **sites)** **Scientific Name**	**Common Name**	**% of sites with each species for sites sampled in detail (146 sites)**	**% of sites with each species for all sites (520**
Ophioglossum lusitanicum	Adders Tongue	1.4	0.4
Cheilanthes sieberi	Narrow Rock-fern	1.4	0.4
Marsilea costulifera	Narrow-leaf Nardoo	8.9	2.7
Azolla filiculoides	Pacific Azolla	2.1	
0.6			
Callitris glaucophylla	**White Cypress-pine**	**8.9**	**5.4**
Damasonium minus	Star Fruit	2.7	0.8
Ottelia ovalifolia	Swamp Lily	0.7	0.6
Triglochin procerum	Water Ribbons	4.1	1.3
Triglochin dubium	**Water Ribbons**	**0.7**	**0.2**
Cyperus gymnocaulos	Spring Flat-sedge	3.4	1.0
Carex exaltatus	Tall Flat-sedge	13.7	4.2
Carex bifax	**Flat-sedge**	**0.7**	
0.2			
Schoenoplectus validus	River Club-rush	0.7	
0.2			
Eleocharis sphacelata	Tall Spike-rush	2.1	1.0
Eleocharis pallens	**Pale Spike-rush**	**4.1**	**2.1**
Carex gaudichaudiana	Tufted Sedge	0.7	0.2
Microlaena stipoides	Weeping grass	0.7	0.2
Stipa elegantissima	Feather Spear-grass	11.6	3.8
Stipa curticoma	Spear-grass	4.8	1.3
Stipa gibbosa	**Spurred Spear-grass**	**11.6**	**1.7**
Poa labillardierei	Common Tussock-grass	10.3	4.0
Glyceria australis	Australian Sweet-grass	1.4	0.4
Agrostis aemula	Blown-grass	0.7	0.2
Dichelachne crinita	Long-hair Plume-grass	0.7	0.2
Dichelachne rara	Plume-grass	0.7	
0.4			
Danthonia eriantha	Hill Wallaby-grass	6.2	2.3
Danthonia racemosa	Clustered Wallaby-grass	0.7	0.2
Phragmites australis	Common Reed	2.7	1.3
Aristida ramosa	Purple Wire-grass	2.1	0.6
Enneapogon nigricans	Niggerheads	0.7	0.2
Eragrostis infecunda	**Southern Cane-grass**	**20.5**	
11.7			
Eragrostis parviflora	Weeping Love-grass	3.4	1.0

Eragrostis brownii	Common Love-grass	1.4	0.4
Eragrostis elongata	Close-headed Love-grass	5.5	1.5
Tragus australianus	**Small Burr-grass**	**0.7**	**0.2**
Panicum decompositum	**Native Millet**	**1.4**	**0.4**
Panicum effusum	Hairy Panic	2.1	0.6
Panicum laevinode	**Pepper Grass**	**0.7**	**0.2**
Eriochloa pseudoacrotricha	Early Spring-grass	2.7	0.8
Digitaria brownii	Cotton Panic-grass	0.7	0.2
Pseudoraphis spinescens	Moira-grass	6.2	3.5
Eulalia aurea	Silky Browntop	9.6	3.7
Dicantheum sericeum	Silky Blue-grass	4.8	1.7
Themeda triandra	Kangaroo Grass	17.1	5.2
Hypoxis vaginata	Yellow Star	0.7	0.2
Tricoryne elatior	Yellow Rush Lily	8.9	2.5
Caesia calliantha	Blue Grass-lily		
Bulbine bulbosa	Bulbine Lily	2.7	0.8
Lomandra multiflora	Many-flowered Mat-rush	19.2	5.8
Lomandra effusa	Scented Mat-rush	12.3	4.2
Allocasuarina luehmannii	**Buloke**	**20.5**	**11.5**
Allocasuarina verticillata	Drooping She-oak	0.7	0.2
Persicaria decipiens	Slender Knotweed	5.5	2.1
Persicaria prostrata	Creeping Knotweed	5.5	1.5
Persicaria hydropiper	Waterpepper	6.2	2.3
Polygonum plebeium	Small Knotweed	0.7	0.2
Rumex dumosus	Wiry Dock	3.4	1.0
Atriplex semibaccata	Creeping Saltbush	14.4	5.0
Atriplex spinibractea	**Spiny-fruit Saltbush**	**1.4**	**0.6**
Chenopodium pumilio	Small Crumbweed	0.7	0.2
Enchylaena tomentosa	Ruby Saltbush	3.4	1.2
Maireana aphylla	**Leafless Bluebush**	**0.7**	**0.2**
Maireana decalvans	Black Cottonbush	11.0	3.8
Maireana humillima	**Dwarf Bluebush**	**8.2**	**2.7**
Maireana pentagona	Slender Fissure-weed	3.4	1.0
Ptilotus exaltatus	Lambs Tails	4.1	1.2
Ptilotus spathulatus	Pussy-tails	6.1	1.7
Boerhavia dominii	Tar Vine	9.6	2.9
Myosurus minimus	Mouse-tail	2.1	0.6
Ranunculus inundatus	River Buttercup	2.1	0.6
Menkea australis	**Fat Spectacles**	**0.7**	**0.2**
Pittosporum phylliraeoides	Weeping Pittosporum	12.3	5.0
Acacia brachybotrya	Grey Mulga	0.0	0.8
Acacia calamifolia	Wallowa	0.7	0.2
Acacia dealbata	Silver Wattle		
Acacia hakeoides	Hakea Wattle	1.4	0.8
Acacia implexa	Lightwood	0.7	1.3

Acacia notabilis	**Mallee Golden Wattle**	**0.7**	**0.2**
Acacia verniciflua	Varnish Wattle	0.0	0.2
Senna artemisioides	Desert Cassia	4.8	2.1
Desmodium varians	**Slender Tick-trefoil**	**2.7**	**0.8**
Dillwynia cinerascens	Grey Parrot-pea	6.2	3.3
Eutaxia diffusa	**Spreading Eutaxia**	**11.6**	**4.6**
Eutaxia microphylla	Common Eutaxia	13.0	4.6
Glycine clandestina	Twining Glycine	2.1	0.6
Lotus australis	Australian Trefoil	0.7	0.2
Lotus cruentus	**Red-flowered Trefoil**	**0.7**	**0.2**
Psoralea tenax	**Tough Psoralea**	**1.4**	**0.4**
Psoralea parva	**Small Psoralea**	**3.4**	**1.0**
Pultenaea largiflorens	Twiggy Bush-pea	2.1	1.3
Swainsona procumbens	Broughtons Pea	18.5	6.0
Templetonia stenophylla	**Leafy Templetonia**	**17.1**	**5.2**
Erodium crinitum	Blue Crowfoot	1.4	0.4
Linum marginale	Native Flax	2.7	0.8
Stackhousia monogyna	Creamy Candles	2.1	0.6
Dodonaea viscosa cuneata	Wedge-leaf Hopbush	3.4	1.0
Sida fibulifera	**Pin Sida**	**0.7**	**0.2**
Hibbertia sericea	Silky Guinea-flower	0.7	0.2
Elatine gratioloides	Waterwort	2.1	0.6
Kunzea parvifolia	Violet Kunzea	0.7	0.2
Eucalyptus albens	White Box	2.1	0.8
Eucalyptus blakelyi	Blakely's Red Gum	3.4	1.2
Eucalyptus largiflorens	Black Box	11.0	5.4
Haloragis glauca	**Grey Raspwort**	**10.3**	**2.9**
Myriophyllum crispatum	Water-milfoil	2.1	0.6
Myriophyllum papillosum	Water-milfoil	0.7	0.2
Myriophyllum variifolium	Water-milfoil	0.7	0.2
Myriophyllum verrucosum	Red Water-milfoil	0.7	0.2
Hydrocotyle laxiflora	Stinking Pennywort	2.1	0.6
Nymphoides crenata	Wavy Marshwort	2.1	1.3
Cynoglossum suaveolens	Sweet Hound's-tongue	13.0	4.6
Solanum esuriale	Quena	12.3	3.8
Mimulus gracilis	Slender Monkey-flower	7.5	2.3
Eremophila longifolia	Berrigan	2.1	1.0
Myoporum montanum	**Waterbush**	**3.4**	**1.5**
Plantago gaudichaudii	Narrow-leaf Plantain	8.2	1.7
Plantago varia	Variable Plantain	14.4	4.0

Wahlenbergia multicaulis	Tadgell's Bluebell	0.7	0.2
Wahlenbergia litticola	Bluebell	0.7	0.2
Goodenia fascicularis	Silky Goodenia	6.2	1.3
Goodenia glauca	Pale Goodenia	3.4	1.0
Goodenia heteromera	Spreading Goodenia	2.7	0.8
Goodenia pinnatifida	Cut-leaf Goodenia	8.2	2.7
Velleia paradoxa	Spur Velleia	1.4	0.4
Minuria leptophylla	Minnie Daisy	2.1	0.6
Minuria integerrima	**Smooth Minuria**	**8.2**	**2.9**
Brachyscome chrysoglossa	**Yellow-tongue Daisy**	**0.7**	**0.4**
Calotis lappulacea	Yellow Burr-daisy	2.7	0.8
Calotis scabiosifolia	Rough Burr-daisy	2.4	0.8
Calotis cuneifolia	Purple Burr-daisy	4.8	1.5
Vittadinia cervicularis	New Holland Daisy	8.2	2.7
Sigesbeckia orientalis	Indian Weed	0.7	0.2
Cotula australis	Common Cotula	4.1	1.3
Centipeda minima	Spreading Sneeze-weed	6.8	1.9
Cymbonotus pressianus	Australian Bear's Ear	2.1	0.6
Cassinia arcuata	Drooping Cassinia	6.8	2.1
Cassinia aculeata	Dogwood	0.7	0.2
Rhodanthe corymbiflora	Grey Sunray	2.1	0.6
Bracteantha sp.	Everlasting sp.	1.4	0.4
Chrysocephalum apiculatum	Common Everlasting	5.5	1.5
Chrysocephalum semipapposum	Clustered Everlasting	4.8	1.5
***Ixiolena sp*.**	**Woolly Plover-daisy**	**4.1**	**1.2**
Leptorhynchos squamatus	Scaly Buttons	9.6	3.3
Leptorhynchos tenuifolius	Wiry Buttons	1.4	0.4
Pycnosaurus globosa	Drumsticks	8.2	3.8
Pycnosaurus glauca	Common Billy Buttons	2.7	1.3
Pycnosaurus chrysantha	Golden Billy Buttons	0.7	0.2
Microseris scapigera	Yam Daisy	1.4	0.4

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Table 15. Distribution of regionally significant native plant species in relation to broad vegetation type. Sandy soil woodlands comprise those of Yellow Box, White Box,Blakely's Red Gum and White Cypress-pine. Damp Woodlands include Damp Grey Box, Riverine Red Gum and Riparian Red Gum. The figures in brackets after sandy soil woodlands and dry Grey Box woodlands show the alternative values if one includes Grey Box/Yellow Box woodland as a sandy soil type. Species listed as threatened either nationally or statewide are included in this analysis.

Vegetation type	% of all sections with each vegetation type	% of all significant species in each vegetation type	No. of significant species
Sandy soil woodlands	3.0 (10.9)	25.3	37
Dry Grey Box woodland	28.6 (20.8)	25.3	37
Wetlands/Swamp Woodland	7.3	19.9	29
Grasslands	0.6	15.8	23
Damp woodland	58.4	9.6	14
Black Box woodland	2.1	4.1	6

3.2.4 Animals present

3.2.4.1. Birds

One hundred and fifty-six species of birds were recorded along the creeks during the survey period (Appendix 4), of which 43 species were waterbirds and 113 were woodland or open country birds.

Of the 43 waterbird species, nearly 70% were recorded at fewer than 5% of all sampled sites (no. of sampled sites = 126) and none was recorded at more than 50% of all the sites (Table 16), even though the survey encompassed nearly every large wetland in the region (Barmah Forest, Black Swamp, Tungamah Swamp, Moodie Swamp, Rowan Swamp) and the creeks system itself provided continuous aquatic habitat for certain species. The most common waterbird species were Pacific Black Duck (at 39% of sites), Wood Duck (25%), White-faced Heron (18%), Purple Swamphen (18%) and Australian Pelican (12%).

Of the 113 landbirds, approximately half were recorded at fewer than 5% of sites and only 10% occurred at more than half of the sampled sites (Table 16). With two exceptions (White-plumed Honeyeater and Brown Treecreeper), the most commonly recorded landbirds were those that prefer to live in open country with scattered trees (Table 17) which have benefited from the clearing of the former woodland landscape (Loyn 1985a; Bennett 1993; Robinson 1994a). By contrast, species identified as needing woodland patches in order to survive in the Northern Plains (from Bennett *et al*. 1992; Bennett 1993;

Table 16. Reporting rates of birds along the Broken, Boosey and Nine Mile Creeks system (n = 126 sites). Figures represent the percentage of species in each reporting rate category. Reporting rates indicate the percentage

of surveyed sites at which a particular species was recorded. Numbers in brackets indicate the total number of species.

Reporting Rate	**Waterbirds (43)**	**Landbirds (113)**	**All birds (154)**
1-5%	67.4	50.4	55.1
6-10%	16.3	13.3	14.1
11-20%	11.6	14.2	13.5
21-50%	4.7	12.4	10.3
> 50%	0.0	9.7	7.0

Table 17. The most common species of all landbirds and of woodland-dependent birds along the Broken, Boosey and Nine Mile Creeks system. Figures indicate the reporting rate of species from 126 sampled sites. Figures in the column 'Bennett *et al.*' indicate comparative reporting rates for the woodland species from a wildlife survey across the entire Northern Plains region (from Bennett *et al*. 1992)

Commonest landbirds		Commonest Woodland Birds		Bennett *et al.*
Striated Pardalote	90.5	White-plumed Honeyeater	85.7	57
White-plumed Honeyeater	85.7	Brown Treecreeper	70.6	41
Red-rumped Parrot	73.8	Tree Martin	41.3	8
Brown Treecreeper	70.6	Grey Shrike-thrush	36.5	36
Willie Wagtail	68.3	Dusky Woodswallow	24.6	12
Australian Magpie	66.7	White-winged Chough	23.8	17
Common Starling	65.1	Crested Shrike-tit	23.0	6
Australian Magpie-lark	61.9	Sacred Kingfisher	18.3	13
Noisy Miner	57.9	Little Friarbird	17.5	14
Welcome Swallow	52.4	White-throated Treecreeper	15.9	17
Laughing Kookaburra	51.6	Jacky Winter	14.3	19

Bennett & Ford in prep.; Robinson 1993a, 1994a) were either rare or absent from along the creeks system. Twenty Northern Plains species identified by Bennett & Ford (in prep.) as needing woodland patches in order to exist were not recorded at all, while 70% of the woodland-dependent birds which were recorded were observed at fewer than 10% of sampled sites (Appendix 4). Significantly, though, three woodland birds - Crested Shrike-tit, Brown Treecreeper and Tree Martin - were recorded much more often along the creeks than in a more general survey of remnants of native vegetation throughout the Northern Plains (Table 17). Each of these species requires older eucalypts for

foraging or nesting (Loyn 1985b; Recher *et al*. 1987; Recher & Lim 1990) and it is likely that their relative abundance along the creeks is a consequence of the old-growth woodland habitat found along the Broken, Boosey and Nine Mile Creeks system (see 3.2.1.4).

Altogether along the creeks, we recorded seven species of birds listed as threatened in Victoria, 16 species listed as declining but not yet threatened and seven species classified as having restricted or colonial breeding grounds in the State (Robinson 1993a, 1994a; CNR 1995) (Appendix 4). At least two other species of threatened bird - Regent Honeyeater and Grey-crowned Babbler - have been recorded along the creek in the past (I. Davidson, H. Marshall, pers. comms).

By far the most important sites along the creeks for these significant bird species were the Wildlife Reserves at Moodie Swamp, Tungamah and Rowan Swamp. Moodie Swamp Wildlife Reserve supports at least one breeding pair of Brolgas and, at times, supports as many as twelve individual birds. It was the major site along the creeks system for wading birds, in particular herons, egrets, spoonbills and stilts, and as many as 50 White-necked Herons, 50 Black-winged Stilts, 10 Great Egrets and 20 Royal Spoonbills were recorded there. Other notable species recorded from Moodie Swamp include Intermediate Egret, Glossy Ibis (K. Costello, pers. comm.), White-bellied Sea-Eagle and Great Crested Grebe (up to 50). Tungamah Swamp also supports at least one breeding pair of Brolgas and nesting colonies of Little Pied Cormorant and Sacred Ibis. A pair of Barking Owls is resident at the reserve (P. Ward, pers. comm.) and Wedge-tailed Eagles and Southern Boobooks were recorded there during the survey. Tungamah Swamp Wildlife Reserve has additional value for birdlife as it is one of the few sites in the eastern Northern Plains with populations of grassland birds such as Brown Songlark and Singing Bushlark. The only other reserve along the creeks system with grassland birds was Rowan Swamp Wildlife Reserve. This reserve is yet to be surveyed in detail for birds but gained special significance as one of the few sites in Victoria at which Red-chested Button-quail has been recorded (Emison *et al*. 1987). It also contained Brown Quail, Brolga, Whistling Kite and Wedge-tailed Eagle, all of which are listed either as threatened or declining statewide (Robinson 1993a, 1994a; CNR 1995).

The next most important group of sites for significant species along the creeks was those sites where overall tree cover or frontage width was greater than 200 metres. There is a large suite of woodland-dependent species of landbird in Australia that is restricted to large patches of woodland vegetation and which cannot survive in narrow remnants of native vegetation along roadsides or streamlines (Bennett 1993; Lynch & Saunders 1991). These woodland-dependent birds are the most threatened group of birds following extensive clearing of habitat for agriculture (Kitchener *et al*. 1982; Saunders 1989). They are generally uncommon in every rural district.

Along the creeks, we found that many of these woodland birds were relatively common in the large forest patches more than one kilometre wide at either end of the creeks system (Barmah Forest, Mount Meg Flora Reserve, Reef Hills Regional Park) but that they were all but absent from the remainder of the creeks system. The only exceptions were where the total area of land with some tree cover along the creeks was more than 200 m wide (Fig. 13, Appendix 5).

For some of these woodland birds, it appeared to be the overall width of the site which determined whether or not they were present, rather than the habitat quality of the site. By contrast, the distribution of several other significant bird species was strongly influenced by habitat quality or vegetation type. Superb Parrots were only recorded from a few narrow sections along the lower Broken Creek where their principal foraging habitat of Yellow Box and an understorey of native shrubs (Webster 1988) occurred (I. Davidson, pers. comm.). The nationally endangered Swift Parrot was only recorded from a couple of sections on the Dookie Plains where they were observed feeding on flowering Grey Box. And Bush Stone-curlews appeared to prefer sites more than 30 m wide where there was box woodland with a high proportion of tree cover, short, mostly native groundcover and a large amount of fallen tree litter. Although Stone-curlews were rarely observed during the survey, they are likely to occur at moderate densities along the creeks system, particularly in the dryland areas wherever suitable habitat is available.

3.2.4.2 Mammals

Only seven species of native mammal (excluding bats) were recorded along the Broken, Boosey and Nine Mile Creeks during the survey period (Table 18). An eighth species, Platypus, was not recorded by us but was said to be present in both the Boosey and Broken Creeks around St. James by a local landholder. Of the eight species, only the Common Brushtail Possum and Common Ringtail Possum were widespread and abundant. Eastern Grey Kangaroos were moderately widespread but tended to be restricted to the broader creek sections. The most rarely observed species were the Black Wallaby (1 site), Sugar Glider (1 site) and the threatened Squirrel Glider (2 sites). Squirrel Gliders were observed along the lower Broken Creek south of Carlands Bridge and along the Nine Mile Creek in Streamside Reserve K12 at Brookfield, east of Wunghnu. They have also been recorded at several other sites along the lower Broken Creek between Barmah and Carlands Bend (Kelly 1993a) and may be more common than records indicate as unidentified glider marks were found on Golden Wattles at several additional sites.

Table 18. Reporting rate of mammals, reptiles and frogs along the Broken, Boosey and Nine Mile Creeks system (n = 126 sites). Figures in parentheses indicate reporting rates for spotlight surveys only (n = 19)

Species	Frequency	%	Classification

Mammals			
Platypus *Ornithorhynchus anatinus*	1	0.8	
Common Brushtail Possum *Trichosurus vulpecula*	34	27.0 (89.4)	
Sugar Glider *Petaurus breviceps*	1	0.8 (5.3)	
Squirrel Glider *Petaurus norfolcensis*	2	1.6 (10.5	Vulnerable
Common Ringtail Possum *Pseudocheirus peregrinus*	22	17.5 (100.0)	
Eastern Grey Kangaroo *Macropus giganteus*	23	18.3	
Black Wallaby *Wallabia bicolor*	1	0.8	
Water Rat *Hydromys chrysogaster*	12	9.5	
Red Fox *Canis vulpes*	18	4.3	
Brown Hare *Lepus capensis*	21	16.7	
European Rabbit *Oryctogalus cuniculus*	19	15.1	
Reptiles			
Common Long-necked Tortoise *Chelodina longicollis*	6	4.8	Uncommon
Marbled Gecko *Christinus marmoratus*	3	2.4	
Olive Legless Lizard *Delma inornata*	1	0.8	Uncommon
Tree Goanna *Varanus varius*	17	13.5	
Southern Rainbow Skink *Carlia tetradactyla*	1	0.8	Uncommon
Carnaby's Wall Skink *Cryptoblepharus carnabyi*	3	2.4	Uncommon
Large Striped Skink *Ctenotus robustus*	3	2.4	
Tree Skink *Egernia striolata*	1	0.8	Uncommon
Boulenger's Skink *Morethia boulengeri*	23	18.3	
Tiger Snake *Notechis scutatus*	2	1.6	
Red-bellied Black Snake *Pseudechis porphryiacus*	1	0.8	
Eastern Brown Snake *Pseudonaja textilis*	11	8.7	
Frogs			
Plains Froglet *Crinia parinsignifera*	30	23.8	
Common Froglet *Crinia signifera*	29	23.0	
Sloane's Froglet *Crinia sloanei*	1	0.8	
Pobblebonk *Limnodynastes dumerili*	6	4.8	
Spotted Marsh Frog *Limnodynastes tasmaniensis*	26	20.6	
Peron's Tree Frog *Litoria peroni*	5	4.0	

The most suprising omission during the survey was the Echidna. We did not see a single animal and did not once come across signs of diggings or scats, even though ant mounds were commonly observed in many sections. Bennett *et al*. (1995) recorded the Echidna as a 'widespread and uncommon' species across the entire Northern Plains region and, statewide, it is considered to have coped well with habitat modification following European settlement (Menkhorst 1995). It's apparent rarity along the creeks system testifies, perhaps, to the extent of habitat modification which has occurred there, and serves as a warning about the urgent plight of woodland animals in the eastern part of the Northern Plains.

3.2.4.3 Terrestrial reptiles

As found by Brown and Bennett (1995) for the entire Northern Plains region, reptiles were the scarcest group of terrestrial vertebrates present along the

creeks. Of the 11 species recorded during the survey, only two were observed regularly - Tree Goanna and Boulenger's Skink - and eight were located at less than five of the 126 sampled sites (Table 18). Furthermore, two species usually regarded as relatively common and widespread in Victoria - Bearded Dragon and Common Blue-tongue - were not observed at all. Although none of the species recorded along the creeks is listed as threatened statewide, four are classified as regionally uncommon (Table 18). Because of reptiles' specific habitat requirements (Brown & Bennett 1995; Hadden & Westbrooke 1996) and their lack of mobility, sites with these regionally significant species or with high reptile diversity should be accorded special protection.

Three reptile records along the creeks system were of special interest: first, the sighting of the Olive Legless Lizard in native grassland at the Numurkah Rifle Range; second, the sighting of a Tree Skink in Grey Box woodland near Waaia, which represented both an unusual habitat (Brown & Bennett 1995) and an extension of range (Fig. 14); and third, the comparative abundance of Tree Goanna along the creeks. Across the entire Northern Plains, the reporting rate for Tree Goannas from woodland remnants was less than 3% (Brown & Bennett 1995). Along the creeks system, we recorded Tree Goannas at 13.5% of sites, presumably because of the comparative abundance of older, hollow-bearing eucalypts (see section 3.2.1.4) which are required by Tree Goannas for shelter and as a source of food (Brown & Bennett 1995). Consequently, although the reptile fauna of the creeks was scarce in comparison to other vertebrate groups, the relative abundance of old-growth, box-woodland habitat along the creeks suggests that the creeks system may be a critical area for the survival of at least one species of old-growth dependent reptile in the eastern Northern Plains.

3.2.4.4 Frogs and Tortoises

Partly because of the dry year, and partly because of the seasonal behaviour of most species of frog, reporting rates for frogs were artificially low (Table 18). At least one species known to occur along the creeks system, Common Spadefoot Toad *Neobatrachus sudelli*, was not recorded at all during the survey, although large numbers were heard calling in paddocks adjacent to the Boosey Creek in the prior wet spring. Additionally, the one threatened species known from along the creeks - Barking Marsh Frog (Fig. 12) - was not recorded at any site, despite specific visits to areas of suitable habitat during spring and summer rains.

Despite these limitations to the sampling method, it is significant that two frog species generally regarded as widespread, Pobblebonk and Sloane's Froglet, were very scarce along the creeks system (Table 18). Contrary to its name, the Common Long-necked Tortoise was similarly found to be scarce along the creeks. It was recorded from only six sites during the survey (Table 18) and only one nest was found.

For each of these species, the modification or destruction of most aquatic vegetation, logs, detritus and ponds (Table 12), appear to be the most likely cause of their scarcity (see Hero *et al*. 1991) or, in the case of the tortoise, their decline from a once abundant species along the creeks (see 2.4.1, 2.4.4) to a species now listed as regionally uncommon throughout the Northern Plains (Brown & Bennett 1995). It thus seems likely that current methods of water delivery along the creeks have destroyed most available habitat for some frog species with more specialised needs and for the Common Long-necked Tortoise. All sites with backwaters, billabongs, wetlands or other natural water bodies should be recognised as having special conservation value for frogs and tortoises. The one known site for the threatened Barking Marsh Frog (Fig. 14) likewise should be protected.

3.2.4.5 Fish

Thirteen species of native fish and five species of exotic fish have been recorded from the Broken, Boosey and Nine Mile Creeks system (Table 19). Of these native species, nine are listed as threatened in Victoria and all but two of the nine threatened species are now confined to the lower reaches of the Broken Creek, despite having occurred formerly much further upstream (see sections 2.4.3, 2.4.4, Table 19). Of the seven threatened species reported only from the lower Broken Creek in recent times, three have not been reported from the creek since 1980, suggesting that recent management of the Broken Creek as a water distribution sytem and drain has had continuing, detrimental impacts on the fish fauna.

In spite of the generally poor condition of the aquatic habitat and ongoing degrading activities (Koehn & O'Connor 1990a, 1990b; SAC 1991a, 1991b, 1991c, 1992b, 1993), the lower Broken Creek is still ranked as one of the most important streams in Victoria for Murray Cod and Freshwater Catfish (W. O'Connor, DNRE, in litt.). Furthermore, the entire creeks system is recognised as having 'considerable value as a lowland river system with much intact habitat and a relatively large [fish] species list' (W. O'Connor, DNRE , in litt.). Under current management, little recognition is being given to the creeks system's importance as fish habitat, or to the fact that many of the water distribution practices happening along the creeks are listed as threatening processes under the Flora and Fauna Guarantee Act (SAC 1991a, 1991b, 1992b, 1993). Immediate protection needs to be given to those creek sections with known habitat for threatened fish species. Protection should also incorporate the adjoining Crown land as a means of reducing the threat to the native fish fauna caused by 'degradation of native riparian vegetation along Victorian rivers and streams' (SAC 1996).

Table 19. Comparative abundance of fish species recorded in the Broken, Boosey and Nine Mile Creeks system in historical and recent times, and their conservation status. Figures in parentheses indicate the number of fish

sampling sites. Figures in table are percentage of sites at which each species recorded. Status categories are taken from CNR (1995).

Species	Reporting Rate Pre 1980 (14)	Reporting Rate Post 1990 (24)	Status
Native species			
Macquarie Perch *Macquaria australasica*	14.3	0.0	Vulnerable
Golden Perch *M. ambigua*	21.4*	16.7	Rare
Murray Cod *Maccullochella peelii*	14.3*	4.2	Vulnerable
Western Carp Gudgeon *Hypseleotris klunzingeri*	7.1	0.0	Rare
Carp Gudgeon sp. *H.* sp.	7.1	25.0	
Freshwater Catfish *Tandanus tandanus*	0.0*	4.2	Vulnerable
Crimson-spotted Rainbowfish *Melanotaenia fluviatilis*	7.1	4.2	Rare
Bony Bream *Nematalosa erebi*	0.0	4.2	Rare
Australian Smelt *Retropinna semoni*	21.4	4.2	
Flat-headed Gudgeon *Philypnodon grandiceps*	7.1	8.3	
Southern Pigmy Perch *Nannoperca australis*	0.0	8.3	
Flat-headed Galaxias *Galaxias rostratus*	7.1	0.0	Rare
Mountain Galaxias *G. olidus*	0.0	4.2	Indeterminate
Introduced species			
Goldfish *Carassius auratus*	14.3	54.2	
Carp *Cyprinus carpio*	35.7	66.7	
Tench *Tinca tinca*	7.1	0.0	
Redfin *Perca fluviatilis*	21.4	16.7	
Gambusia *Gambusia holbrooki*	14.3	41.7	

* noted as being plentiful at Katamatite before 1945 (A. Rudd, in litt.).

3.2.4.6 Freshwater Invertebrates

The presence or absence of two groups of freshwater invertebrates was recorded at sample sites along the creeks system. Freshwater mussels (species unknown) were recorded at 11 sites (9% of sampled sites) distributed throughout the Broken, Boosey and Nine Mile Creeks system. Yabbies *Cherax destructor* were recorded from 23 sites (18%) and were likewise distributed along every creek. The Murray Crayfish *Euastacus armatus*, a species listed as threatened in Victoria (CNR 1995), was recorded from one site along the lower Broken Creek in Barmah Forest.

3.2.4.7 Butterflies

Twelve species of butterfly were incidentally recorded during the survey, of which the Common Grass Blue *Zizinia otis labradus*, the introduced Cabbage White *Pieris rapae rapae* and the Common Brown *Heteronympha merope merope* were the most common (Table 20). Of these 12 species, only one, the

Chequered Blue *Theclinesthes serpentata serpentata*, depends on native vegetation for food. All of the others feed on a range of introduced or native plants in the grass, cabbage, nettle, citrus, pea or daisy families (Fisher 1978). The butterfly fauna thus consisted mostly of generalists, with the one species dependent on native plants being relatively rare because its food plant species (saltbushes) grew at 10% or less of sites along the creeks (Appendix 3).

Further species are likely to be found with more intensive sampling.

Table 20. Butterfly species recorded along the creeks. Note that sampling was undertaken in a particularly dry year.

Species	**Number of records**
Common Grass Blue *Zizinia otis labradus*	40
Cabbage White *Pieris rapae rapae*	30
Common Brown Brown *Heteronympha merope merope*	29
Meadow Argus *Precis villida calybe*	20
Orchard Butterfly *Papilio aegeus aegeus*	6
Painted Lady *Vanessa kershawi*	4
Dingy Swallowtail *Papilio anactus*	3
Chequered Blue *Theclinesthes serpentata serpentata*	2
Imperial White *Delias harpalyce*	1
Caper White *Anapheis java teutonica*	1
Australian Admiral *Vanessa itea*	1
Yellow-banded Grass-dart *Ocybadistes walkeri*	1

3.3 CULTURAL VALUES

Nearly half of the 352 sections inspected in detail contained recognisable aboriginal middens (only in or near Barmah Forest) or trees scarred by aborigines for the manafacture of vessels and tools. Scarred trees were recorded along the entire length of the Broken, Boosey and Nine Mile Creeks (Fig. 15) and were common at some of the sites. They are likely to have been much more common in former times as scars were seen only on large box trees, many of which have been cleared from the rear portions of frontages or taken for timber. Similarly, many middens are likely to have been obscured by various earthwork activities or by the flooding of the creeks.

4 THREATS

4.1 LANDSCAPE SCALE THREATS TO REMNANT VEGETATION ALONG THE CREEKS SYSTEM

Many studies have shown that the biological functioning of small and/or narrow remnants of native vegetation is particularly prone to external factors occurring in the surrounding, modified landscape; for example raised water tables, nutrient runoff, weed invasion, water runoff and grazing by stock (Saunders *et al*. 1991; Hobbs & Saunders 1993; George *et al*. 1995). In addition, the small internal area and the high edge to area ratio of most remnants of native vegetation in rural districts causes changes in their internal microclimate, in the form of higher wind speeds, greater fluctuations in temperature, higher temperatures and higher water tables (Saunders *et al*. 1991).

Along the Broken, Boosey and Nine Mile Creeks system, 83% of all sections sampled were less than 100 m wide and only 8% of sections were more than 200 m wide (3.2.1.1). The ecosystem dynamics of nearly the entire 450 km system are consequently driven by external factors. In particular, biological functioning and ecosystem stability along the Broken, Boosey and Nine Mile Creeks system are strongly influenced by the adjoining land use, by the major modification of the creeks for industrial use and by the extensive removal of native vegetation from the surrounding landscape.

4.1.1 Adjoining land use

Ninety-eight percent of the creeks system flows through a highly modified landscape in which there is only 1% remnant treecover and the predominant land uses are grazing and cropping. As a consequence of those land uses, sediment loads and nutrient inputs of nitrogen and phosphorus into the Crown land frontage and creek waters are extremely high (OCE 1988; Mitchell 1990; CMPS & F 1995; Hydrotechnology 1995; Nicholas & Mack 1996). Furthermore, in that half of the creeks system flowing through the Shepparton Irrigation Region, there is significant runoff of irrigation waters from adjacent paddocks into the Crown land frontage, often causing tree dieback and weed invasion (see section 4.1.2, Appendix 6).

All of these environmental threats are exacerbated along the creeks system because much of the creeks system is bordered by public roads (Appendix 6) and much is licenced for grazing or is allowed to be grazed (Table 21). As a consequence, there is often direct access to the frontage for vehicles and domestic stock, which has the following effects:

- increased bank erosion
- increased sediment inputs
- increased nutrient inputs

- the removal of vegetation from the creek waters, creek banks and Crown land frontage
- changes to the species composition of the native plant communities
- the transfer of weeds from roadsides and paddocks to the Crown land frontage
- damage to soil from vehicle tracks and pugging by stock
- disturbance of soil as a result of activities such as bardi-grubbing and firewood cutting, and
- disturbance of soil as a result of rubbish-dumping, gravel dumping or creekspoil dumping (Table 22; Appendix 6).

Table 21. Stock-access to remnant vegetation along the Broken, Boosey and Nine Mile Creeks. Categories refer to the status of the surveyed Crown land frontage or private land immediately next to the creeks. Grazing levels are defined in Appendix 1. Note that current grazing does not include grazing by droving stock.

Category	**no. of sections**	**%**
Agricultural Licence Status		
Licenced for grazing	167	37.0
Partly licenced for grazing	40	8.9
Not licenced for grazing but grazed	172	38.1
Not licenced for grazing, not grazed	72	16.0
Status of Fencing		
Completely fenced	220	46.7
Partly fenced	110	23.4
Not fenced	141	29.9
Status of Current Grazing		
Much grazing	186	39.5
Some grazing	198	42.0
No grazing	87	18.5

4.1.2 Modification of the creeks

Nearly all of the creeks system has been severely modified for the delivery of water for domestic and agricultural uses throughout the dryland and irrigation regions (see 3.2.2). The ecological impacts of these industrial disturbances on instream habitat, flora and fauna have already been described (see 3.2.2, 3.2.4.4, 3.2.4.5). However, most of these disturbances have also had severe, deleterious impacts on the associated dryland and wetland ecosystems.

The most far-reaching ecological consequences of these industrial disturbances have been the transformation of the Broken, Boosey and Nine Mile Creeks from intermittent creeks with peak flows in spring into permananent creeks with peak flows in summer and autumn (Fig. 10), and the associated rise of the water table beneath the nearby land. As a result, the dryland ecosystem abutting the creeks is being transformed from a grassy woodland dominated by box eucalypts to a moisture-dependent vegetation community of River Red Gum, sedges, introduced weeds such as exotic docks *Rumex* spp., Drain Flat-sedge *Cyperus eragrostis*, Paspalum *Paspalum dilatatum* and Water couch *Paspalum distichum* and, in lightly grazed situations, Tangled Lignum (see 3.2.1.3, 3.2.1.5, 3.2.1.6). As a further consequence of permanent inundation and raised water tables near the creeks' edge (see Kelly 1994), many of the older box trees are suffering from dieback and few young box are managing to grow (see Table 4).

Throughout the creeks system, some level of tree dieback was already evident at 90% of sections, with raised water tables being rated as the most common cause (Fig. 16). At 26% of sites, tree dieback was rated as severe (more than 25% of all trees affected). At the other 64% of sites, dieback was rated as moderate to minor. Dieback levels were most severe in environments where water levels were most highly modified: in the meandering lower sections of the Broken Creek, in channelised sections, in narrow sections, upstream of weirs and at some of the wetlands away from the creek where water was being permanently retained. If current management of the creeks system as an industrial water conduit continues, it seems inevitable that most of the environmental and cultural values for which many parts of the creek are classified as significant (see section 6) will disappear as the box woodlands are gradually replaced by a weedy vegetation community adapted to damper environments, and the instream habitat is increasingly destroyed by degrading processes.

In addition to these profound and broadscale effects, creek modification has also caused some more immediate localised problems. Thus, earthworks undertaken to modify the streambeds and banks have caused:

- old-growth habitat on creek banks to be destroyed;
- species-rich ecotonal communities to be destroyed or highly disturbed as a result of spoil dumping and other earthworks (for instance, at James Bridge);
- weed invasion, particularly by thistles *Xanthium, Onopordium* spp. and Prickly Lettuce *Lactuca serriola*;
- alterations to existing water regimes (e.g. prevention of flooding behind the banks of creekspoil deposited along the banks);
- small populations of significant plants to be destroyed. For instance, a population of Creamy Candles *Stackhousia monogyna* at James Bridge, Picola - one of only three known sites for the species along the creek - was buried beneath spoil in the 1960s (H. Marshall, pers. comm.); and

- loss of potential habitat for most plant species in an already narrow area of riparian reserve.

Most channelised sections consequently have low overall conservation value because of these extreme alterations to the species composition and structure of the groundlayer and canopy layer of vegetation, and because of the difficulty of habitat restoration due to the major soil disturbance (see Hobbs & Hopkins 1990).

4.1.3 Broadscale removal of native forest and woodland vegetation from the surrounding landscape

In addition to the raised water tables underlying much of the remnant vegetation along the Broken, Boosey and Nine Mile Creeks system as a consequence of the use of the creeks for water supply, water tables are rising throughout most of the Broken, Boosey and Nine Mile Creek catchment because of the removal of 99% of all native trees from the catchment, the removal of 99.97% of all shrubs from the landscape and the irrigation of approximately one third of the catchment.

Water-table measurements are not available for most parts of the dryland area of the Broken, Boosey and Nine Mile Creek catchment. It is noteworthy, however, that recent analyses of salinity trends in the Goulburn-Broken Catchment have highlighted the Broken Riverine Plain as the area most prone to future salinity risk, with an estimated 800% increase in the salt load exported from that area being predicted to occur within the next thirty to fifty years (Sinclair Knight Merz 1996).

Concurrently, water tables within the irrigation region are continuing to rise steadily (OCE 1992; Norman 1996) and 60% of the irrigation region is expected to have water tables within one metre of the surface within 25 years if nothing is done (Norman 1996). Already in the irrigated region of the Broken Creek catchment, 53% of all remnant native vegetation is threatened by water tables within three metres of the surface and 36% of native vegetation is underlain by water tables within two metres of the surface (from Kelly 1994). Most remnant vegetation in the irrigated sector of the Broken Creek catchment is therefore at risk of death or disease because of salinity or inundation (Kelly 1994).

Moreover, judging from the impacts of dryland salinity and rising water on the environmental condition of nature reserves in the Western Australian wheatbelt, most remnants of native vegetation in the Shepparton Irrigation Region are too small to counter the effects of rising water throughout the broader, cleared landscape without active intervention (George *et al*. 1995). Accordingly, it is urgent that land managers and land management agencies understand the national significance of the natural environment along the

Broken, Boosey and Nine Mile Creeks system and begin to develop plans to counter the effects of rising groundwater throughout the catchment. Otherwise, within fifty years, the unique environmental and cultural attributes of the creeks system will be destroyed (see Kelly 1993a, 1993b, 1993c, 1994; George *et al*. 1995; Robinson & Traill 1996).

4.2 SITE-SPECIFIC THREATS TO REMNANT VEGETATION ALONG THE BROKEN, BOOSEY AND NINE MILE CREEKS SYSTEM

Because of the narrowness of the strip of remnant native vegetation along the creeks system, the predominantly agricultural use of the surrounding land and the accessibility of the creeks system by road, nearly every creek section was found to be under some environmental threat. In particular, nearly every section was degraded to some extent because of grazing by domestic stock, earthworks of various types and weed invasion. These three types of threat are discussed briefly here but are intended to be analysed in more detail elsewhere. Details of the frequency of other threats and human uses of the creeks system are given in Appendix 6.

4.2.1 Effects of grazing by domestic stock on the natural environment

Along the 360 km of the Broken, Boosey and Nine Mile Creeks system that was sampled, we found no site that had never been grazed by domestic stock and only thirteen sections (3%) at which there had never been over-grazing in the past. That is, throughout the length of the creeks system, 97% of sections were evaluated as having been over-grazed at least occasionally in the past and 76% were evaluated as having had persistent over-grazing (Appendix 6). Even within the 'current grazing' period (1993-1995), 81.5% of sections were considered to have experienced some over-grazing and only 18.5% had not been over-grazed. Altogether then, we rated only three sections along the creek as never having had any over-grazing, either historically or in the recent past (Appendix 6). The majority of sections instead were rated as having had moderate to severe levels of grazing by stock (Appendix 6).

Although most of this grazing was attributable to local stock, it is noteworthy that mnay sites were severely over-grazed by droving stock in the summer of 1994/95, with as many as 6000 sheep and 300 cattle descending on biologically important sites such as Drumanure along the Nine Mile Creek (Robinson 1995b).

The principal effects of all of this grazing by local livestock and droving stock on the natural environment along the creeks system have been:

- significant reductions in the amount of plant biomass and litter on the ground,
- significant changes in grass species composition;

- significantly fewer shrubs,
- significantly more bare ground, pugging and active soil erosion,
- significantly less lignum, and
- significantly less regeneration of young trees

at sections with high levels of grazing than at sections with little grazing (Table 22).

Table 22. Effects of stock-grazing and soil disturbance on elements of the natural environment along the Broken, Boosey and Nine Mile Creeks system (sample size = 473 sections). Numbers indicate the degree of positive or negative (-) correlation between different levels of grazing and earthworks, and the abundance of different natural attributes in the landscape. For example, for % abundance of plant and litter biomass, the correlation value indicates that as the amount of grazing increases, the amount of plant biomass significantly decreases, whereas there is no observed relationship between earthworks and plant biomass. Rank abundance means that the abundance of a particular variable was not measured absolutely but by reference to a series of ranks. Thus, grazing pressure was ranked from 0 (none) to 6 (much). Earthworks were ranked from 0 (none) to 2 (much). For definitions of each variable's ranking system, see Appendix 1. Asterisks show significance levels: * = P < 0.05, *** = P < 0.001.

Environmental Variable	**Grazing**	**Earthworks**
% abundance of plant and litter biomass	-0.536***	0.040
% abundance of bare ground	0.356***	-0.099
% of native ground cover	-0.195*	-0.374***
native grass-species composition	-0.525***	0.017
rank abundance of native shrubs	-0.649***	0.086
rank abundance of lignum	-0.330***	-0.007
rank abundance of regeneration	-0.456***	0.162
rank abundance of tree dieback	-0.070	0.086
rank abundance of weed areas requiring management	0.007	0.363***
rank abundance of noxious weeds	0.030	0.066

All of these changes have been shown to significantly affect:

- the composition and abundance of the native flora (Table 22; Moore 1970; Scougall *et al*. 1993),
- the species diversity and abundance of reptiles (Brown & Bennett 1995; Hadden & Westbrooke 1996),
- the species diversity and abundance of birds (Arnold & Weeldenburg), and
- the species diversity of some invertebrate groups (Hobbs *et al*. 1993; Scougall *et al*. 1993).

In addition, the lack of regeneration, lack of plant biomass, and actively eroding soil at some sections along the creeks have all been identified as significant causes of soil movement and nutrient movement into waterways in the Goulburn-Broken catchment (CMPS & F 1995; Hydrotechnology 1995; Nicholas & Mack 1996), thus contributing to the decline in quality of the natural, aquatic environment and the decline in quality of stock and domestic drinking water in the catchment and other parts of the Murray Darling Basin (OCE 1988; Koehn & O'Connor 1990b; Mitchell 1990; MDBMC 1994, 1995).

At current levels of grazing along the Broken, Boosey and Nine Mile Creeks system, therefore, the natural environment on both the dryland and in the waterways is deteriorating throughout most of the system. If some level of biodiversity is to be maintained, the use of Crown land frontage along the creeks for stock grazing needs to be reviewed and, at the very least, greatly reduced.

4.2.2 Effects of earthworks on the natural environment

Some level of soil disturbance as a result of earthworks was present at 78% of sections along the creeks. At 44% of sections, soil disturbance was severe (Appendix 6), with the main types of disturbance comprising soil dumping (particularly of creek dredgings, waste earth from shire works and road materials stockpiling), soil extraction (especially for creek works) and soil moving (especially for creek works and the construction of levees) (Appendix 6).
Three additional types of soil disturbance were particularly common in certain sections of the creeks system. Bardi grubbing (the digging up of larvae of native goat moths (Cossidae) for use as fish bait) was recorded at 62% of sections (sample size = 74 sections) along the lower Broken Creek between Waaia and Barmah. It was a major cause of soil disturbance at 28% of those sites. Cultivation was widespread throughout the system but became more prevalent in the upper reaches of the Boosey and Broken Creeks (38% of sections, sample size = 194), where the rear part of the frontage had often been cleared for crops and pastures. Soil disturbance or compaction by the off-road use of vehicles was also widespread throughout the creeks system but was restricted to sites where there was some access. Overall, there were off-road vehicle tracks at 81% of sections (Appendix 6).

The major effects of all of these different types of soil disturbance were weed invasion, particularly of species requiring control, and a loss of native ground cover (Table 22). Accordingly, even though some sections where there had been earthworks had high densities of tree regeneration and shrubs (Table 22), the groundlayer was found to be significantly altered and unsuitable as habitat for some species of native wildlife (see Robinson 1994a). Some other effects of soil disturbance on the natural environment are listed in 4.1.2.

4.2.3 Weed invasion in the natural environment

Weeds were a pervasive element of the natural environment along the creeks system. Altogether, weed species (120 species) represented about one-third of the total flora found along the creek and at only 9% of sections did we find the plant cover in the groundlayer to consist predominantly (> 90%) of native species. At half of all sections surveyed, there were some weed plants in the shrub or tree layers (Appendix 6).

Sixteen of the weed species recorded during the survey are listed as regionally prohibited or regionally controlled species in the Goulburn-Broken catchment, and one or more of these were found at 57% of sections along the Broken, Boosey and Nine Mile Creeks system (Appendix 6). Noxious weeds were most likely to be found at sites where there had been soil dumping (mostly from creek works), soil excavation, cultivation or current grazing by stock, and where sections were licenced for grazing (Table 23). Most of the dryland and aquatic ecosystems along the creeks system are consequently at risk of further invasion by noxious weed species, since all of these land and water-use activities are still happening throughout the creeks system (Appendix 6).

Table 23. Relationships between the incidence of noxious weeds and land-use activities along the creeks system (sample size = 473 sections). For an explanation of correlation values see the caption to Fig. 21. Asterisks show significance levels: * = P < 0.05, ** = P < 0.01.

Land-use activity	Correlation Value
Cultivation	-0.114*
Earth Dumping	0.136**
Earth Excavation	0.107*
Earth Moving	0.059
Levees	0.082
Drains	-0.053
Current grazing levels	0.099*
Past grazing levels	-0.032
Grazing index	0.030
Licenced for grazing	0.134**

5 RECOMMENDATIONS FOR THE BROKEN, BOOSEY AND NINE MILE CREEKS SYSTEM

5.1 OVERVIEW OF ENVIRONMENTAL VALUES OF THE CREEKS SYSTEM

5.1.1 Environmental values at a landscape scale

The Broken, Boosey and Nine Mile Creeks drain a catchment of approximately 370,000 ha (CMPS & F 1993) located within a one million hectare region known as the eastern Northern Plains. Both the Northern Plains and the eastern half of the Northern Plains are well recognised as distinctive physiographic and biogeographic regions (Hills 1946; Butler *et al*. 1973; LCC 1983; Conn 1993; Foreman 1995; Thackway & Cresswell 1995) with their own distinctive flora (Conn 1993; Foreman 1995) and fauna (LCC 1983; Brown & Bennett 1995; Robinson & Traill 1996; Sherwin 1996; Bennett *et al*. in prep.).

But because of the inherent suitability of the plains' grasslands and grassy woodlands for agriculture, nearly all of the Northern Plains was rapidly taken over by Europeans and cleared for grazing and cropping soon after the introduction of the 1869 Land Act. As a result, just 6% of the Northern Plains still retains any tree cover, only 1% of the former extent of the grassy woodlands remains (DNRE 1996) and only 0.03% of the former woodland estate still contains abundant shrubs. Moreover, because nearly all of the woodlands region was alienated for agriculture soon after the introduction of the 1869 Land Act, there are no large woodland reserves and few opportunities for creating one (Fig. 2). For example, the largest reserve in the eastern Northern Plains (Rowan Swamp Wildlife Reserve) measures 430 ha but is also the single largest patch of grassy woodland vegetation in the eastern Northern Plains. Most other reserves designated for nature conservation measure less than 13 ha (LCC 1985; Robinson 1993b, 1994b), and tend to be isolated from other woodland remnants (see Figs 5, 6; Kelly 1994; Brown & Bennett 1995; Bennett *et al*. in prep.).

In comparison, the remnant vegetation along the Broken, Boosey and Nine Mile Creeks system provides a connected habitat network that:

- spans 450 km in length
- totals more than 4000 ha in area
- occurs predominantly on public land
- links many of the larger conservation reserves in the region (Fig. 2)
- represents the largest remaining example of Plains Grassy Woodland in the eastern Northern Plains (3.1.1.)
- is of historical significance as one of the few surviving remnants of native vegetation of the Northern Plains landscape as it once was (3.1.2)
- is of cultural significance for its many aboriginal artifacts and sites of cultural significance to the traditional owners of the land (3.3.)
- includes the largest patches of remnant vegetation in the region (3.1.1)
- traverses a steep environmental gradient from southeast to northwest (3.1.3.2)
- is ecologically distinguishable from most other Victorian creeks and rivers because of its riparian Grey Box vegetation (3.1.3.1)
- incorporates at least 13 different vegetation types (3.2.1.2)
- is relatively intact, albeit simplified, because of the 1874 prescription prohibiting timber cutting and cultivation (2.7)

- incorporates several of the largest wetlands in the eastern Northern Plains (LCC 1985)
- provides habitat connectivity along the length of the creeks system for dispersing animals on land and in water (3.1.3.3), and
- provides an important biogeographic corridor for species migrating between the cooler highlands to the southeast and the semi-arid woodlands to the northwest (3.1.3.3; Robinson & Traill 1996).

The Broken, Boosey and Nine Mile Creeks system thus provides a special opportunity within a mostly cleared and freehold landscape to expand the existing conservation reserve system in the eastern Northern Plains and to create a significant conservation reserve for two of the most endangered ecosystems in Victoria and southeastern Australia - native grasslands and grassy woodlands (Frood & Calder 1987; LCC 1988; Foreman 1995; Ross 1994).

5.1.2 Specific environmental and cultural values

At a more local scale, the Broken, Boosey and Nine Mile Creeks system:
- includes some of the largest remnants of native vegetation in the eastern Northern Plains (3.2.1.1)
- contains a significantly higher proportion of old-growth woodland than most other remnants in the Northern Plains (3.2.1.4)
- contains approximately one tenth of Victoria's native vascular flora (3.2.3.1)
- includes some sites with spectacular plant-species richness (3.2.3.1)
- contains 27 species of threatened plants and more than 100 species of regionally significant plant (3.2.3.2, 3.2.3.3)
- is the only known area in Victoria in which three plant species occur; Fat Spectacles, Pepper Grass and Spiny Saltbush (3.2.3.2)
- contains a significant population of more than 500 plants of one plant species listed as nationally endangered, the Small Psoralea (3.2.3.2)
- contains large populations of several other threatened plant species, notably Pale Spike-rush, Southern Cane-grass, Spreading Eutaxia, Smooth Minuria, Yellow-tongue Daisy, Waterbush and Leafy Templetonia (3.2.3.2)
- includes several notable disjunct populations of plant species usually found further inland, for instance Mallee Golden Wattle, Pin Sida, Leafless Bluebush, Golden Billy Buttons and Minnie Daisy (3.2.3.3).
- supports a significant number of old-growth dependent animals such as Tree Goanna and Crested Shrike-tit (3.2.4.1, 3.2.4.3)
- supports woodland dependent birds (3.2.4.1)
- provides habitat for 9 species of threatened bird, 16 species of declining bird and 7 species of waterbird with restricted or colonial breeding sites (3.2.4.1)
- is an important site for the nationally vulnerable Superb Parrot (3.2.4.1)
- includes several breeding pairs of the threatened Brolga (3.2.4.1)

- is one of few areas in Victoria in which Red-chested Button-quail has occurred (3.2.4.1)
- provides habitat for 1 threatened mammal, 1 threatened frog and four species of regionally uncommon reptile (3.2.4.2, 3.2.4.3, 3.2.4.4)
- provides habitat for 13 species of native fish, nine of which are listed as threatened (3.2.4.5)
- is one of the most important stream systems in the State for Murray Cod and Freshwater Catfish (3.2.4.5)
- contains much suitable habitat for native fish in the middle and upper sections (3.2.4.5), and
- supports one known species of threatened invertebrate - Murray Crayfish (3.2.4.6).

On the basis of these biological and cultural values, nearly 60% of the land (and 70% of individual sections) along the creeks system was rated as having moderate to excellent conservation values, and 9% (13% of sections) was rated as having high or excellent conservation values (Table 24). Those sites considered to be nationally significant are decribed in Chapter 6.

Table 24. Summary of the overall conservation rankings of sections along the creeks system. Definitions of the rankings are given in 1.7.

Conservation ranking	no. of sections	%	area (ha)	%
Excellent	26	5.5	150.2	3.7
High	37	7.8	210.7	5.1
Moderate-High	143	30.2	1248.9	30.6
Moderate	120	25.4	811.8	19.8
Moderate-Low	98	20.7	1294.2	31.7
Low	49	10.4	372.2	9.1

5.2 OVERVIEW OF THREATS ALONG THE CREEKS SYSTEM

Because of the overall narrowness of the Broken, Boosey and Nine Mile Creeks system, and the location of the creek ecosystem within an agricultural landscape, the ecosystem dynamics and ecosystem future of nearly the entire 450 km system are determined principally by external factors; in particular by adjoining land-use activities, modification of the creek environment for industrial use and the clearing of nearly all native vegetation from the surrounding landscape. Nearly every section along the creeks system is consequently exposed to a range of short-term and long-term threats (Table 2), of which the most pervasive are over-grazing of the dryland environment (see

4.2.1), soil disturbance of the dryland and aquatic environments (4.2.2) and inundation and physical modification of the aquatic environment (4.1.2).

As a consequence of these and other threats, only two (0.4%) of the 473 sections sampled along a 360 km length of the creeks system were identified as ecologically intact and well protected. By contrast, 49% of sections (41% of the land) were classed as having severe threats to their existing values and a further 37% of sites (45% of land) as having moderate to severe threats (Table 25). Consequently, unless the remnant woodlands along the creeks system frontage and the associated creek waters are immediately accorded their true value as nationally significant remnants of the Northern Plains' natural heritage and managed for nature conservation, the natural and cultural values of the environment along the creeks will inevitably decline.

Table 25. Summary of the overall threat rankings along the creeks system. For an explanation of the threat rankings used see 1.7.

Threat ranking	no. of sections	%	area (ha)	%
None	2	0.4	7.2	0.2
Light	13	2.7	101.9	2.5
Moderate	50	10.6	489.2	12.0
Moderate-severe	177	37.5	1832.7	44.8
Severe	231	48.8	1657.1	40.5

5.3 OVERALL MANAGEMENT RECOMMENDATIONS FOR THE BROKEN, BOOSEY AND NINE MILE CREEKS SYSTEM

On the basis of the national significance of the Broken, Boosey and Nine Mile Creeks system as the largest connected remnant of Grey Box woodland vegetation in the Northern Plains, with 47 known species of threatened plant or animal distributed along its 450 km length, and the range and severity of threats to those natural values, the Goulburn Valley Environment Group recommends that:

1. The dryland and aquatic environments along the entire Broken, Boosey and Nine Mile Creeks system should be managed primarily for conservation.

2. The most significant natural elements of the creeks system should be incorporated into a State Park (see 5.4.3).

3. Management within the State Park may vary in different sections, but the unifying objective should be to increase the habitat values and conservation values of the whole creeks system.

4. Use of the creeks system as a conduit for industrial water use should cease in the future and a new infrastructure should be developed to carry water around the region.

5. There should be unified management of the creeks system and adjoining land by the different land managers to ensure that recommendation 1 is achieved.

6. There should be an active program of habitat restoration along the creeks system to increase its ecological viability and value as wildlife habitat.

7. There should be an education program throughout the Goulburn-Broken catchment to highlight the significance of the Broken, Boosey and Nine Mile Creeks ecosystem as a fundamental part of our natural and cultural heritage in a landscape in which 99.97% of the natural environment has disappeared or been severely altered.

8. All current land-use and water-use activities should be done in accordance with the legal requirements of the various acts or regulations governing the management of the creeks' land, water and wildlife. In particular, all activities listed as potentially threatening processes under the *Flora and Fauna Guarantee Act* (1988) must cease or be modified in accordance with the conservation and management objectives of the Act. Those of relevance to the creeks system are:
(a) Alteration to the natural flow regimes of rivers and streams
(b) Alteration to the natural temperature regimes of rivers and streams

(c) Increase in sediment input into Victorian rivers and streams due to human activities
(d) Input of toxic substances into Victorian rivers and streams
(e) Introduction of live fish into waters outside their natural range within a Victorian river catchment after 1770
(f) Prevention of passage of aquatic biota asa result of the presence of instream structures
(g) Removal of wood debris from Victorian streams
(h) Degradation of native riparian vegetation along Victorian rivers and streams
(i) Loss of hollow-bearing trees from Victorian native forests
(j) Predation of native widlife by the cat, *Felis catus*
(k) Predation of native wildlife by the introduced Red Fox *Vulpes vulpes*
(l) The invasion of native vegetation by 'environmental weeds'.

5.4 SPECIFIC RECOMMENDATIONS FOR THE BROKEN, BOOSEY AND NINE MILE CREEKS SYSTEM

5.4.1 Australian Heritage Commission

The remnant vegetation along the Broken, Boosey and Nine Mile Creeks system represents the largest and best connected remnant of a woodland ecosystem that once covered nearly one million hectares of land across the eastern Northern Plains but now occupies only 1% of that former area in any form and only 0.03% of that area as an intact example of the woodland ecosystem as it once was. On the basis of this woodland ecosystem's extreme rarity and the representation of that ecosystem provided by the Crown land along the creeks system, we recommend that:

The sites indicated in Fig. 17 and described in Chapter 6 should be nominated to the Australian Heritage Commission's Register of the National Estate as nationally significant examples of the Northern Plains' natural heritage.

5.4.2 Goulburn-Broken Catchment and Land Protection Board

As stated in the draft Goulburn-Broken Catchment Strategy (Brown *et al*. 1996), the Goulburn-Broken CALP Board believes that 'the enhancement and protection of catchment biodiversity is a high priority in the Catchment Strategy'. Accordingly, the CALP Board intends to ensure that, *inter alia*:

- all revegetation programs will have a biodiversity component;
- all natural resource management programs will have guidelines which will ensure remnant vegetation is protected/enhanced;
- rural zones will have a biodiversity overlay and appropriate planning mechanisms which will protect remnant vegetation;
- best management practices will be developed in conjunction with local government on roadside management;
- management plans for parks and forests will include biodiversity objectives; and
- the review of agricultural licences will develop best management practices for grazing of streams.

GVEG supports each of these policy ambitions and believes that they they should be implemented as speedily as possible, particularly at those sites identified as being in need of conservation action by the Trust for Nature/DNRE/GBCALBP and Greening Australia (Raven 1997).

5.4.3 Parks Victoria

We recommend that:

1. Those parts of the creeks system indicated in Fig. 17 and described in Robinson & Mann (1996) be declared as a State Park as part of the Land Conservation Council's Special Investigation of the Box-Ironbark Study Area.

2. The additional areas indicated as Crown land reserves along the creek system (see LCC 1985) should continue to be managed by Parks Victoria for their conservation values.

3. Sections with lower conservation ranking within areas recommended for management by Parks Victoria should be targetted for habitat restoration works, chiefly by fencing, stock removal and weed control.

4. Wherever one bank of the creek is proposed for inclusion in the State Park, the opposite bank should also be managed for conservation to protect and restore instream habitat values for aquatic wildlife.

5. Parks Victoria should take an active role in increasing instream habitat values in those sections of creek running through Parks-managed land

6. Increased funding should be provided to Parks Victoria for specific management of the existing and proposed Park estate along the creeks system.

7. A construction program should be started to provide bridges and walking tracks along the creeks system to improve pedestrian access (see Robinson & Mann 1996).

5.4.4 Goulburn Murray Water/Irrigation agencies

Current management of the creeks system's waterways by GMW and other irrigation agencies poses the most serious threat to the ecological viability of much of the remnant native vegetation along the creeks system (see 4.1.2) and is consequently in clear contravention of the Flora and Fauna Guarantee Act (1988), under which many of the activities occurring along the creeks are listed as Potentially Threatening Processes (see 5.3). Current waterways management along the creeks is also in contravention of the spirit of the Register of the National Estate whereby sites are listed on the Register because of their outstanding contribution to Australia's natural heritage. As outlined in 5.4.1, parts of the creeks system are to be nominated for listing on the Register because of their existing biological values. Current waterways management jeopardises the future of many of the sites to be nominated (4.1.2).

We recommend that:

(1) Use of the creeks system as a conduit for industrial water use should cease in the future and a new infrastructure should be developed to carry water around the region.

(2). A feasibility study should be begun as soon as possible to investigate alternative means of industrial water movement through the region.

(3) There should be no further channelisation of the creeks.

(4) There should be no snag removal from anywhere along the creeks system

(5) No works should be undertaken on public land without consultation with DNRE managing staff

(6) GMW and other agencies should co-operate with Shires to install bridges at those crossings where existing road fords prevent the passage of aquatic biota and increase sediment inputs into the creeks

(7) GMW should remove unoffical weirs installed by adjoining landholders from along the creeks.

(8) GMW and other agencies should aim to prevent irrigation water entering the creeks system from adjacent paddocks via drains or paddock runoff.

(9) In conjunction with Parks Victoria, GMW and other irrigation agencies should install groundwater bores to monitor water tables at all significant sites, and subsequently control groundwater as required (e.g. by the installation of groundwater pumps).

(10) GMW, DNRE and CALP should lobby for and develop legislation requiring landholders with irrigation properties to construct retardation basins and prevent run-off into natural waterways.

(11) No further areas should be allowed to be developed for irrigation along the creeks system.

5.4.5 Department of Natural Resources and Environment (Crown Land and Assets section and Catchment and Land Management section)

For those areas currently licenced for grazing, we recommend that:

(1) No long-term licences should be issued for any areas indicated as having significant conservation value (i.e. those shown as having Excellent, High, Moderate-High or Moderate values in the map appendix and text of Robinson & Mann 1996).

(2) Renewal of grazing licences for the remaining sites (i.e. Moderate-Low and Low value sites) should be contingent upon sites being fenced to allow for stock management. Fencing subsidies should be provided by CALM as a water-quality initiative for the catchment.

(3) Renewal of grazing licences should be contingent upon sites having tree regeneration over more than 50% of the area and more than 2 m in height. If these conditions are not met, licences should be cancelled until regeneration has occurred.

(4) Issuing or renewal of licences should be contingent upon the completion of successful control of noxious weeds by the licencee (*Crown Lands Acts (Amendment) Act* 1994, Part 1, 130AC, *Catchment and Land Protection Act* 1994, Part 3(2), Part 8(70, 71, 72, 73)).

(5) Adjoining landholders or licencees should be subsidised by CALM to install off-creek watering systems (Nicholas & Mack 1996) so that access to the frontage is not required for watering stock that are grazing adjacent land.

For unlicenced land along the creek, we recommend that:

(6) CLAD investigate all cases of unlicenced grazing and impose the above conditions in deciding whether or not to allow licenced grazing, (*Catchment and Land Protection Act* 1994, Part 3(2), Part 8(70, 71, 72, 73)).

5.4.6 Shires

We recommend that:

(1) The protection of natural and cultural values on roads along the creeks system should be given high priority in roadside management considerations by the Shires.

(2) All roadsides abutting Excellent, High or Moderate-High value sections of the creeks system as identified in Robinson & Mann (1996) should be clearly signposted as such (either by Shires or by Parks Victoria).

(3) All significant roadsides abutting the creeks should be clearly identified on Shire planning maps, work-crews' maps and maps issued to works contractors or to other authorities (e.g. Telstra, Eastern Energy, Country Fire Authority). Special conditions should be developed for management of these significant roads.

(4) Droving stock should not be allowed to move along roads next to the creeks or camp along the creeks under any circumstance.

(5) No materials should be stockpiled on Crown land frontage identified as having a conservation value of Moderate-Low or higher (see Robinson & Mann 1996 for detailed information on sites).

(6) Firewood collection should not be permitted along roads next to the creeks or on any Crown land along the creeks.

6 Sites to be nominated to the Register of the National Estate

6.1 East bank of Broken Creek within Barmah Forest, Parish of Moira (39 hectares)

Barmah Forest is already listed on the Register of the National Estate on the basis of its:

- aboriginal cultural significance
- internationally significant wetlands
- largest remaining example of River Red Gum forest in Australia
- diversity of vegetation types
- high diversity of plant species
- high number of threatened plant species
- high number of threatened animals, and
- significance as a European cultural site (AHC 1994).

Results from this survey furnished further information underlining the national significance of this forest. We found that the Barmah Forest section of the Broken Creek:

- contains numerous aboriginal cultural sites (AHC Criterion A1, AHC 1990);
- provides excellent examples of Black Box woodland close to the biogeographic edge of its range (AHC Criterion A1, see Appendix 2);
- supports biogeographically disjunct populations of several species of animal - e.g. Striated Thornbill, White-browed Scrubwren, White-throated Treecreeper, Buff-rumped Thornbill, Red-bellied Black Snake (AHC Criteria A1, B);
- provides some of the best examples of Black Box woodland in the eastern Northern Plains (AHC Criteria A2, D1);
- supports the only known population in Victoria of the endangered plant Fat Spectacles (AHC Criterion B); and
- supports populations of at least four plants listed as threatened in Victoria - Smooth Minuria, Fat Spectacles, Red-flowered Trefoil and Grey Raspwort (AHC Criterion B).

6.2 East bank of Broken Creek, James Bridge, Parish of Narioka (5 hectares)

- contains numerous aboriginal sites (Criterion A1);
- provides good examples of Dry Grey Box Woodland and Yellow Box vegetation communities (Criteria A2, D1);
- contains at least 12 species of plants listed as regionally significant (Criteria A3, B);
- contains unusual reptile-species richness in a regional context, with five known species (Criterion A3); and

- contains a population of the nationally endangered plant Small Psoralea (Criterion B).

6.3 Northwest bank of Broken Creek, Fairmans Bridge, Parish of Narioka (10.4 hectares)

- contains aboriginal sites (Criterion A1);
- supports a very isolated population of a plant listed as threatened in Victoria, Mallee Golden Wattle (see Fig. 12) (Criterion A1);
- provides an excellent example of Yellow Box-White Cypress-pine Woodland with a dense understorey comprising 9 species of shrub (Criterion A2);
- contains unusual species richness in a regional context (Table 10) (Criterion A3);
- is representative of an endangered sandy-soil woodland community (currently undescribed) now restricted in the eastern Northern Plains to the lower parts of some of the rivers and streams and to the Murray River floodplain (e.g. Margules & Partners 1990) (Criterion B);
- until recently supported, and may still support, a population of the nationally endangered plant Small Psoralea (Criterion B); and
- contains populations of at least three plants listed as threatened in Victoria (Leafy Templetonia, White Cypress-pine and Mallee Golden Wattle) (Criterion B).

6.4 Broken Creek from Thompsons Road to Walshes Bridge Road, (left bank) and from Mathers Road to Katamatite Road (right bank), Parish of Waaia (55.6 hectares)

- contains aboriginal sites (Criterion A1);
- provides the most consistent example of the geomorphologically distinctive character of the lower Broken Creek and its associated sandy-soil vegetation (Criterion A1);
- provides an excellent example of intact Yellow Box-White Cypress-pine Woodland with an understorey containing 11 species of shrub (Criterion A2);
- contains unusual plant species richness in a regional context (Table 10) (Criterion A3);
- is representative of an endangered sandy-soil woodland community (currently undescribed) now restricted in the eastern Northern Plains to the lower parts of some of the rivers and streams and to the Murray River floodplain (e.g. Margules & Partners 1990) (Criterion B);
- contains populations of at least five plants listed as threatened in Victoria (Buloke, White Cypress-pine, Leafy Templetonia, Small Burr-grass, Spreading Eutaxia) (Criterion B); and
- contains two species of animal threatened in Victoria (Squirrel Glider, Bush Stone-curlew) (Criterion B).

6.5 Northwest bank of Broken Creek, Galt's Bridge, Mundoona, Parish of Mundoona (6.4 hectares)

- contains an intact example of Northern Plains Grassland, a community described as endangered in Victoria (SAC 1992a; Foreman 1995) Criteria A2, B);
- contains relatively high variation in soils and vegetation, with four different vegetation types (Damp Grassland, Dry Grassland, Dry Grey Box Woodland, Riparian River Red Gum Woodland) (Criteria A2, A3);
- contains unusual plant species richness in a regional context (Table 13), with at least 18 species classed as regionally significant (Criterion A3); and
- supports populations of at least four species of plant listed as threatened in Victoria (Buloke, Plover-daisy, Dwarf Blue-bush and Southern Cane-grass (Criterion B).

6.6 Numurkah Rifle Range, Township of Numurkah (10.3 hectares)

- represents an intact and relatively large remnant of the endangered Northern Plains grassland community (SAC 1992a) which is distinguished from most remnants by its long history of no grazing or soil disturbance (Criterion A2);
- shows high microtopographic variation from woodland to grassland and dry grassland to damper grassland (Criteria A2, C1, D1);
- has high native plant species richness (about 90 known species) (Criterion A3); and
- contains populations of at least four species of plants listed as threatened in Victoria (Yellow-tongue daisy, Plover Daisy, Dwarf Bluebush, Smooth Minuria) (Criterion B).

6.7 Wungnhu Bushland Reserve (H27, LCC 1985), Township of Wunghnu (33 hectares)

- contains aboriginal sites (Criterion A1);
- provides one of the best remaining example of Dry Grey Box Woodland in the eastern Northern Plains (Criteria A1, A2, B);
- contains relatively high microtopographic variation, with a transition from Yellow Box/Grey Box Woodlands to Dry Grey Box Woodlands to Damp Grey Box Woodlands (Criterion A2);
- contains unusual plant-species richness in a regional context, with 89 known native plant species (Table 13) (Criterion A3);
- contains unusual reptile-species richness in a regional context, with four recorded species (Criterion A3); and

- contains populations of at least eight plants listed as threatened in Victoria (Buloke, Waterbush, Spreading Eutaxia, Plover Daisy, Leafy Templetonia, Smooth Minuria, Spurred Spear-grass, Native Millet), (Criterion B).

6.8 Both banks of Nine Mile Creek, from the edge of Black Swamp Wildlife Reserve to Harris' Bridge, Parish of Drumanure (233 hectares)

- includes many aboriginal sites (Criterion A1);
- provides the most consistent example of the geomorphologically distinctive character of the middle section of the creeks system; characterised as a moderately well drained plain but with some channels and depressions (Riverine Plain 6, LCC 1983) (Criterion A1);
- provides a large and mostly-intact area of Grey Box woodland vegetation, with excellent examples of Dry Grey Box Woodland and Damp Grey Box Woodland (Criteria A2, D1);
- provides an excellent example of mostly fenced Crown land water frontage (see 2.7) and its historical significance in retaining elements of our natural and cultural heritage (Criterion A4);
- because of its width, dense tree cover, predominantly old-growth habitat and many trees scarred by aborigines, provides observers with one of the few examples of a sense of the Northern Plains landscape as it once was (Criterion B);
- has unusual plant-species richness in a regional context (about 100 species) (Criterion A3);
- has unusual animal-species richness in a regional context, supporting relatively many species dependent on large woodland remnants (Criterion A3);
- contains at least nine known species of plants listed as threatened in Victoria (Buloke, White Cypress-pine, Dwarf Bluebush, Spiny Saltbush, Waterbush, Leafy Templetonia, Spreading Eutaxia, Yellow-tongue Daisy, Smooth Minuria), (Criterion B)
- contains two species of threatened animal (Bush Stone-curlew, Squirrel Glider) (Criterion B); and
- contains two of the four known Victorian populations of Spiny Saltbush (Criterion B).

6.9 Both banks of Broken and Boosey Creeks from just west of Dip Bridge to Katamatite Township, Parishes of Naringaningalook and Katamatite (98 hectares)

- includes many aboriginal sites (Criterion A1);
- is representative of a part of the creeks system distinguished geomorphologically from other parts of the creeks system because the plain is slightly raised, the creek level is lower than the surrounding plain (Butler

et al. 1973; LCC 193), soils are mostly fairly light (Skene & Poutsma 1962) and soils include a layer of lime (Cockcroft 1965) (Criterion A1);
- as a consequence of the above, supports a regionally distinctive vegetation type, with regionally significant plants such as White Cypress-pine, Kangaroo Grass and Silky Blue Grass becoming more common (Criterion D1);
- includes a small area west of Dip Bridge with a disjunct example of woodland vegetation resembling the Riverine Red Gum Forest community found in Barmah Forest (Criteria A1, D);
- has unusual plant-species richness in a regional context, with about 80 known species of native plants (Criterion A3); and
- contains populations of at least five plants listed as threatened in Victoria (White Cypress-pine, Buloke, Waterbush, Leafy Templetonia, Smooth Minuria), (Criterion B).

6.10 Katamatite Bushland Reserve (H40, LCC 1985) and disused railway reserve, Township of Katamatite (17 hectares)

- contains aboriginal sites (Criterion A1);
- provides one of the best and largest (17 hectares) remnants of grassy woodland in the Northern Plains (Criteria A2, B);
- provides a biogeographically significant site with intergradation of three different grassy woodland sub-communities - Western Grassy Woodland, Eastern Grassy Woodland and Wet Grassland (Foreman 1995), (Criterion A1);
- provides intact examples of Dry Grey Box Woodland and Damp Grey Box Woodland (Criteria A2, A3, B);
- supports a viable population of the threatened plant, Pin Sida, well outside of its usual range (see Fig. 12) (Criterion A1);
- supports a viable population of one other plant species, Minnie Daisy, outside of its usual range (Criterion A1);
- contains relatively high microtopographic variation, with a physical transition from Yellow Box-White Cypress-pine Woodlands to Dry Grey Box Woodlands to Damp Grey Box Woodlands (Criterion A2);
- contains unusual plant-species richness in a regional context, with 130 known native plant species (Table 13) (Criterion A3);
- supports a relatively diverse woodland fauna in a regional context (Criterion A3);
- contains populations of at least eleven species of plants listed as threatened in Victoria (Southern Cane-grass, Buloke, White Cypress-pine, Leafless Bluebush, Dwarf Bluebush, Spiny Saltbush, Spreading Eutaxia, Plover Daisy, Leafy Templetonia, Grey Raspwort, Pin Sida), (Criterion B);
- helps demonstrate the ecological transition from woodland to open woodland and from drier grassy sites to damper sites (Criteria C1, D1); and

- is a valuable site for an understanding of the significance of gilgais in influencing local plant-species distributions (Criterion D).

6.11 Both banks of Boosey Creek from Youarang Road to Tungamah Road, Parishes of Boosey, Youarang and Tharanbegga (192.5 hectares)

- includes many aboriginal sites (Criterion A1);
- provides the most consistent example of the geomorphologically distinct character of the middle section of the creeks system; characterised as a moderately well drained plain but with some channels and depressions (Riverine Plain 6, LCC 1983) (Criterion A1);
- provides a large and mostly intact area of Dry Grey Box woodland vegetation (Criteria A2, D1);
- demonstrates ecological transition in plant-species composition, as rainfall increases (Criteria A1, C1, D1);
- provides an excellent example of mostly fenced Crown land water frontage (see 2.7) and its historical significance in retaining elements of our natural and cultural heritage (Criterion A4);
- because of its width, dense tree cover, predominantly old-growth habitat and many trees scarred by aborigines, provides observers with one of the few examples of a sense of the Northern Plains landscape as it once was (Criterion B);
- has unusual plant-species richness in a regional context (about 90 species) (Criterion A3);
- contains populations of at least five species of plants listed as threatened in Victoria (Spurred Spear-grass, White Cypress-pine, Buloke, Spreading Eutaxia, Leafy Templetonia), (Criterion B); and
- provides an excellent example of a lowland stream with intact, instream habitat and riparian vegetation (Criterion A2).

6.12 Tungamah Swamps (Wildlife Reserve C27, LCC 1985), Parish of Tharanbegga (146 hectares)

- contains many aboriginal sites (Criterion A1);
- supports a large population of more than 1000 plants of a regionally significant plant species, Golden Billy-buttons, occurring well outside its usual range (Fig. 12) (Criterion A1);
- provides a regionally very large and intact area of native grasslands and woodlands (Criteria A2, B, D1);
- is part of an important chain of wetlands in the region for many species of breeding and migratory waterbird (e.g. cormorants, ibis, Brolga, Black-winged Stilt, Great Egret, Intermediate Egret) (Criterion A2);
- contains a high diversity of vegetation types and habitats, ranging from Yellow Box Woodlands to damp gilgai grasslands (Criterion A2);

- supports unusual plant-species richness in a regional context (about 50 species) (Criterion A3);
- supports unusual animal-species richness in a regional context, with a number of woodland-dependent animals such as Wedge-tailed Eagle, Southern Boobook and Barking Owl, and several species of grassland bird (Brolga, Brown Songlark, Singing Bushlark) (Criterion A3);
- contains four species of plants listed as threatened in Victoria (Grey Raspwort, Pale Spike-rush, Southern Cane-grass, Buloke) (Criterion B);
- contains two species of threatened animal (Brolga, Barking Owl);
- helps demonstrate the ecological transition from woodland to open woodland and from drier grassy sites to damper sites (Criteria C1, D1); and
- is a valuable site for an understanding of the significance of gilgais in influencing local plant-species distributions (Criterion D).

6.13 Rowan Swamp Wildlife Reserve (C28, LCC 1985), Parishes of Karrabumet and Bungeet (430 hectares)

- contains many aboriginal sites (Criterion A1);
- is the largest woodland remnant and reserve in the eastern northern Plains;
- provides a regionally very large and intact area of native grasslands and woodlands (Criteria A2, B, D1);
- is part of an important chain of wetlands in the region for many species of breeding and migratory waterbird (e.g. cormorants, ibis, Brolga, Great Egret) (Criterion A2);
- contains a high diversity of vegetation types and habitats, ranging from Yellow Box-White Cypress-pine Woodlands to damp gilgai grasslands (Criterion A2);
- supports unusual plant-species richness in a regional context, with 80 known species (Criterion A3);
- supports unusual animal-species richness in a regional context, with a number of woodland-dependent animals such as Wedge-tailed Eagle, Southern Boobook and Whistling Kite, and several species of grassland bird (Brolga, Brown Songlark, Singing Bushlark) (Criterion A3);
- because of its width, dense tree cover, predominantly old-growth habitat and many trees scarred by aborigines, provides observers with one of the few examples of a sense of the Northern Plains landscape as it once was (Criterion B);
- contains six species of plant listed as threatened in Victoria (Pale Spike-rush, Southern Cane-grass, Buloke, Small Psoralea, Slender Tick-trefoil, Native Millet) (Criterion B);
- contains three known species of animal listed as threatened in Victoria (Brolga, Bush Stone-curlew, Red-chested Button-quail) (Criterion B);
- supporta a large population of more than 500 plants of a nationally endangered plant, Small Psoralea (Criterion B);

- helps demonstrate the ecological transition from woodland to open woodland and from drier grassy sites to damper sites (Criteria C1, D1); and
- is a valuable site for an understanding of the significance of gilgais in influencing local plant-species distributions (Criterion D).

6.14 Moodie Swamp Wildlife Reserve (C26, LCC 1985), Parish of Waggarandall (198 hectares)

- contains aboriginal sites (Criterion A1);
- contains populations of at least six species of plant which are otherwise absent or extremely rare in the eastern Northern Plains (Twining Glycine, Annual New Holland Daisy *Vittadinia cervicularis,* Tadgell's Bluebell *Wahlenbergia multicaulis,* Bluebell *Wahlenbergia littoricola,*Cotton Panic-grass *Digitaria brownii,* Tufted Sedge *Carex gaudichaudii*) (Criterion A1);
- supports a biogeographically distinct plant community restricted entirely to the sandy lunette at the eastern edge of the swamp (Criterion A1);
- is the only known, intact example of a lunette in the eastern northern Plains (Tickell 1989) (Criterion A1);
- is part of an important chain of wetlands in the region for many species of breeding and migratory waterbird (e.g. cormorants, ibis, spoonbills, Brolga, Black-winged Stilt, Great Egret, Pacific Heron, Great Crested Grebe, Intermediate Egret) (Criterion A2);
- contains a high diversity of vegetation types and habitats, ranging from Yellow Box-White Cypress-pine Woodlands to shallow wetlands (Criteria A2, D1);
- supports unusual plant-species richness in a regional context, with more than 100 recorded species (Table 13) (Criterion A3);
- supports unusual animal-species richness in a regional context, with a large number of wetland species (Criterion A3);
- contains three species of plant listed as threatened in Victoria (Southern Cane-grass, Buloke, Leafy Templetonia) (Criterion B); and
- contains two species of animal listed as threatened in Victoria Brolga, White-bellied Sea-eagle) (Criterion B).

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Appendix 1 Environmental variables measured during the creek survey and a list of definitions

Background Information

1. Site (prefix 1 for left bank, 2 for right bank, 3 for off-creek) = continuous numbers from 1-500+
2. Creek division (broad landscape divisions used along creek to subdivide data).
3. Parish
4. Land tenure (1 = waterfrontage, 2 = streamside or bushland reserve; 3 = wildlife reserve; 4 = State Forest; 5 = unreserved Crown land; 6 = private).
5. LCC code, if there is one
6. Agricultural licence status (2 = all, 1 = part, 0 = none). Categories only apply to Crown land. Information derived from Parish Plans and LIMS printouts
7. Area of section (in ha, measured from parish plans).

Landscape Information

8. Adjoining land use (1 = much tree cover, 2 = some tree cover, some other use; 3 = unimproved, 4 = some unimproved, some improved, 5 = improved, 6= some improved, some irrigated, 7 = irrigated, 8 = part urban, 9 = urban
9. Adjacent houses (1 = yes, 0 = No)
10. Site width (1= <30 m, 2 = 30-50, 3= 50-75, 4= 75-100; 5=100-150; 6=150-200; 7=>200 - number refers to average category
11. Total treecover width (defined as point where aerial photos show connected treecover across both sides of creek and creek less than 8 m wide): 1 = <30 m; 2 = 30-50; 3 = 50-75; 4 = 75-100; 5 = 100-150; 6 = 150-200; 7 = > 200.
12. Creek value (1= channelised and frequently irrigated; 2 = channelised, sometimes irrigated; 3 = not channelised, frequently irrigated; 4 = not channelised, sometimes irrigated; 5 = channelised, rarely irrigated; 6 = not channelised, rarely irrigated; 7 = intact with natural flows. Frequently irrigated indicates that the section receives irrigation water over several months every year; regularly irrigated indicates that the section received irrigation water at least once a year; and rarely irrigated indicates that the section received irigation water less than once every year.
13. Creek height (refers to how high the land at every site is above the weir level or how much higher the high water level is at a site than its natural level because of the weir). Estimate given in cm or metres.

Vegetation Information

14. Tree Cover (1 = Dense, whereby canopies separated by less than one canopy width 2 = part dense, part scattered, 3 = scattered, 4 = part dense, part none, 5 = part scattered, part none, 6= part scattered or dense, much none; 7 = none).
15. Biomass (3= much, 2 = some, 1= little, 0=none - value = average for all veg. communities). 3 = 100% ground cover of plant material or litter and extensive, deep litter; 2= 20-100% plant cover, and extensive shallow litter or plant height > 5 cm high; 1 = plant cover 1-20%, or scattered litter or plant height less than 5 cm; None = bare ground or less than 1% cover.
16. Tree Dieback (value averaged over all of the site: 2= much (more than 25% of trees affected, 1=some, 0=none, all trees apparently healthy)
17. Causes of dieback: Causes of dieback were scored in the field as due to flooding, irrigation runoff, changed water regimes, stock grazing, rubbing or trampling, soil cultivation, other soil works, creek channelisation works, exposure, soil damage by vehicles. Flooding was recorded as the principal cause where: trees in low points but not higher points, were suffering dieback; trees nearest the creek were toppling over; old trees were dead, the groundlayer included plants that naturally occurred in damper environments (Margules & Partners 1990). Irrigation runoff was readily visible as narrow lines of damper, often weedy vegetation and

stricken trees along a drain. Altered water regimes were sometimes apparent because the effects of dieback were restricted to localised areas of damper ground with weedy vegetation and damper trees. Where not enough water was being received, trees tended to be enduring massive insect attack. Stock-related dieback was usually apparent because the effects were localised and restricted to trees with clear evidence of long-term stock-camps (e.g. thistle patches) or physical damage. Cultivation, other earthworks, vehicle disturbance and creek works were likewise apparent because the effects were localised and could be related to a particular practice at a particular tree or trees. Exposure was listed as the cause where dieback was most evident on trees most exposed to wind and damage was greatest on the windward side.

18. Abundance of trees larger than 1 m: 2 = much(>10/ha); 1= some(<10/ha); 0=none.
19. Trees > 50 cm & < 100 cm: 2 = much (> 20/ha); 1 = some (< 20/ha); 0 = none.
20. Trees > 25 cm & < 50 cm: 2 = much (> 40ha); 1 = some (< 40/ha); 0 = none.
21. Seedlings: 2 = much (> 50/ha and over > 50% of the site); 1 = some (< 50/ha and over <50% of the site); 0 = none.
22. Dominant mature tree species (1 = Grey Box; 2 = Yellow Box; 3 = Black Box; 4 = White Box; 5 = combined box; 6 = box and red gum equal; 7 = River Red Gum.
23. Dominant regeneration species (code as above).
24. Number of all dryland shrubs (excluding lignum): 4 = many (> 50% of site with some shrubs); 3 = moderate (20 - 50% of site or community); 2 = some (5 - 20% of site with shrubs); 1 = few(< 5% of site with shrubs or less than 5 shrubs in total); 0 = none.
25. Number of lignum only. Code as in 24.
26. Groundlayer vegetation: 5 = All Native (> 90% native); 4 = Mostly native (71 - 90% native); 3 = Moderately native (56 - 70%); 2 = 50/50 native and weedy (45 - 55%); 1 = 55-90% weedy; 0 = > 90% weedy. Note that if there is a bare ground component, this calculation only refers to the plant cover columns.
27. Grass value: 1 = tall warm season perennials; 2 = short warm season perennials;; 3 = medium cool season perennials; 4 = combination of 1 or 2 and 4; 5 = combination of 5 and 1 or 2; 6 = combination of 5 and 4; 7 = volunteer short, warm season perennials; 8 = short cool-season perennials; 9 = *Juncus* spp. / *Carex inversa* / *Eleocharis pusilla*; 10 = other (e.g. wetlands).
28. Bare earth (%).
29. Weed trees and shrubs: 2 = many (found over > 50% of site); 1 = some (5 - 50% of site); 0 = none.

Site Management

30. Fenced from grazing or not (if a road site is not fenced but the road is fenced from adjacent paddock then the site is rated as fenced, even if grazing is happening there): 2 = yes, 1 = partly, 0 = no.
31. Fenced from vehicles or not: 2 yes, 1 = partly, 0 = no. This refers only to public vehicles, not vehicles in the adjoining paddock.
32. Publicly accessible: 1 = yes, 0 = no. A site may not be accessible because there is no public road access, it is across the creek from an access point or because of deliberate efforts to discourage access. All are scored as "no".
33. Appropriated: 2 = yes, 1 = partly, 0 = no). A site is appropriated if it has been clearly incorporated into the adjoining farm, if there has been clearing or cultivation of the site, if houses or yards, etc are built on it, if it has been converted to an apparently private driveway, or is signed 'keep out'.
34. Road access: 3 = major road next to or through the site; 2 = minor road but managed by Shire; 1 = bush track but open to everyone; 0 = none.
35. Present grazing levels: 2 = much (many stock, pugging, shit or camps apparent, little biomass, any shrubs present chewed or trampled); 1 = some (some stock, shit, or pugging, some species of grazing-sensitive plants, some regenerating trees or shrubs, some biomass); 0 = none (no stock, no shit, higher biomass).
36. Current stockfeeding: 1 = yes, 0 = no.

37. Stock traffic: 3 = heavy traffic route (e.g. to dairy); 2 = frequent stock travel; 1 = occasional stock travel; 0 = none.
38. Past persistent grazing level: 2 = much (extensive pugging, old shit or stock camps; little tree regeneration or shrubs and, if present, are young; multi-stemmed tree regeneration); 1 = some (some pugging and old shit, some stock camps, some tree regeneration and/or shrubs which may include old specimens that survived light levels in past; 0 = none.
39. Overall grazing index (summarises impacts of 35, 37, 38): 6 = severe (much past heavy grazing and current grazing, or past heavy grazing, some current grazing and stock traffic in levels 3 or 2)); 5 = severe/moderate (much past heavy grazing, some current grazing, some stock traffic (levels 1,2,3)); 4 = moderate (some past grazing but much heavy grazing now or, some past heavy grazing and some grazing now and some stock traffic); 3 = moderate/light (some past heavy grazing and some current grazing or current stock traffic, or much past heavy grazing and none now); 2 = light (some past grazing but no grazing now, or no past grazing but some grazing now); 1 = very light (some past grazing and no current grazing but some stock traffic); 0 = none.
40. Soil extraction: 2 = much; 1= som;, 0 = none.
41. Soil dumping: 2 = much; 1= some; 0 = none.
42. Earth-moving or verge grading.
43. Road drains.
44. Cultivation (ploughing and sowing of pasture or crops only, grass mowing excluded).
45. Earthworks summary: 2 = much; 1= some; 0 = none. Note that "2" has been given to all sites that have been cultivated.
46. Pest levels (rabbits, hares, foxes): 2 = high; 1= moderate; 0 = low.
47. Weediness of troublesome weeds: 2 = extensive weed invasion; 1 = patchy areas of weeds, 0 = none.
48. Noxious weeds present: 0 = no; 1=yes.

Recreational uses

49. Bardi grubbing: 2 = much; 1 = some 0 = none.
50. Firewood collection: 2 = much; 1 = some; 0 = none.
51. Shooting: 2 = much; 1 = some; 0 = none.
52. Camping: 2 = much; 1 = some; 0 = none.
53. Fishing: 2 = much; 1 = some; 0 = none.
54. Rubbish dumping: 2 = much; 1 = some; 0 = none.

Appendix 2 Summary of Threshold Criteria for Grasslands and Grassy Woodlands from Ross, J. (1994).

A1: THRESHOLD CRITERION FOR GRASSLANDS AND GRASSY WOODLANDS IN VICTORIA

1. The place supports a biogeographically significant or disjunct plant sub-community
2. The place supports a viable population of a greatly disjunct species uncommon in the region
3. The place represents the limit of range of several taxa or a community, that demonstrates critical environmental limits within evolutionary processes.
4. The place is a refugia for species rare at State level.

A2: THRESHOLD CRITERION FOR GRASSLANDS AND GRASSY WOODLANDS

1. An intact or extensive stand or series of smaller stands of a native grassland or grassy woodland sub-community and distinctive faunal assemblage or the most intact and extensive stand occurring in a biological reserve in a particular biogeographic region.
2. An intact and extensive primary habitat link containing comparable habitat attributes to two connecting sites or a series of sites of high conservation significance.
3. Important breeding sites for fauna that is rare at the State level.
4. Areas designated as Critical Habitat under section 20 of the Flora and Fauna Guarantee Act for species dependent upon grassland and grassy woodland habitat or for grassland and grassy woodland communities.
5. Sites which contain relatively high microtopographic variation, a variety of habitat and which may provide refugial habitat.

A3: THRESHOLD CRITERION FOR GRASSLANDS AND GRASSY WOODLANDS

1. Places supporting unusual floral and/or faunal species richness based on regional norms.
2. Places supporting a relatively diverse range of vegetation types and/or faunal assemblages.

B: THRESHOLD CRITERION FOR GRASSLANDS AND GRASSY WOODLANDS

1. A population of a species or sub-species listed as endangered in Australia by ANZECC (1991), Briggs & Leigh (1988) or one of the largest or last known populations of a species or sub-species listed as vulnerable in Australia or endangered or vulnerable in Victoria by CNR (1993) or Gullan, Cheal & Walsh (1989).
2. Four or more species which are listed as endangered, vulnerable, rare, indeterminate or insufficiently known in Victoria.
3. An intact or extensive stand or series of smaller stands of a native grassland or grassy woodland sub-community and distinctive faunal assemblage or the most intact and extensive occurring in a biological reserve in a particular biogeographic region.
4. The only known, or one of the largest known, populations of an undescribed species
5. Rare or uncommon associations of vegetation types and/or faunal assemblages.

C1: THRESHOLD CRITERION FOR GRASSLANDS AND GRASSY WOODLANDS

1. The place is the recognised Type locality and a current locality for rare or otherwise significant taxa (State level).
2. The place is recognised or proposed under the *Reference Areas Act* (1978)(Victoria).
3. The place is used to produce significant research information, particularly in relation to monitoring of ecological processes.
4. The place is significant as a teaching or educational area by students of natural history.

5. The place has high potential for rehabilitation and management for public appreciation of grassland flora and fauna values. N.B. The status and outlook of the place must be considered in respect to this criterion.

D1: THRESHOLD CRITERION FOR GRASSLANDS AND GRASSY WOODLANDS

1. The place is representative of a particular vegetation type (defined according to floristics but also considering important structural variants) including the range of geology and soil types. [See type profiles]
2. The place is representative of an identifiable faunal assemblage.
3. The place demonstrates the typical natural development of the type and where disturbance to natural processes are minimal or where management of the site has been consistent and is a positive factor in the maintenance of biodiversity.
4. The place demonstrates a particularly significant variation within the type in relation to substrate, altitude, latitude and/or climate.

Appendix 3 Native plant species recorded during the creek survey and their relative abundance

SPECIES		% of sites with each species for sites sampled in detail (146 sites)	% of sites with each species for all sites (520 sites)
PTERIDOPHYTES			
Ophioglossaceae			
Ophioglossum lusitanicum	Adders Tongue	1.4	0.4
Adiantaceae			
Cheilanthes sieberi	Narrow Rock-fern	1.4	0.4
Marsileaceae			
Marsilea costulifera	Narrow-leaf Nardoo	8.9	2.7
Marsilea drummondii	Common Nardoo	24.7	8.3
Pilularia novaehollandiae	Austral Pilularia		
Azollaceae			
Azolla filiculoides	Pacific Azolla	2.1	0.6
CONIFERS			
Cupressaceae			
Callitris glaucophylla	White Cypress-pine	8.9	5.4
MONOCOTYLEDONS			
Alismataceae			
Damasonium minus	Star Fruit	2.7	0.8
Hydrocharitaceae			
Ottelia ovalifolia	Swamp Lily	0.7	0.6
Juncaginaceae			
Triglochin procerum	Water Ribbons	4.1	1.3
Triglochin dubium	Water Ribbons	0.7	0.2
Lemnaceae			
Spirodela punctata	Thin Duckweed	0.7	0.2
Juncaceae			
Juncus amabilis	Rush	4.8	1.9
Juncus aridicola	Tussock Rush	2.1	0.8
Juncus bufonius	Toad Rush	1.4	0.6
Juncus holoscoenus	Joint-leaf Rush	3.4	1.0
Juncus homalocaulis	Wiry Rush	0.7	0.2
Juncus ingens	Giant Rush	1.4	0.4
Juncus subsecundus	Finger Rush	12.3	3.8
Juncus usitatus	Rush	0.7	0.2
Cyperaceae			

Schoenus apogon	Common Bog-rush	0.7	0.2
Cyperus gymnocaulos	Spring Flat-sedge	3.4	1.0
Cyperus difformis	Variable Flat-sedge	0.0	0.2
Cyperus exaltatus	Tall Flat-sedge	13.7	4.2
Cyperus victoriensis?	Flat-sedge	0.7	0.2
Cyperus gunnii?	Flat-sedge	0.7	0.2
Cyperus bifax	Flat-sedge	0.7	0.2
Cyperus lhotskyanus?	Flat-sedge	0.7	0.2
Isolepis hookeriana	Club-rush	0.7	0.2
I. platycarpa	Club-rush	0.7	0.2
I. marginata	Club-rush	0.7	0.2
Schoenoplectus validus	River Club-rush	0.7	0.2
Eleocharis sphacelata	Tall Spike-rush	2.1	1.0
Eleocharis pusilla	Small Spike-rush	44.5	31.9
Eleocharis acuta	Common Spike-rush	33.6	15.2
Eleocharis pallens	Pale Spike-rush	4.1	2.1
Carex bichenoviana	Sedge	13.0	11.3
C. gaudichaudiana	Tufted Sedge	0.7	0.2
C. inversa	Knob Sedge	68.5	43.1
C. tereticaulis	Poong'ort	44.5	32.9

Poaceae

Microlaena stipoides	Weeping grass	0.7	0.2
Stipa elegantissima	Feather Spear-grass	11.6	3.8
Stipa scabra	Rough Spear-grass	26.0	10.6
Stipa nodosa	Spear-grass	20.5	8.3
Stipa curticoma	Spear-grass	4.8	1.3
Stipa bigeniculata	Yanganbil	8.2	3.3
Stipa aristiglumis	Plains Spear-grass	39.7	20.4
Stipa gibbosa	Spurred Spear-grass	11.6	1.7
Stipa blackii	Crested Spear-grass	23.2	8.1
Poa fordeana	Forde Poa	39.7	15.8
Poa sieberiana sieberiana	Tussock Grass	33.6	11.0
Poa labillardierei	Tussock Grass	10.3	4.0
Glyceria australis	Australian Sweet-grass	1.4	0.4
Amphibromus nervosus	Swamp Wallaby-grass	4.8	2.7
Agrostis aemula	Blown-grass	0.7	0.2
Agrostis avenacea	Common Blown-grass	28.1	9.8
Dichelachne crinita	Long-hair Plume-grass	0.7	0.2
Dichelachne rara	Plume-grass	0.7	0.4
Elymus scaber	Common Wheat-grass	51.4	18.5
Danthonia linkii	Wallaby-grass	13.0	4.0
Danthonia setacea	Bristly Wallaby-grass	56.2	33.5
Danthonia caespitosa	Common Wallaby-grass	43.1	15.2
Danthonia duttoniana	Brown-back Wallaby-grass	34.9	16.3
Danthonia eriantha	Hill Wallaby-grass	6.2	2.3
Danthonia racemosa	Clustered Wallaby-grass	0.7	0.2
Phragmites australis	Common Reed	2.7	1.3
Aristida behriana	Brush Wire-grass	19.9	6.5
Aristida ramosa	Purple Wire-grass	2.1	0.6
Enneapogon nigricans	Niggerheads	0.7	0.2
Eragrostis infecunda	Southern Cane-grass	20.5	11.7
Eragrostis parviflora	Weeping Love-grass	3.4	1.0
Eragrostis brownii	Common Love-grass	1.4	0.4
Eragrostis elongata	Close-headed Love-grass	5.5	1.5
Chloris truncata	Windmill-grass	39.0	15.0
Enteropogon acicularis	Spider-grass	58.9	25.7

Tragus australianus	Small Burr-grass	0.7	0.2
Panicum decompositum	Native Millet	1.4	0.4
Panicum effusum	Hairy Panic	2.1	0.6
Panicum laevinode	Pepper Grass	0.7	0.2
Eriochloa pseudoacrotricha	Early Spring-grass	2.7	0.8
Paspalidium jubiflorum	Warrego Summer-grass	18.5	6.1
Homopholis proluta	Rigid Panic	61.6	25.0
Digitaria brownii	Cotton Panic-grass	0.7	0.2
Pseudoraphis spinescens	Moira-grass	6.2	3.5
Eulalia aurea	Silky Browntop	9.6	3.7
Dicantheum sericeum	Silky Blue-grass	4.8	1.7
Bothriochloa macra	Red-leg Grass	26.0	9.0
Themeda triandra	Kangaroo Grass	17.1	5.2
Hydatellaceae			
Trithuria submersa	Trithuria	0.7	0.2
Typhaceae			
Typha sp.	Cumbungi	13.0	2.9
Liliaceae			
Hypoxis vaginata	Yellow Star	0.7	0.2
Hypoxis glabella	Tiny Star	2.1	0.6
Hypoxis exilis?	Yellow Star	1.4	0.4
Hypoxis hygrometrica	Golden Weather-grass	0.7	0.2
Dianella revoluta	Black-anther Flax-lily	41.8	15.6
Dianella longifolia	Pale Flax-lily	40.4	12.9
Tricoryne elatior	Yellow Rush Lily	8.9	2.5
Caesia calliantha	Blue Grass-lily		
Athropodium minus	Small Vanilla-lily	3.4	1.0
Arthropodium strictum	Chocolate Lily	0.7	0.2
Arhtropodium fimbriatum	Nodding Chocolate-lily	1.3	1.5
Bulbine bulbosa	Bulbine Lily	2.7	0.8
Wurmbea diocia	Early Nancy	1.4	0.4
Wurmbea latifolia?	Broad-leaf Early Nancy		
Xanthorrhoeaceae			
Lomandra multiflora	Many-flowered Mat-rush	19.2	5.8
Lomandra effusa	Scented Mat-rush	12.3	4.2
Lomandra filiformis	Wattle Mat-rush	31.5	9.4
DICOTYLEDONS			
Casuarinaneae			
Allocasuarina luehmannii	Buloke	20.5	11.5
Allocasuarina verticillata	Drooping She-oak	0.7	0.2
Loranthaceaea			
Amyema miquelii	Box Mistletoe	3.4	1.2
Muellerina eucalyptoides	Creeping Mistletoe	1.4	0.4
Polygonaceae			
Muehlenbeckia florulenta	Tangled Lignum	26.7	28.1
Persicaria decipiens	Slender Knotweed	5.5	2.1
Persicaria prostrata	Creeping Knotweed	5.5	1.5
Persicaria hydropiper	Waterpepper	6.2	2.3

Polygonum plebeium	Small Knotweed	0.7	0.2
Rumex brownii	Slender Dock	47.3	13.3
Rumex crystallinus	Shiny Dock	15.1	4.4
Rumex dumosus	Wiry Dock	3.4	1.0
Rumex tenax	Narrow-leaf Dock	11.0	3.3
Chenopodiaceae			
Atriplex semibaccata	Creeping Saltbush	14.4	5.0
Atriplex spinibractea	Spiny-fruit Saltbush	1.4	0.6
Sclerolaena muricata	Five-spined Bassia	19.9	6.5
Chenopodium desertorum microphyllum	Frosted Goosefoot	19.2	6.2
Chenopodium pumilio	Small Crumbweed	0.7	0.2
Enchylaena tomentosa	Ruby Saltbush	3.4	1.2
Maireana aphylla	Leafless Bluebush	0.7	0.2
Maireana decalvans	Black Cottonbush	11.0	3.8
Maireana enchylaenoides	Wingless Fissure-weed	50.0	15.0
Maireana humillima	Dwarf Bluebush	8.2	2.7
Maireana pentagona	Slender Fissure-weed	3.4	1.0
Einadia nutans	Climbing Saltbush	32.2	9.8
Salsola kali	Buckbush	4.8	1.3
Amaranthaceae			
Alternanthera denticulata	Lesser Joyweed	37.8	11.5
Alternanthera nodiflora	Common Joyweed	38.4	13.7
Ptilotus exaltatus	Lambs Tails	4.1	1.2
Ptilotus spathulatus	Pussy-tails	6.1	1.7
Nyctaginaceae			
Boerhavia dominii	Tar Vine	9.6	2.9
Portulacaceae			
Portulaca oleracea	Common Purslane	5.5	1.9
Ranunculaceae			
Myosurus minimus	Mouse-tail	2.1	0.6
Ranunculus inundatus	River Buttercup	2.1	0.6
Ranunculus pumilio	Ferny Buttercup	10.3	3.1
Ranunculus sessiliflorus	Small-flowered Buttercup	2.1	0.6
Brassicaceae			
Menkea australis	Fat Spectacles	0.7	0.2
Rorippa laciniata	Perennial Marsh Cress	13.7	3.9
Cardamine paucijuga	Bitter Cress	6.8	1.9
Droseraceae			
Drosera glanduligera	Scarlet Sundew	0.7	0.2
Drosera peltata peltata	Pale Sundew	0.7	0.2

Crassulaceae			
Crassula colorata	Dense Stonecrop	2.1	0.6
Crassula helmsii	Swamp Stonecrop	0.7	0.2
Crassula peduncularis	Purple Stonecrop	0.7	0.2
Crassula sieberiana	Austral Stonecrop	0.7	0.2
Pittosporaceae			
Bursaria spinosa	Sweet Bursaria	30.8	19.2
Pittosporum phylliraeoides	Weeping Pittosporum	12.3	5.0
Rosaceae			
Acaena ovina	Australian Sheeps-burr	0.7	0.2
Mimosaceae			
Acacia acinacea	Gold-dust Wattle	34.9	20.4
Acacia brachybotrya	Grey Mulga	0.0	0.8
Acacia calamifolia	Wallowa	0.7	0.2
Acacia dealbata	Silver Wattle		
Acacia hakeoides	Hakea Wattle	1.4	0.8
Acacia implexa	Lightwood	0.7	1.3
Acacia montana	Mallee Wattle	29.5	16.7
Acacia notabilis	Mallee Golden Wattle	0.7	0.2
Acacia pycnantha	Golden Wattle	27.4	14.4
Acacia verniciflua	Varnish Wattle	0.0	0.2
Senna artemisioides	Desert Cassia	4.8	2.1
Fabaceae			
Desmodium varians	Slender Tick-trefoil	2.7	0.8
Dillwynia cinerascens	Grey Parrot-pea	6.2	3.3
Eutaxia diffusa	Spreading Eutaxia	11.6	4.6
Eutaxia microphylla	Common Eutaxia	13.0	4.6
Glycine clandestina	Twining Glycine	2.1	0.6
Glycine tabacina	Variable Glycine	25.3	10.0
Lotus australis	Australian Trefoil	0.7	0.2
Lotus cruentus	Red-flowered Trefoil	0.7	0.2
Psoralea tenax	Tough Psoralea	1.4	0.4
Psoralea parva	Small Psoralea	3.4	1.0
Pultenaea largiflorens	Twiggy Bush-pea	2.1	1.3
Swainsona procumbens	Broughtons Pea	18.5	6.0
Templetonia stenophylla	Leafy Templetonia	17.1	5.2
Geraniaceae			
Erodium crinitum	Blue Crowfoot	1.4	0.4
Geranium retrorsum	Common Cranesbill	2.7	0.8
Geranium solanderi	Australian Cranesbill	1.4	0.4
Oxalidaceae			
Oxalis perennans	Perennial Wood-sorrel	65.1	18.3
Linaceae			
Linum marginale	Native Flax	2.7	0.8
Euphorbiaceae			
Chamaescyce drummondii	Caustic Weed	43.2	12.1
Callitrichaceae			
Callitriche sonderi	Starwort	1.4	0.4

Stackhousiaceae			
Stackhousia monogyna	Creamy Candles	2.1	0.6
Sapindaceae			
Dodonaea viscosa cuneata	Wedge-leaf Hopbush	3.4	1.0
Malvaceae			
Sida corrugata	Corrugated Sida	62.3	20.4
Sida humillima	Sida	27.4	8.3
Sida fibulifera	Pin Sida	0.7	0.2
Dilleniaceae			
Hibbertia sericea	Silky Guinea-flower	0.7	0.2
Hypericaceae			
Hypericum gramineum	Small St John's Wort	0.7	0.2
Elatinaceae			
Elatine gratioloides	Waterwort	2.1	0.6
Thymelaeaceae			
Pimelea curviflora	Curved Rice-flower	32.2	10.0
Lythraceae			
Lythrum hyssopifolia	Hyssop Loosestrife	3.4	1.0
Myrtaceae			
Kunzea parvifolia	Violet Kunzea	0.7	0.2
Eucalyptus albens	White Box	2.1	0.8
Eucalyptus blakelyi	Blakely's Red Gum	3.4	1.2
Eucalyptus camaldulensis	River Red Gum	74.0	88.3
Eucalyptus largiflorens	Black Box	11.0	5.4
Eucalyptus melliodora	Yellow Box	26.0	24.8
Eucalyptus microcarpa	Grey Box	80.1	85.4
Onagraceae			
Epilobium billardierianum	Willow-herb	8.2	2.3
Epilobium hirtigerum	Hoary Willow-herb	1.4	0.4
Ludwigia peploides	Water Primrose	3.4	1.0
Haloragaceae			
Haloragis aspera	Rough Raspwort	34.2	11.9
Haloragis glauca	Grey Raspwort	10.3	2.9
Myriophyllum crispatum	Water-milfoil	2.1	0.6
Myriophyllum glomeratum	Water-milfoil	0.7	0.2
Myriophyllum gracile	Water-milfoil	0.7	0.2
Myriophyllum papillosum	Water-milfoil	0.7	0.2
Myriophyllum variifolium	Water-milfoil	0.7	0.2
Myriophyllum verrucosum	Red Water-milfoil	0.7	0.2
Apiaceae			
Eryngium ovinum	Blue Devil	30.1	10.8
Hydrocotyle laxiflora	Stinking Pennywort	2.1	0.6
Menyanthaceae			
Nymphoides crenata	Wavy Marshwort	2.1	1.3

Convolvulaceae			
Convolvulus erubescens	Australian Bindweed	45.9	14.2
Dichondra repens	Kidneyweed	20.5	6.3
Boraginaceae			
Cynoglossum suaveolens	Sweet Hound's-tongue	13.0	4.6
Lamiaceae			
Mentha satureoides	Native Pennyroyal	35.6	12.3
Teucrium racemosum	Grey Germander	39.7	12.5
Solanaceae			
Solanum esuriale	Quena	12.3	3.8
Scrophulariaceae			
Glossostigma elatinoides	Small Mudmat	1.4	0.4
Limosella australis	Australian Mudwort	1.4	0.4
Limosella curdieana	Large Mudwort	2.7	1.0
Mimulus gracilis	Slender Monkey-flower	7.5	2.3
Lentibulariaceae			
Utricularia dichotoma	Fairies Aprons	0.7	0.2
Myoporaceae			
Eremophila longifolia	Berrigan	2.1	1.0
Myoporum montanum	Waterbush	3.4	1.5
Plantaginaceae			
Plantago gaudichaudii	Narrow-leaf Plantain	8.2	1.7
Plantago varia	Variable Plantain	14.4	4.0
Rubiaceae			
Asperula conferta	Common Woodruff	41.1	13.3
Campanulaceae			
Wahlenbergia communis	Tufted Bluebell	40.4	11.5
Wahlenbergia fluminalis	River Bluebell	16.4	5.0
Wahlenbergia gracilis	Australian Bluebell	4.1	1.2
Wahlenbergia luteola	Bluebell	11.0	3.1
Wahlenbergia multicaulis	Tadgell's Bluebell	0.7	0.2
Wahlenbergia litticola	Bluebell	0.7	0.2
Wahlenbergia gracilenta	Annual Bluebell	2.7	0.8
Lobeliaceae			
Isotoma fluviatilis	Swamp Isotome	8.2	2.3
Lobelia pratioides	Poison Lobelia	0.7	0.2
Pratia concolor	Poison Pratia	37.7	12.1
Goodeniaceae			
Goodenia fascicularis	Silky Goodenia	6.2	1.3
Goodenia glauca	Pale Goodenia	3.4	1.0
Goodenia gracilis	Slender Goodenia	25.3	9.2
Goodenia heteromera	Spreading Goodenia	2.7	0.8
Goodenia pinnatifida	Cut-leaf Goodenia	8.2	2.7
Velleia paradoxa	Spur Velleia	1.4	0.4

Asteraceae			
Minuria integerrima	Smooth Minuria	8.2	2.9
Minuria leptophylla	Minnie Daisy	2.1	0.6
Brachyscome basaltica	Swamp Daisy	28.8	8.8
Brachyscome chrysoglossa	Yellow-tongue Daisy	0.7	0.4
Brachyscome ciliari	Variable Daisy	20.5	6.3
Calotis hispidula	Bogan Flea	0.7	0.2
Calotis lappulacea	Yellow Burr-daisy	2.7	0.8
Calotis scabiosifolia	Rough Burr-daisy	2.4	0.8
Calotis scapigera	Tufted Burr-daisy	24.0	11.3
Calotis cuneifolia	Purple Burr-daisy	4.8	1.5
Calotis anthemoides	Cut-leaf Burr-daisy	22.6	8.3
Solenogyne dominii	Solenogyne	21.2	6.0
Vittadinia cervicularis	New Holland Daisy	8.2	2.7
Vittadinia cuneata	New Holland Daisy	24.0	6.9
Vittadinia gracilis	Woolly New Holland Daisy	26.0	7.5
Eclipta platyglossa	Yellow Twin-heads	41.8	13.1
Sigesbeckia orientalis	Indian Weed	0.7	0.2
Cotula australis	Common Cotula	4.1	1.3
Centipeda cunninghamii	Common Sneeze-weed	30.8	8.8
Cotula minima	Spreading Sneeze-weed	6.8	1.9
Isoetopsis graminifolia	Grass Cushions	0.7	0.2
Myriocephalus rhizocephalus	Woolly Heads	0.7	0.2
Senecio quadridentatus	Cotton Fireweed	4.1	1.3
Senecio runcinifolius	Tall Groundsel	2.7	0.8
Senecio tenuiflorus	Groundsel	2.1	0.6
Cymbonotus pressianus	Australian Bear's Ear	2.1	0.6
Euchiton sphaericus	Japanese Cudweed	13.7	2.7
Euchiton involucratus	Common Cudweed	2.7	0.8
Gnaphalium indutum	Tiny Cudweed	2.7	0.8
Pseudognaphalium luteoalbum	Jersey Cudweed	19.9	5.7
Cassinia arcuata	Drooping Cassinia	6.8	2.1
Cassinia aculeata	Dogwood	0.7	0.2
Rhodanthe corymbiflora	Grey Sunray	2.1	0.6
Triptilodyscus pygmaeus	Common Sunray	0.7	0.2
Bracteantha sp.	Everlasting sp.	1.4	0.4
Chrysocephalum apiculatum	Common Everlasting	5.5	1.5
Chrysocephalum semipapposum	Clustered Everlasting	4.8	1.5
Ixiolena sp.	Woolly Plover-daisy	4.1	1.2
Leptorhynchos squamatus	Scaly Buttons	9.6	3.3
Leptorhynchos tenuifolius	Wiry Buttons	1.4	0.4
Calocephalus citreus	Lemon Beauty-heads	37.0	12.9
Pycnosaurus globosa	Drumsticks	8.2	3.8
Pycnosaurus glauca	Common Billy Buttons	2.7	1.3
Pycnosaurus chrysantha	Golden Billy Buttons	0.7	0.2
Microseris scapigera	Yam Daisy	1.4	0.4

Appendix 4. Bird species recorded along the creeks. (sample = 126 bird lists)

	Frequency of sites	**%**	**Status**	**Woodland species (W)**
Emu	1	0.8	Declining	W
Brown Quail	2	1.6	Declining	

Plumed Whistling Duck	1	0.8			
Black Swan	4	3.2			
Australian Shelduck	3	2.4			
Wood Duck	31	24.6			
Grey Teal	12	9.5			
Chestnut Teal	1	0.8			
Pacific Black Duck	49	38.9			
Australasian Shoveler	1	0.8			
Hardhead	1	0.8			
Hoary-headed Grebe	1	0.8			
Great Crested Grebe	1	0.8			
Darter	5	4.0	Restricted Breeder		
Little Pied Cormorant	8	6.3			
Little Black Cormorant	3	2.4			
Great Cormorant	4	3.2			
Australian Pelican	15	11.9	Restricted Breeder		
White-faced Heron	23	18.3			
Intermediate Egret	1	0.8	Restricted Breeder		
White-necked Heron	6	4.8			
Great Egret	7	5.6	Restricted Breeder		
Nankeen Night Heron	9	7.1	Restricted Breeder		
Australian White Ibis	13	10.3			
Straw-necked Ibis	1	0.8			
Royal Spoonbill	1	0.8	Restricted Breeder		
Yellow-billed Spoonbill	10	7.9			
Black-shouldered Kite	1	0.8			
Black Kite	1	0.8			
Whistling Kite	10	7.9	Declining	W	
White-bellied Sea Eagle	1	0.8	Rare		
Swamp Harrier	5	4.0			
Spotted Harrier	2	1.6			
Brown Goshawk	5	4.0			
Wedge-tailed Eagle	9	7.1	Declining	W	
Little Eagle	1	0.8			
Brown Falcon	7	5.6			
Australian Hobby	2	1.6			
Peregrine Falcon	6	4.8			
Brolga	3	2.4	Rare		
Purple Swamphen	22	17.5			
Dusky Moorhen	9	7.1			
Black-tailed Native-hen	3	2.4			
Eurasian Coot	1	0.8			
Painted Button-quail	3	2.4	Declining	W	
Red-chested Button-quail	1	0.8	Insufficiently Known		
Latham's Snipe	3	2.4			
Bush Stone-curlew	5	4.0	Vulnerable	W	
Black-winged Stilt	1	0.8			
Red-kneed Dotterel	1	0.8			
Black-fronted Dotterel	2	1.6			
Masked Lapwing	6	4.8			
Whiskered Tern	1	0.8	Restricted Breeder		
Common Bronzewing	6	4.8		W	
Crested Pigeon	35	27.8			
Peaceful Dove	12	9.5		W	
Galah	62	49.2			
Sulphur-crested Cockatoo	19	15.1			
Little Corella	2	1.6			

Long-billed Corella	7	5.6				
Cockatiel	2	1.6				
Musk Lorikeet	2	1.6			W	
Little Lorikeet	6	4.8	Declining		W	
Purple-crowned Lorikeet	3	2.4			W	
Superb Parrot	2	1.6		Vulnerable		W
Crimson Rosella	14	11.1				W
Eastern Rosella	44	34.9				
Red-rumped Parrot	93	73.8				
Blue-winged Parrot	1	0.8		Declining		
Swift Parrot	3	2.4		Endangered		W
Fan-tailed Cuckoo	5	4.0				W
Shining Bronze-Cuckoo	2	1.6				W
Horsfield's Bronze-Cuckoo	10	7.9				W
Barn Owl	1	0.8				
Southern Boobook	9	7.1				W
Barking Owl	1	0.8		Rare		W
Tawny Frogmouth	7	5.6		Declining		
Australian Owlet-nightjar	1	0.8	Declining		W	
Azure Kingfisher	2	1.6		Declining		W
Laughing Kookaburra	65	51.6				
Red-backed Kingfisher	1	0.8				
Sacred Kingfisher	23	18.3				W
Rainbow Bee-eater	9	7.1				
Dollarbird	3	2.4				W
White-throated Treecreeper	20	15.9				W
Brown Treecreeper	89	70.6				W
Superb Fairy-wren	27	21.4				
Spotted Pardalote	2	1.6				W
Striated Pardalote	114	90.5				
White-browed Scrubwren	4	3.2				W
Buff-rumped Thornbill	5	4.0			W	
Yellow-rumped Thornbill	25	19.8				
Yellow Thornbill	13	10.3				W
Striated Thornbill	6	4.8			W	
Weebill	17	13.5			W	
Western Gerygone	11	8.7				W
Fuscous Honeyeater	1	0.8				W
White-plumed Honeyeater	108	85.7				W
White-naped Honeyeater	5	4.0				W
Black-chinned Honeyeater	17	13.5		Declining		W
Brown-headed Honeyeater	18	14.3				W
Little Friarbird	22	17.5				W
Noisy Friarbird	7	5.6				W
Blue-faced Honeyeater	2	1.6		Declining		W
Noisy Miner	73	57.9				
Red Wattlebird	5	4.0				W
Jacky Winter	18	14.3		Declining		W
Scarlet Robin	3	2.4				W
Red-capped Robin	4	3.2		Declining		W
Flame Robin	3	2.4				
Varied Sittella	7	5.6				W
Crested Shrike-tit	29	23.0				W
Golden Whistler	15	11.9				W
Rufous Whistler	12	9.5				W
Grey Shrike-thrush	46	36.5				W
Restless Flycatcher	57	45.2				

Magpie-lark	78	61.9			
Willie Wagtail	86	68.3			
Grey Fantail	16	12.7			W
Black-faced Cuckoo-shrike	54	42.9			
White-bellied Cuckoo-shrike	1	0.8	Declining		W
White-winged Triller	2	1.6			W
Olive-backed Oriole	14	11.1			W
White-breasted Woodswallow	1	0.8			
White-browed Woodswallow	17	13.5			
Black-faced Woodswallow	1	0.8			
Dusky Woodswallow	31	24.6			W
Grey Butcherbird	1	0.8			
Pied Butcherbird	8	6.3			
Australian Magpie	84	66.7			
Pied Currawong	12	9.5			
Australian Raven	55	43.7			
Little Raven	29	23.0			
White-winged Chough	30	23.8			W
Singing Bushlark	1	0.8			
Richard’s Pipit	2	1.6			
House Sparrow	25	19.8			
Diamond Firetail	3	2.4	Declining		W
Red-browed Firetail	2	1.6			
Zebra Finch	3	2.4			
European Goldfinch	4	3.2			
Mistletoebird	2	1.6			W
Welcome Swallow	66	52.4			
Tree Martin	52	41.3			W
Fairy Martin	8	6.3			
Clamorous Reed-Warbler	15	11.9			
Little Grassbird	2	1.6			
Rufous Songlark	33	26.2			
Brown Songlark	2	0.8			
Golden-headed Cisticola	2	1.6			
Silvereye	1	0.8			
Common Blackbird	5	4.0			
Common Starling	82	65.1			

Appendix 5 Frequency occurrence of selected woodland-dependent bird species in large woodland patches at each end of the creeks system and in creek sections of different widths. Figures represent the % of all lists made in a creek section-width category for which a species was present. The total number of lists made for every size-width category are given below.

	Barmah Forest	Creek > 200 m	Creek 100-200	Creek 50-100< 50	Creek	Reef Hills/ Mt Meg
Number of samples	7	33	19	35	32	2
<u>Species</u>						
Emu	14.0					
Wedge-tailed Eagle	14.0	9.0	10.5	11.4		50.0
Painted Button-quail	14.0	6.0	3.0			50.0
Peaceful Dove	43.0		10.5	11.4	12.5	50.0
Common Bronzewing	14.0	6.0	16.0	3.0		50.0
Fan-tailed Cuckoo	57.0	3.0				
Southern Boobook	43.0	9.0	5.0	3.0	3.0	
White-bellied Cuckoo-shrike	14.0					50.0
Red-capped Robin	43.0	6.0				
Jacky Winter	57.0	24.0	5.0	11.0	6.0	50.0
Grey Shrike-thrush	100	39.0	32.0	34.0	25.0	100.0
Crested Shrike-tit	29.0	33.3	21.0	26.0	9.0	50.0
Grey Fantail	86.0	15.2		6.0	6.0	100.0
White-browed Babbler	14.0					50.0
Western Gerygone	71.0	12.0		3.0	3.0	50.0
Buff-rumped Thornbill	57.0				3.0	50.0
Weebill	86.0	18.0		6.0	9.0	
Varied Sittella	29.0	12.0	5.0			100.0
Brown Treecreeper	100	73.0	53.0	66.0	56.0	50.0
White-throated Treecreeper	100	9.0		9.0	19.0	50.0
Spotted Pardalote	29.0		5.0			100.0

Appendix 6 Frequency occurrence of various land-use, water-use and recreational activities along the creeks system. For an explanation of the variables, see Appendix 1.

Land-use activity	no. of sites	%
General land-use issues		
1. Road access along the creeks system		
None	261	55.4
Track	71	15.1
Minor road	101	21.4
Major road	38	8.1
2. Accessibility		
Yes	233	51.5
No	219	48.5
3. Appropriation		
None	228	50.4
Part	67	14.8
All	157	34.8
4. Licenced for grazing		
None	244	54.1
Part	40	8.9
All	167	37.0
5. Fenced from stock		
None	141	29.9
Part	110	23.4
All	220	46.7
6. Fenced from vehicles		
None	172	36.5
Part	36	7.6
All	263	55.8
Stock-grazing issues		
1. Past Grazing Levels		
None	13	2.8
Some	101	21.4
Much	357	75.8
2. Current Grazing Levels		
None	87	18.5
Some	198	42.0
Much	186	39.5
3. Grazing by travelling stock		
None	304	64.8
Little	63	13.4

Some	93	19.8
Much	9	1.9
4. Provision of feed for stock on frontages		
None	409	88.0
Some	54	11.6
Much	2	0.4
5. Overall Grazing Index		
0	3	0.6
1	5	1.1
2	17	3.6
3	34	7.2
4	105	22.3
5	145	30.8
6	162	34.4

Soil-disturbance issues

1. Soil excavation		
None	240	51.1
Some	140	29.8
Much	90	19.1
2. Soil dumping		
None	238	50.6
Some	135	28.7
Much	97	20.6
3. Soil moving		
None	269	57.2
Some	117	24.9
Much	84	17.9
4. Cultivation		
None	336	72.3
Some	69	14.8
Much	60	12.9
5. Use of off-track vehicles		
None	88	19.1
Some	220	47.7
Much	153	33.2
6. Table-drains on frontage		
None	369	78.5
Some	80	17.0
Many	21	4.5
7. Soil-disturbance index		
None	86	18.2
Some	177	37.6
Much	208	44.2

Water-use issues

1. Weirs or other impoundments		
None	413	90.2
Some	45	9.8
2. Levees on frontage		
None	368	79.8
Some	93	20.2
3. Drains into creek		
None	245	57.5
Some	181	42.5
4. Channels out of creek		
None	366	81.7
Some	82	18.3
5. Pumplines out of creek		
None	285	65.4
Some	151	34.6
6. Pump-sheds on frontage		
None	379	81.7
Some	85	18.3
7. Dams		
None	382	81.8
Some	85	18.2

Pest plant and animal issues

1. Abundance of animal pests		
None	261	66.8
Some	91	23.3
Many	39	9.9
2. Abundance of weed species requiring management		
None	83	17.7
Some	223	47.5
Much	163	34.8
3. Abundance of weed trees and shrubs		
None	234	50.4
Some	182	39.2
Many	48	10.3

Human-use issues

1. Sheds or other buildings on frontage		
None	438	93.4
Some	31	6.6
2. Internal fencing within frontage		
None	272	59.0
Some	189	41.0

3. Bardi-grubbing		
None	312	72.9
Some	78	18.2
Much	38	8.9
4. Firewood collecting		
None	58	13.0
Some	197	44.3
Much	190	42.7
5. Rubbish-dumping		
None	122	27.2
Some	249	55.4
Much	78	17.4
6. Tree-burning		
None	433	94.7
Some	11	2.4
Much	13	2.9
7. Fishing		
None	127	39.2
Some	148	45.7
Much	49	15.1
8. Duck-shooting		
None	147	44.5
Some	144	43.6
Much	39	11.8
9. Camping		
None	266	73.9
Some	79	21.9
Much	15	4.2