Australian Capital Territory

Nature Conservation (Ginini Flats Wetland Complex Ramsar Site) Management Plan 2017

Disallowable instrument DI2017–36

made under the

Nature Conservation Act 2014, section 198 (Draft Ramsar wetland management plan—Minister's approval and notification)

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1 Name of instrument

This instrument is the *Nature Conservation (Ginini Flats Wetland Complex Ramsar Site) Management Plan 2017*.

2 Commencement

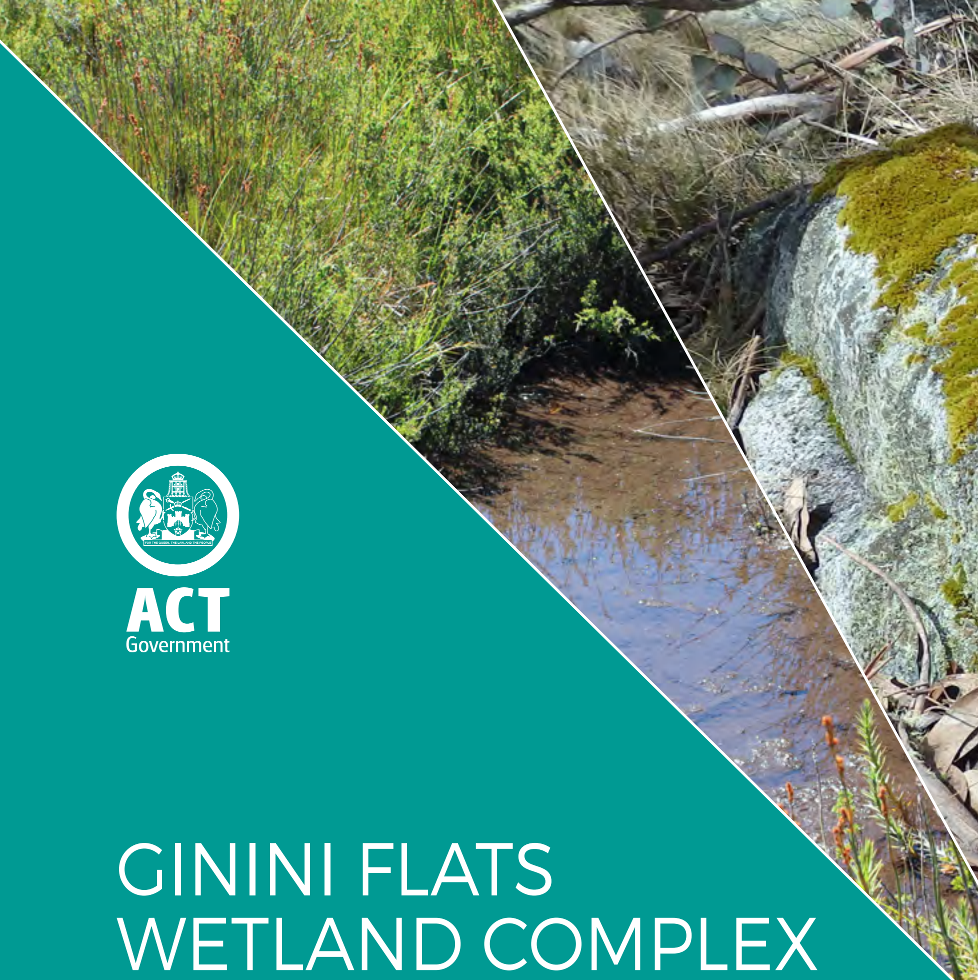
This instrument commences on the day after its notification day.

3 Approval and notification of Ramsar wetland management plan

Under section 197(a) of the *Nature Conservation Act 2014,* I approved the draft Ramsar wetland management plan entitled 'Ginini Flats Wetland Complex Ramsar Site Management Plan' included in the schedule.

Mick Gentleman
Minister for the Environment and Heritage
31 March 2017

Schedule
(see s3)



ACT Government

GININI FLATS WETLAND COMPLEX RAMSAR SITE **MANAGEMENT PLAN**

JANUARY 2017

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EXECUTIVE SUMMARY

The Ginini Flats Wetland Complex Ramsar Site (Ginini Flats Wetland Complex) was designated as a wetland of international importance under the Ramsar Convention in 1996. The Environment Protection and Biodiversity Conservation Regulations 2000 set out principles for best practice management planning for Ramsar wetlands. These principles include review of management plans at intervals of not less than seven years. This management plan replaces the original plan of management for the site (Environment ACT 2001).

Ginini Flats lies at the head of Ginini Creek near the crest of the Brindabella Range on the north-eastern summit slopes of Mount Ginini, about 800 metres east of the ACT–NSW border, within Namadgi National Park. The Ramsar site is a mosaic of subalpine *Sphagnum* bogs and associated fens, wet heath, wet grassland communities and surrounding Snow Gum woodland that occurs across a series of interconnected wetlands known as West Ginini, East Ginini and Cheyenne Flats within Namadgi National Park.

The site is at the northern extreme of the climatic range for alpine *Sphagnum* bog wetlands, and is the largest intact bog and fen community in the Australian Alps. The site also provides habitat for migratory birds listed under several international migratory bird agreements (JAMBA, CAMBA and ROKAMBA).

Ginini Flats Wetland Complex is within a National Park and at the top of the catchment and is therefore protected from many developmental and upper catchment impacts. However, alpine and subalpine vegetation is particularly susceptible to environmental change, particularly the Alpine *Sphagnum* Bogs and Associated Fens ecological community. Some of the likely threats or threatening activities for this site include fire, climate change, pest animals and weeds, and infrastructure, development and recreation impact.

The management plan sets management guidelines and objectives for the Ginini Flats Wetland Complex, and provides detail on management actions that are to be carried out to manage the site and avoid or minimise the impact of threats. Actions under each objective relate to the following:

- Fire management
- Managing hydrological changes
- Protection and rehabilitation of peatland
- Invasive species management
- Recreation and visitor management
- Infrastructure changes
- Climate change
- Research and monitoring.

1. BACKGROUND

1.1 INTRODUCTION

The Ginini Flats Wetland Complex was designated as a wetland of international importance under the Ramsar Convention in 1996. The Ramsar Convention, an international intergovernmental treaty adopted in the Iranian city of Ramsar in 1971, came into force in 1975. The broad aims of the Ramsar Convention are to halt and, where possible, reverse the worldwide loss of wetlands and to conserve those that remain through 'wise use' and management. The Ramsar Convention defines the wise use of wetlands as 'the maintenance of their ecological character, achieved through the implementation of ecosystem approaches'.

Australia was one of the first countries to become a Contracting Party to the Ramsar Convention. The Environment Protection and Biodiversity Conservation Regulations (the EPBC Act Regulations) Schedule 6—Australian Ramsar management principles, sets out guidelines for best practice management planning to maintain the ecological character of Ramsar wetlands. These principles include review of management plans at intervals of not less than seven years.

Under new provisions of the ACT *Nature Conservation Act 2014* (the NC Act), the Conservator of Fauna and Flora (the Conservator) must report to the Minister about each Ramsar wetland management plan at least once every five years. The original non-statutory plan of management for the site commenced in 2001 (ACT Government 2001). The Conservator must undertake public consultation on a draft Ramsar management plan for six weeks under section 195 of the NC Act. Following public consultation the conservator must consider the submissions received, make any revisions considered appropriate and prepare a final version of the draft management plan. The conservator must then submit the draft plan to the Minister for approval.

The Ramsar site is a mosaic of subalpine *Sphagnum* bogs and associated fens, wet heath, wet grassland communities and surrounding Snow Gum woodland that occurs across a series of interconnected wetlands. The largely intact *Sphagnum* bogs and fens on the site forms part of the nationally significant 'Alpine *Sphagnum* bogs and associated fens' ecological community, and is the main reason for its listing as a Ramsar site. Mackey, Jacobs and Hugh (2015, p.195) describe Alpine *Sphagnum* Bogs and fens as follows:

> "Alpine *Sphagnum* Bogs and associated Fens occur in waterlogged and permanently wet treeless areas, such as along streams, drainage lines, valley edges and valley floors generally between 1200m to 1800m ASL. They differ from Wet Heathland and Sedgeland in that they contain *Sphagnum* spp. (which is typically underlain by peat), the most common of which is *Sphagnum cristatum*, along with a diversity of sedges, herbs and shrubs. Species commonly include *Empodisma minus*, Epacris glacialis, E. paludosa, *Baeckea gunniana*, B. utilis, Pratia surrepens & *Richea continentis*. Fens adjoin the bog and are devoid of woody vegetation, commonly dominated by sedges such as *Carex gaudichaudiana*".

1.2 PURPOSE AND SCOPE

The key desired outcome of this and subsequent management plans is that the Ginini Flats Wetland Complex is conserved as a sustainable natural ecosystem, providing ecosystem services and habitat for the native plants and animals that are representative of the community, in perpetuity. It also aims to protect the cultural heritage significance and values that are associated with the site.

The Ginini Flats Wetland Complex occurs entirely within Namadgi National Park, which is Public Land (National Park) under the *ACT Planning and Development Act 2007* (P&D Act) as defined in the Territory Plan (ACT Government, 2008a). Schedule 3 of the P&D Act sets out management objectives for the categories of Public Land in which the wetland complex occurs as:

» to conserve the natural environment and

» to provide for public use of the area for recreation, education and research.

Although the Namadgi National Park Plan of Management 2010 (Namadgi National Park PoM) (ACT Government 2010) applies to the area in which the Ramsar site occurs, it does not provide detailed management actions for the site. Namadgi National Park is managed for biodiversity conservation, water supply, appropriate recreation, natural and cultural heritage conservation, visual character, research and education. The wetland occurs in Zone 1 of the Namadgi National Park management zones (Namadgi National Park PoM p. 225). This is the Remote Zone, the core conservation and catchment area that includes the Bimberi Wilderness and the Middle Cotter Catchment and adjacent areas.

This management plan sets strategic management guidelines and objectives for the Ginini Flats Wetland Complex Ramsar Site (Ginini Flats Wetland Complex) and provides detail on management actions that are to be carried out to conserve the wetland and avoid or minimise the impact of threats. It fulfils part of the ACT Government obligations under the Ramsar Convention for the Ginini Flats Wetland Complex, as prescribed in the EPBC Regulations 2000, and also meets the requirements of the ACT *Nature Conservation Act 2014*. The ecological integrity of the Ramsar site will be conserved by delivering the management objectives and actions of this management plan.

In prioritising works to address threats in all the *Sphagnum* bogs and fens within Namadgi National Park , the Ginini Flats Wetland Complex have the highest overall priority; for example, in responding to widespread wildfire, the Ginini Flats Wetland Complex will be the highest priority for preventing fire entering bogs and fens.

This plan replaces the Ginini Flats Wetlands Ramsar Site Plan of Management 2001 (ACT Government 2001).

1.3 OUTLINE OF MANAGEMENT PLAN

This management plan:

» describes the biophysical and cultural values of the Ginini Flats Wetland Complex, including an ecological character description

» describes the current and future threats to the site

» defines the broad management approach to be taken to conserve the site and protect it from threats

» defines objectives and management actions to be applied.

This management plan follows the format recommended by *Ramsar Handbook 18—Managing wetlands* (Ramsar 2010) (See Appendix 1).

1.4 KEY OBJECTIVES OF THIS MANAGEMENT PLAN

This management plan provides a framework to:

A. maintain, enhance and restore the ecological character of the Ginini Flats Wetland Complex through informed and appropriate management practices

B. ensure the biodiversity, ecosystems and habitats of the wetland complex are conserved and protected in perpetuity.

1.5 POLICY AND LEGISLATIVE FRAMEWORK

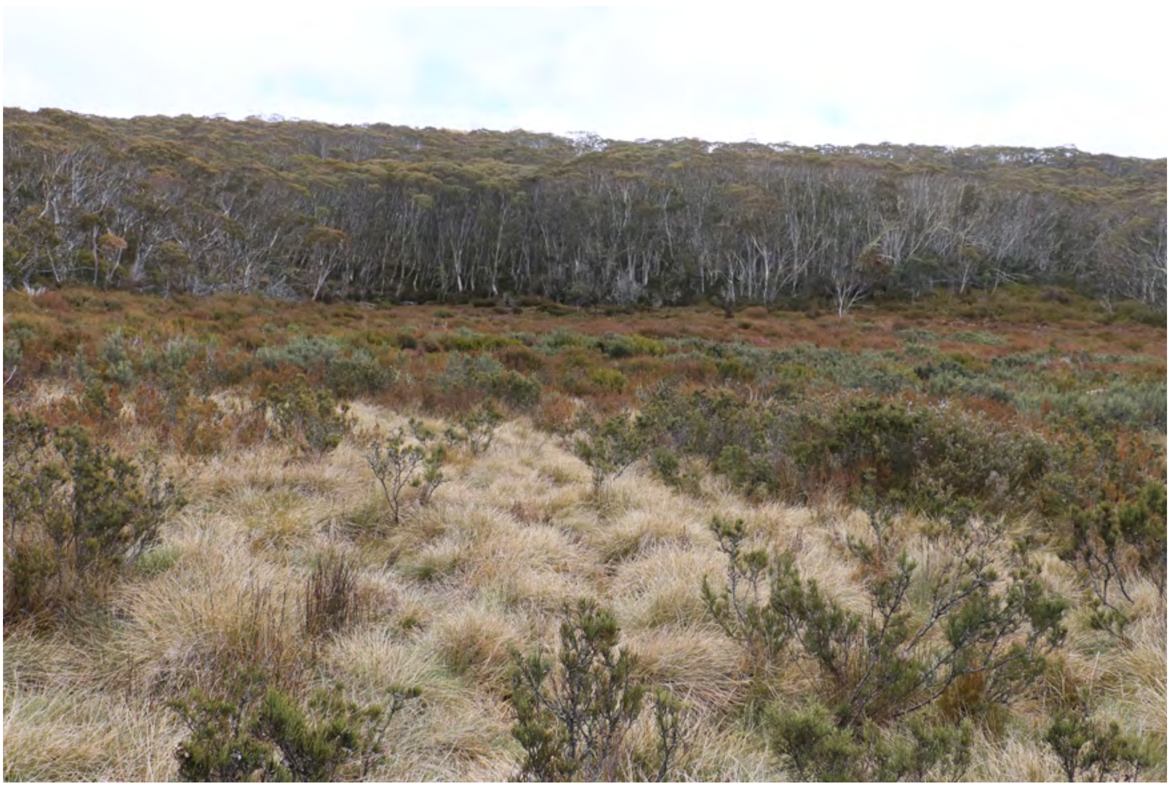
The Ginini Flats Wetland Complex is situated in Namadgi National Park and managed as part of the ACT conservation estate. The management of Namadgi National Park is underpinned or influenced by a wide range of legislation, agreements and government planning and policy documents (ACT Government, 2010), including international and national agreements, Commonwealth and ACT legislation, plans and policies. The Namadgi National Park Plan of Management (2010, sections 2.1–2.3) provides further details of these.

In addition to its management under the Namadgi National Park Plan of Management, a hierarchy of legislation, regulations and policy ranging from international treaties, such as the Ramsar Convention, to supporting Commonwealth and Territory legislation such as the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and ACT *Nature conservation Act 2014* is relevant to the management of the Ginini Flats Wetland Complex. A comprehensive listing and description of these policies and legislation can be found in Appendix B.

This management plan aims to integrate these legislative obligations, policy directions, agreements and guidelines to ensure the values of the Ramsar site are conserved.

1.6 CRITERIA MET FOR RAMSAR LISTING

To be designated a Wetland of International Importance, a wetland has to meet at least one of the 'Criteria for Identifying Wetlands of International Importance'. The Ginini Flats Wetland Complex meets the following Ramsar criteria (Wild et al. 2010):



Ramsar Criteria	Justification
Criterion 1: A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near natural wetland type found within the appropriate biogeographic region.	The Alpine *Sphagnum* Bogs and Associated Fens ecological community has a limited geographic distribution nationally. The Ginini Flats Wetland Complex is recognised as a significant example of this wetland type because it is situated at the northern extreme of the climatic range for *Sphagnum* bog wetlands within the Murray–Darling Drainage Division.
Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.	The Ginini Flats Wetland Complex supports a nationally threatened ecological community: the Alpine *Sphagnum* Bogs and Associated Fens ecological community is listed as endangered under the EPBC Act. It also supports two nationally listed threatened animal species; the Northern Corroboree Frog (*Pseudophryne pengilleyi*) is listed as Critically Endangered and the Broad-toothed Rat is listed as vulnerable under the EPBC Act.
Criterion 3: A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.	The Ginini Flats Wetland Complex is at the northern biophysical limit of this habitat type within the Murray–Darling Drainage Division and is important in maintaining the genetic and ecological diversity of endemic and restricted species that occur in subalpine wet heaths and bogs. Significant plant species associated with the site include: Peat Moss (*Sphagnum cristatum*), Alpine Plum Pine (*Podocarpus lawrencei*), Alpine Ballart (*Exocarpos nanus*), Dwarf Buttercup (*Ranunculus millanii*), Silver Caraway (*Oreomyrrhis argentea*), and Craspedia species. The wetlands also support: the Northern Corroboree Frog (Psuedophryne pengilleyii), which is endangered under ACT legislation and critically endangered nationally; the Broad-toothed Rat *(Mastacomys fuscus*), which is listed as vulnerable in NSW and nationally; occasionally, Latham's Snipe, which is a migratory bird protected under international agreements; and the Alpine Water Skink, which is restricted largely to *Sphagnum* moss bogs and subalpine wetlands.
Criterion 4: A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.	Ginini Flats Wetland Complex provides critical breeding habitat for the Northern Corroboree Frog. This species relies on the availability of small ephemeral or semi-permanent pools for breeding—suitable pools are formed by a high water table accompanied by appropriate hydrological conditions such as low flow rates.
Criterion 9: A wetland should be considered internationally important if it regularly supports 1 per cent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.	The Ginini Flats Wetland Complex supports more than one per cent of individuals in the wild of the Northern Corroboree Frog, which is a wetland dependent species.

2. SITE DESCRIPTION

2.1 OVERVIEW

The Ginini Flats Wetland Complex consists of a composite of subalpine *Sphagnum* bogs and associated wet heath and wet grassland habitats occupying a series of interconnected wetlands known as Ginini West, Ginini East and Cheyenne Flats (see Figure 1).

The site is situated at the northern extreme of the climatic range for *Sphagnum* bog wetlands in the Australian Alps. The 'Alpine *Sphagnum* Bogs and Associated Fens' ecological community, the Northern Corroboree Frog (*Pseudophryne pengilleyi*) and broad-toothed rat (*Mastacomys fuscus*) communities on site are nationally significant.

The Ginini Flats Wetland Complex contains the largest intact *Sphagnum* bog and fen community in the Australian Alps. The site also provides habitat for migratory birds listed under several international migratory bird agreements (JAMBA[1], CAMBA[2] and ROKAMBA[3]).

1 Japan-Australia Migratory Bird Agreement
2 Chinese-Australia Migratory Bird Agreement
3 Republic of Korea-Australia Migratory Bird Agreement

2.2 LOCATION

The Ginini Flats Wetland Complex is located on the north-eastern summit slopes of Mount Ginini in the Brindabella Range within the Namadgi National Park, 40 kilometres south-west of Canberra in the ACT (see Figure 2). The total Ramsar site catchment[4] area is 350 hectares, including 50 hectares of wetland complex and 75 hectares of open flats. While this plan relates to the official Ramsar site catchment, management within the overall hydrological catchment is also important. Elevation of Ginini Flats Wetland Complex ranges from 1520–1600 metres ASL (Wild et al. 2010). It is about 800 metres east of the ACT–NSW border. The area is relatively undisturbed.

The Ginini Flats Wetland Complex is at the head of Ginini Creek in the upper reaches of the Cotter River catchment, which is within the Murrumbidgee River Drainage Basin in south-eastern Australia. This catchment in turn is a component of Australia's largest river system, the Murray–Darling Drainage Division (Wild et al. 2010). The Drainage Division extends from north of Roma in Queensland to Goolwa in South Australia and includes three quarters of New South Wales and half of Victoria. It covers 1,060,000 square kilometres (km2)and is the third largest in Australia after the Western Plateau (2,450,000 km2) and Lake Eyre (1,170,000 km2) (Murray–Darling Basin Commission, cited in Wild et al. 2010). The site is also of hydrological importance due to the wetlands' role in maintaining water quality and, to a lesser extent, moderating runoff. The Cotter River catchment is a primary water source for Australia's capital city, Canberra, in the ACT.

The drainage division classification has been further divided into biogeographic regions following the Interim Biogeographic Regionalisation for Australia (IBRA), which identifies geographically distinct areas of similar climate, geology, landform, vegetation and animal communities. It divides the Australian land mass into 85 bioregions and 403 subregions. Ginini Flats Wetland Complex falls within the Australian Alps IBRA bioregion, which is characterised by a series of high elevation plateaux capping the South Eastern Highlands (Region SEH) and the Southern Tablelands in New South Wales (NSW) and ACT. The geology of this bioregion consists predominantly of granitic and basaltic rocks. Vegetation is dominated by alpine herbfields and other treeless communities, Snow Gum woodlands and montane forests dominated by Alpine Ash (DEWHA, cited in Wild et al. 2010).

4 The catchment boundary referred to in this plan is the officially designated Ramsar site catchment, not the hydrological catchment.

Figure 1: Ginini Flats Wetland Complex

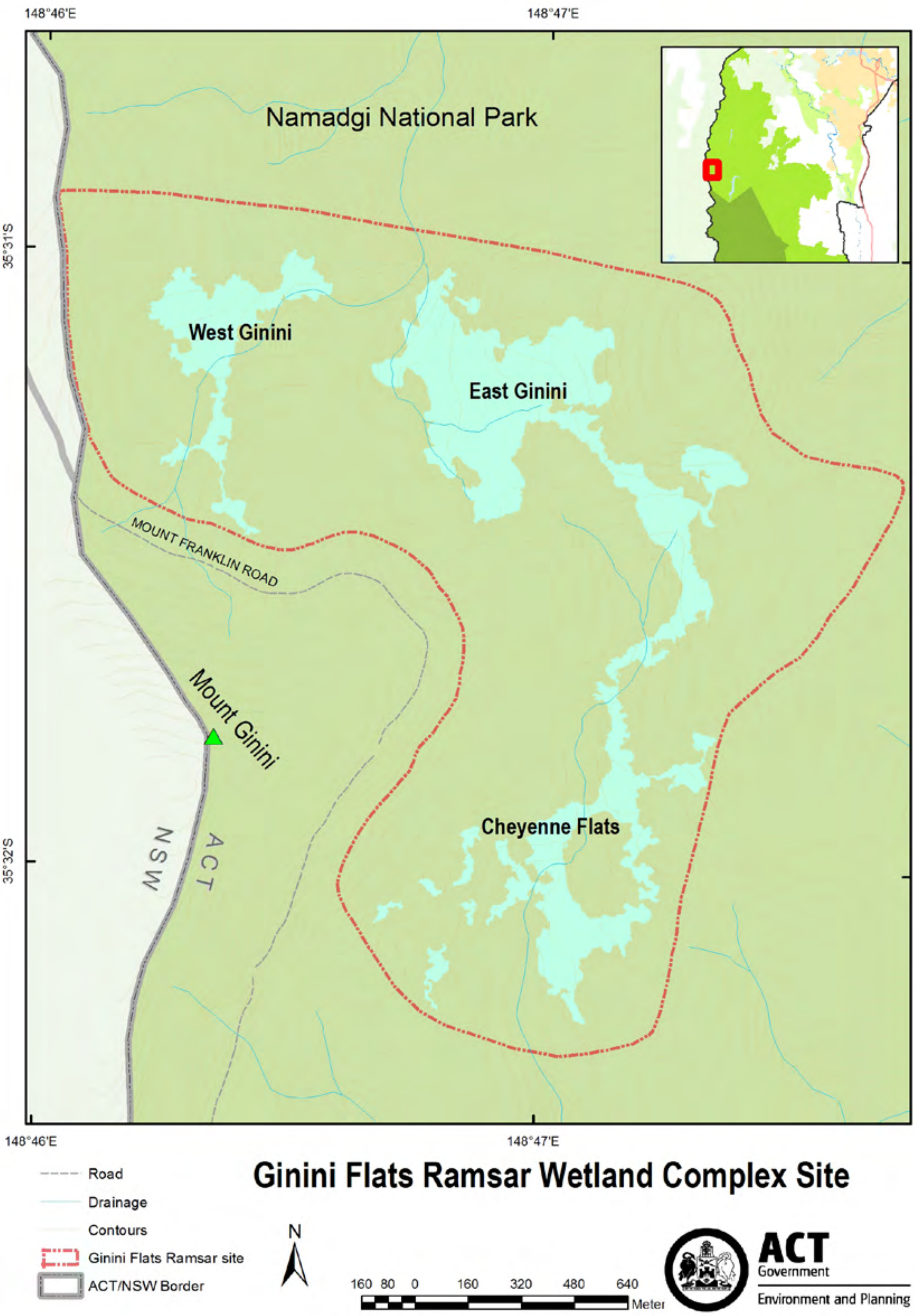
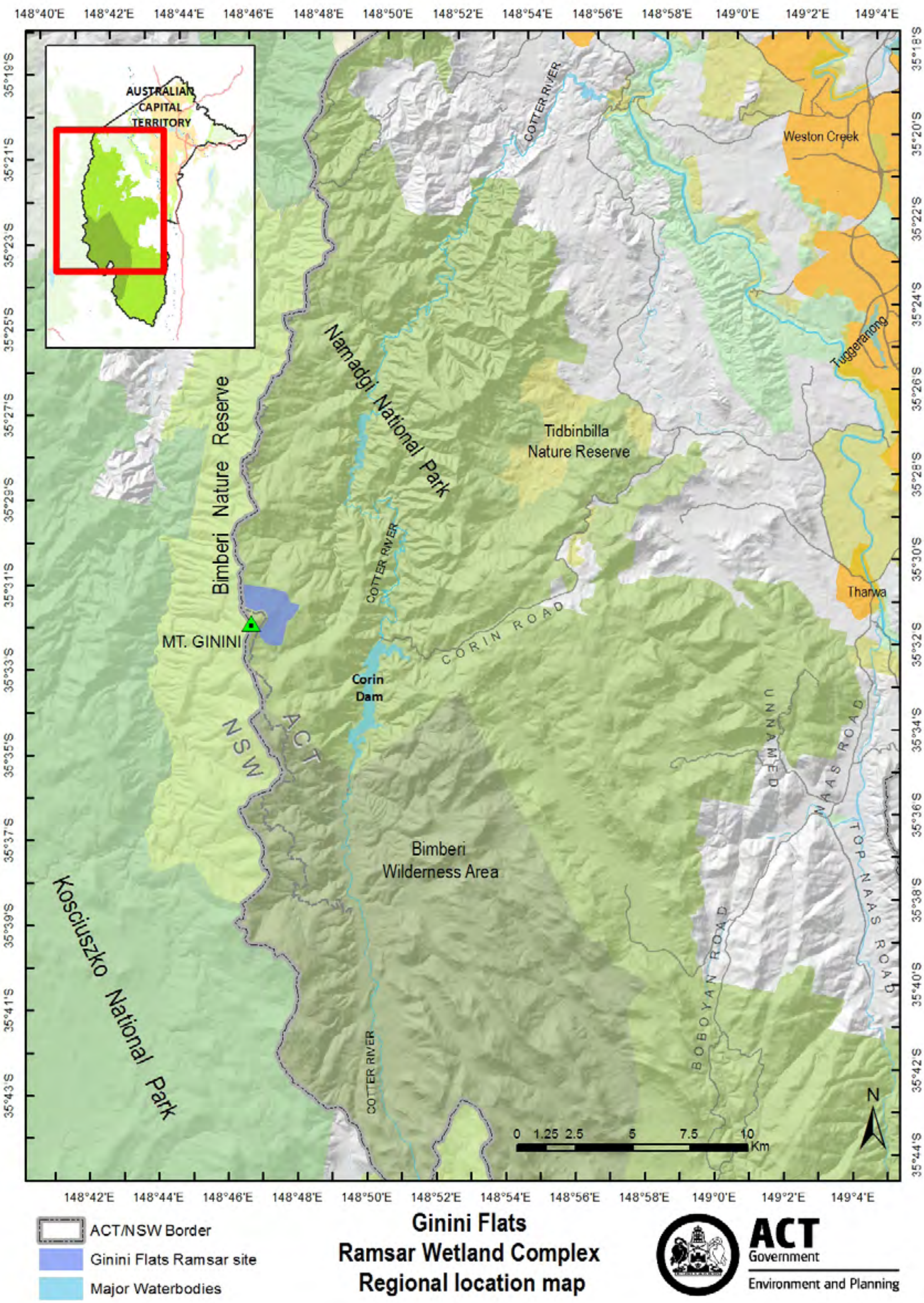


Figure 2: Regional location of Ginini Flats Wetland Complex



2.3 WETLAND TYPE

The Ramsar Classification System for Wetland Type (Ramsar Convention 2008) lists different wetland types. While Ginini Flats Wetland Complex has numerous vegetation communities that define its ecological character, there is only one Ramsar-designated wetland type within the Inland Wetlands category relevant to the site:

» U – **Non-forested peatlands**; includes shrub or open bogs, swamps, fens.

This wetland type is composed of the following vegetation communities: *sphagnum* bog, sedgeland, wet herbfield, wet heath, and tall wet heath (Hope et al. 2009).

Muller et al. (2016) recently classified the wetland as 'Pp3 Peat bogs and fen marshes' according to the Australian National Aquatic Ecosystems (ANAE) classification (Aquatic Ecosystems Task Group 2012—Aquatic Ecosystems Toolkit. Module 2. Interim Australian National Aquatic Ecosystem Classification Framework), using the methodology of Brooks et al.—Murray–Darling Basin aquatic ecosystem classification: Stage 2 report.

Using the classification of Claus et al. (2011)—Assessing the extent and condition of wetlands in NSW: Supporting report A – Conceptual framework, the wetland can be classified as 'subalpine bogs and fens'.

2.4 VEGETATION DESCRIPTION

The Ginini Flats Wetland Complex falls within the Australian Alps IBRA[5] bioregion, which contains only one subregion (Australian Alps), occurring across the Alps in NSW, Victoria and the ACT. The Ginini Flats Wetland Complex is an extensive mosaic of Alpine *Sphagnum* bogs and associated fens, wet heath and wet grassland communities. The Alpine *Sphagnum* Bogs and Associated Fens ecological community is usually defined by the presence or absence of *Sphagnum* spp. on a peat substratum.

The Alpine *Sphagnum* bogs and fens ecological community is described by the listing information for the nationally endangered ecological community Alpine *Sphagnum* Bogs and Associated Fens (DEWHA 2009). A more recent description can be found in the classification and mapping of Alpine vegetation undertaken by Mackey et al. (2015).

Hope et al., cited by Wild et al. (2010), identified three classifications of bogs, based on their topographic setting, that occur within the Ginini Flats Wetland Complex:

1. Slope bog and fens are found at breaks of slope on valley slopes indicating groundwater supply.
2. Headwater bogs occur at the head of small streams, often surrounded by heath of Woolly Teatree (*Leptospermum lanigerum*) and other shrubs.
3. Valley floor bogs and fens occur on the floor of valleys, often with meandering incised streams dammed by peat ponds.

All three types of *sphagnum* bogs at Ginini Flats Wetlands Complex are dominated by large hummock forming mosses, predominantly *Sphagnum cristatum*, and other waterloving, oligotrophic plants including a covering of shrubs and restiads. *Sphagnum* spp. is a slow growing moss species that forms extensive wetland communities and has been recorded to increase in length by up to 30 cm in a growing season at Ginini Flats Wetlands Complex (before compression from snow pack).

The other predominant vegetation community within the Ramsar site boundary is Snow Gum (*Eucalyptus pauciflora* ssp. *pauciflora* and ssp. *debeuzevillei*) woodland with a grassy ground cover (*Poa* spp.) or a shrubby understorey dominated by *Bossiaea foliosa*, *Oxylobium ellipticum* and *Daviesia ulicifolia* (Wild et al. 2010). Refer to Appendix E for a more comprehensive vegetation description.

5 Interim biogeographic regionalisation of Australia

2.5 FAUNA

At the time of listing in 1996, the Ginini Flats Wetland Complex supported a range of wetland habitats including *sphagnum* bog, wet herbfield and wet heath. Vertebrate fauna species that have been recorded in the area (ACT Government 2001) are wetland dependent and are expected to have been present around the time of listing, including:

» the Northern Corroboree Frog (*Pseudophryne pengilleyi*)

» Broad-toothed Rat *(Mastacomys fuscus*)

» Latham's Snipe (*Gallinago hardwickii*)

» Alpine Water Skink (*Eulamprus kosciusko*)

» Mountain Swamp Skink (*Niveoscincus rawlinsoni*)

» Mountain Water Skink (*Pseudemoia rawlinsoni*)

A number of notable invertebrate species have been recorded within Ginini Flats Wetland Complex, including:

» Metallic Bog Cockroach (*Polyzosteria viridisma*)

» Mountain Grasshopper (*Acripeza reticulate*)

» Spotted grasshopper (*Yeelanna* sp.)

» Alpine Chameleon Grasshopper (*Kosciuscola tristis*)

» various species of *Lycosa* (alpine wolf spiders).

The Mountain Galaxias (*Galaxias olidus*) has been recorded within streams in the Ginini Flats Wetlands Complex.

Refer to Appendix E for a more comprehensive description of fauna species found in the wetlands.

2.6 LAND TENURE AND MANAGEMENT

2.6.1 Historical management

There is little evidence that Ginini Flats were used by Australian Aboriginals; however Flood (cited in Wild et al. 2010) reports considerable evidence that Australian Aboriginals used the nearby Mt Gingera area, 6 kilometres south of the wetland complex. Clark (cited in Wild et al. 2010) argues it is likely that the open flats would have been traversed by people en route to the high peaks during the annual Bogong Moth (*Agrotis infusa*) harvest. Archaeological evidence exists for campsites 4 kilometres south of the flats (Flood, cited in Wild et al. 2010).

European use of the area has been recorded since the early 1830s, when stock was moved to high country pastures in the summer (Wild et al. 2010). However, given the lack of extensive grasslands or heathlands in the immediate vicinity, this use is likely to have been intermittent outside serious drought periods. Following acquisition of the land by the Australian Government in 1909, grazing was officially ceased in 1913 although one short period of grazing was allowed for drought relief in the 1920s. The site was included in the reserve system when the Namadgi National Park was declared in 1984.

Other than the impacts from feral animals (horses, pigs and rabbits), anthropogenic disturbances within the catchment and the wetland complex have been limited. In 1938 a two metre deep, 50 metre long trench was cut in West Ginini Flats by the Australian Forestry School for a study of peat profiles. This trench has not fully recovered and is still evident today, with some local impacts to hydrology and subsequent changes in vegetation community. In the 1940s, *sphagnum* from West Ginini Flats was cut for use as filters in vehicle gas production during World War II. Records show that in 2003 these areas were burnt to a greater degree than surrounding areas that had not been mined and show slower recovery (Wild et al. 2010).

Higgins (cited in Wild et al. 2010) reports that in 1936, members of the Canberra Alpine Club assessed Ginini Flats as a potential site for the development of a ski lodge in their endeavour to develop the area into a major ski centre for the population of Canberra.

Due to the good shelter from the westerly and southerly winds and abundant clean water supply, it was considered very desirable. However, the Mt Franklin site was eventually chosen due to the absence of timber at Ginini Flats for the construction of a lodge. In the 1960s ski development on the Kosciuszko Range, where conditions for skiing were more reliable, led to reduced use of the area and the facilities at Mt Franklin were demolished in 1969 with the exception of the Chalet that was destroyed in the 2003 bushfires. The chalet was later rebuilt as a memorial to the 2003 fires.

Evidence of past skiing use remains; outside the wetland area trees have been cleared to form a ski run on the eastern slope of Mt Ginini, upslope of the wetlands, which did allow access to the wetland in winter (Wild et al. 2010). This cleared area is revegetated now.

2.6.2 2003 to present

Following the 2003 fires, when most of the bogs and fens in the ACT burned, these communities were assessed to see if rehabilitation was required. A number of the bogs appeared to have incipient stream entrenchment and a program of rehabilitation to spread water and prevent further entrenchment was commenced. Damming of stream lines and spreading of water across peat slopes was undertaken using semi-permeable materials (hay bales and coir fibre logs that will, over time, become incorporated into the natural bog structure). Photo monitoring of this work has indicated that the surface vegetation is recovering and there has been reduced stream entrenchment. Monitoring to see if bog functionality is changing or improving has not been carried out, except to a minor degree at two sites (Macdonald 2009).

Experimental work was commenced to assess whether re-colonisation recovery of *Sphagnum* could be enhanced by simple interventions suitable for broad scale application. This was a cooperative project between NSW National Parks and Wildlife and ACT Parks Conservation and Lands (now Parks and Conservation Service). Experimental treatments included: fertiliser, transplanted moss, fertiliser and transplanted moss, and control (no treatment).

These treatments were also tested with and without horizontal shade and vertical shade cover (Macdonald 2009). The experimental treatment plots were established at a number of bogs including Ginini Flats Wetland Complex.

In 2009 the ACT Government engaged the Australian National University (ANU), to map the peatlands (bogs and fens) of the ACT, including the Ginini Flats Wetland Complex. The mapping was based on orthorectified aerial photography (immediately following the 2003 fires) and satellite imagery, and provided land managers with a base line assessment of the condition of the peatlands against which future changes in their characteristics could be assessed (Hope et al. 2009).

2.6.3 Current management

All upper and middle sub-catchments of the Ginini Flats Wetland Complex are protected in Namadgi National Park, which is managed by the Parks and Conservation Service under the *Nature Conservation Act 2014*. The Namadgi National Park PoM (ACT Government 2010) specifically recognises the significance of the Ginini Flats Wetland Complex. The Ginini Flats Wetland Complex Ramsar site management plan is supported with additional management actions in the Namadgi National Park PoM to reflect changed circumstances since the 2003 bushfire. Ginini Flats Wetland Complex is designated as part of the Remote Area Zone under the Namadgi National Park PoM, which has the primary purpose of core conservation and catchment area maintenance. This zoning requires that recreation is limited to low impact activities. Protection and management of the site is further supported through implementation of the Strategic Bushfire Management Plan v3 2014 and the annual ACT Bushfire Operations Plan. The western edge of the site extends close to the boundary between the ACT and NSW. Bimberi Nature Reserve is located on the NSW side of the border, offering similar protection to that of a national park.

3. ECOLOGICAL CHARACTER

3.1 DESCRIBING ECOLOGICAL CHARACTER

The principal undertaking of the Contracting Parties to the Ramsar Convention with respect to listed wetlands is to promote their conservation with the aim of preventing changes to their ecological character. Under the Environment Protection and Biodiversity Conservation Regulations 2000 Schedule 6—Australian Ramsar management principles, a management plan for a declared Ramsar wetland should describe its ecological character.[6]

As part of the ecological character description (ECD) for the Ginini Flats Wetland Complex, critical services, components and processes for the site have been identified along with their interactions through the use of conceptual diagrams (Wild et al. 2010). The ECD forms a baseline to assess changes in the ecological character of the Ramsar wetland. The ECD also addresses changes in the ecological character of the Ramsar wetland since the time of listing.

The ECD of Ginini Flats Wetland Complex was completed in 2010, and provides a description of the wetland at the time of Ramsar listing (1996) and any changes to its ecological character since then. Included in the ECD is a description of key threats to the ecological character (since time of listing), identification of limits of acceptable changes, key knowledge gaps and recommended monitoring, and assessment of the current condition of the site, including known changes in ecological character since the time of listing.

6 The Ramsar Convention has defined ecological character as "the combination of the ecosystem components, processes and benefits/services that characterise the wetlands at a given point in time" (Australian Government Department of *Environment, Water Heritage and the Arts 2008*).

3.2 SUMMARY OF GININI FLATS WETLAND COMPLEX ECOLOGICAL CHARACTER DESCRIPTION

The Ginini Flats Wetland Complex is a composite of subalpine *sphagnum* bogs and associated wet heath and wet grassland habitats occupying a series of interconnected wetlands. The Ginini Flats Wetland Complex is known to have a recognised presence of a nationally listed ecological community (Alpine *Sphagnum* Bogs and Associated Fens) and threatened fauna species, the Northern Corroboree Frog (*Pseudophryne pengilleyi*). The Ginini Flats Wetland Complex incorporates one wetland type as defined by the Ramsar Classification System for Wetland Type (Ramsar Convention 2008): U – Nonforested peatlands which includes shrub or open bogs, swamps and fens.

The Complex is at the northern biophysical limit of this habitat type within the Murray–Darling Drainage Division and is of importance in maintaining the genetic and ecological diversity of a number of endemic and restricted species found in subalpine wet heaths and bogs.

Sites with extensive bog development dominated by *Sphagnum* are uncommon on the mainland of Australia. Significant plant species associated with the wetlands include the Peat Moss (*Sphagnum cristatum*), Alpine Plum Pine (*Podocarpus lawrencei*), Alpine Ballart (*Exocarpos nanus*), Dwarf Buttercup (*Ranunculus millanii*), Silver Caraway (*Oreomyrrhis argentea*) and Craspedia sp. The site provides critical habitat for breeding cycles of the Northern Corroboree Frog (*Pseudophryne pengilleyi*). The Northern Corroboree Frog relies on the availability of small ponds in the wetlands for nests; with suitable ponds formed by a high water table accompanied by suitable hydrological conditions such as low flow rates.

The site supports greater than one per cent of individuals in the wild of the Northern Corroboree Frog (Wild et al. 2010). Ecosystem components and process of the wetlands are further discussed in Appendix C.

3.3 MAJOR ECOLOGICAL CHANGES SINCE LISTING

The Ramsar convention has defined the 'change in ecological character' as 'the human induced adverse alteration of any ecosystem component, process and/or ecosystem benefit/service' (DEWHA 2008). Wild et al. reported in 2010 that there has not been a significant alteration in ecological character of Ginini Flats Wetland Complex since the initial listing in 1996. This is despite the fact there has been a substantial natural disturbance (2003 fire), a significant decline in the population of the Northern Corroboree Frog and potential ongoing, and incremental changes of the functioning of the peatland system (ongoing climate alteration).

The three *sphagnum* bogs which collectively comprise the Ginini Flats Wetland Complex were all burnt in the landscape scale fires of 2003 in which most ACT mountain bogs had between 55 and 100% of the surface burnt (Hope et al. 2003; Carey et al. 2003) with up to 30 centimetres of peat destroyed in some parts and severe damage to a large proportion of the *Sphagnum*. Around 45% of the surface of Ginini west and east bogs were badly burnt in the fires with around 50% (22 ha) of the *sphagnum* bog as a whole burnt.

Ginini Flats Wetland Complex was burnt twice in the 2003 fires, with the main damage along the stream channel where high shrub densities occurred. Peat fires also burnt into the trench dug in the 1940s but otherwise the fibrous surface was generally retained in the centre of the bog and the residual moisture in the peat had prevented burning of the peat at depth. Where the peat did burn to between 5 and 20 cm a sterile, often hydrophobic ash surface remained, with a neutral pH unlike the normally acidic bogs. These areas were also susceptible to frost heave and erosion after being burnt. In the deeper bog areas the loss of hummock forming *Sphagnum cristatum*, which is critical to bog function and hydrology, was considered to be a serious impact that may have long-term effects on the wetlands.

Observations in 2009 showed that some areas where *Sphagnum* retreated following the 2003 fires were recolonised by *Empodisma minus* fen, while other areas remain bare. Some of the fringing peat surface has been exposed and this area is likely to continue to oxidise and erode due to the lack of vegetation cover and loss of moisture. In April 2009, field observations showed a persistence of some ruderal weeds such as Sheep's Sorrel (*Rumex acetosella*), thistles (*Carduus* spp.) and cats ear (*Hypochaeris* sp.) which were also recorded immediately following the fires. Whilst these have persisted they are expected to decline as regeneration of native species continues. Some bare areas (hydrophobic peat ash) and dead *sphagnum* hummock masses still remain 13 years post-fire (2016), particularly at Ginini West (M. Evans personal communication, July 2016).

Following the extensive fires in 2003, concerns were raised about the long-term health and recovery of the bog system from ongoing damaging processes such as accelerated runoff and subsequent stream entrenchment. Observations at Ginini Flats Wetland Complex showed there to be active peat tunnelling, which is the incision and erosion of the peat dams that could lead to long-term impacts and slow recovery. Restoration works have focussed on techniques that restore hydrological functionality to the bogs to enable recovery of the key bog species—*Sphagnum*, *Empodisma* and Carex—and to increase the residence time and infiltration of surface water by slowing flow rates.

Water quality declined following the January 2003 bushfires. It was particularly impacted by large rain events in February and March of 2003, which led to large scale erosion of the denuded slopes of the catchment. Data from nearby catchments indicates that water quality in sub-catchments of the Australian Alps affected by the 2003 fires has returned to the high water quality previously considered representative of these environments and it is expected that the water quality in Ginini Flats Wetland Complex has followed a similar trend.

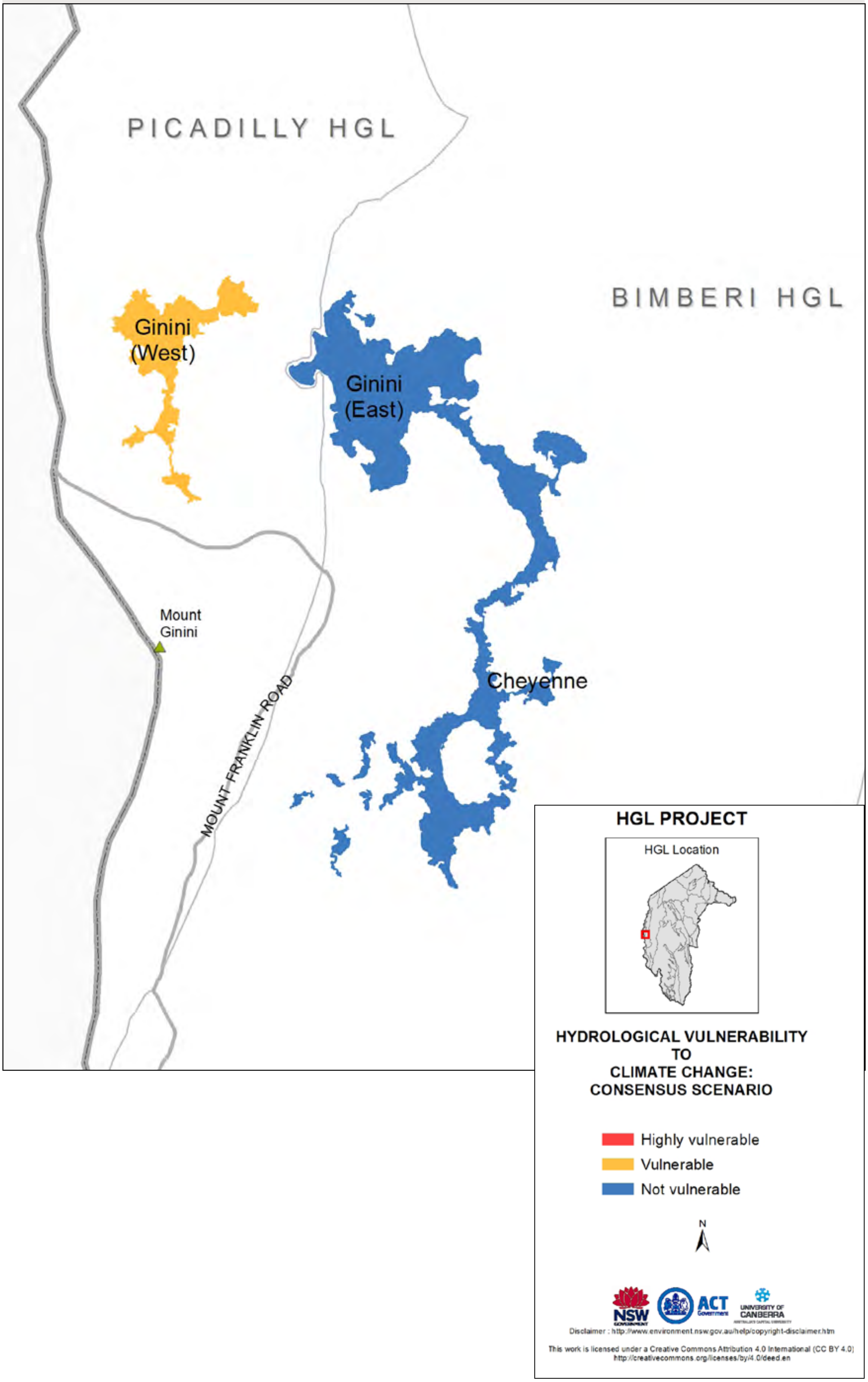
The decline of Northern Corroboree Frog population that began in the 1980s due to the introduced Chytrid fungus raised concerns about the long-term viability of populations. The fires of 2003 had immediate direct and indirect impacts on the already low frog populations. The fires occurred during the 2003 breeding season, which reduced overall numbers through direct mortality. Indirect impacts include changes in habitat, as all known corroboree frog over-wintering habitat was burnt by moderate to high severity fires. Whilst breeding and overwintering habitats have recovered, corroboree frog populations have not recovered due to the continued presence of Chytrid fungus.

4. KEY THREATS IMPACTING ECOLOGICAL CHARACTER

Ginini Flats Wetland Complex is within a national park and at the top of the catchment; it is therefore protected from many developmental and upper catchment impacts. However, alpine and subalpine vegetation is particularly susceptible to environmental change, due in part to the restricted growing season of the alpine and subalpine regions, but also the very fragile nature of some systems, particularly the Alpine *Sphagnum* Bogs and Associated Fens ecological community.

The greatest threat with the most severe consequences is associated with climate change. Increased temperatures and altered rainfall regimes have been predicted for the Australian Alps under climate change scenario modelling, which may in turn affect the carbon and water cycle processes in the wetlands (Muller et al. 2016). The impact of increased temperatures may be both positive and negative, with increased vegetation growth rates likely. Increased rates of evapotranspiration and decay of peat surfaces are also likely. Future higher temperatures and altered rainfall patterns may result in the demise of *Sphagnum* bogs at the hottest and driest margins of their Australian distribution. This at-risk distribution will almost certainly include the Ginini Flats Wetland Complex.

Figure 3: Hydrological vulnerability to climate change



Hydrogeological (HGL) maps and associated management recommendations have been produced for the ACT Government by the NSW Office of Environment and Heritage (OEH) and NSW Department of Primary Industries (DPI) (see Appendix D). As a component of the ACT HGL project, wetland mapping, classification and assignment of wetland condition was carried out for wetlands across the ACT. This included an assessment of wetland hydrological vulnerability to climate change (see Figure 3 above for consensus scenario, see also Figures 8–10):

- In the consensus scenario the Ginini West wetland is indicated as highly vulnerable. Cheyenne and Ginini East is indicated as not vulnerable.
- In the best case (wetter) scenario, the whole Ginini Flats area is indicated as vulnerable.
- In the worst case (drier) scenario, the whole Ginini Flats area is indicated as highly vulnerable.

The Ginini West wetland exist in the Adaminaby Group of Ordovician geologies which is in the Picadilly HGL; whilst the Ginini East and Cheyenne wetlands occur in granitic geologies which is in the Bimberi HGL (see Appendix D for a comprehensive discussion on HGL). This is the reason for the differences in modelled hydrological vulnerability to climate change, as indicated in the dot points above. A case study (Nicholson et al. 2016) of the application of the HGL project to the Ginini Flats Wetland Complex wetlands is presented in Appendix H.

Modelled climate change impacts predict increased frequency and intensity of precipitation events that may alter the overall hydrology of peatlands (see Appendix G for more information on the specific modelling). This may result in the reduction of peatbog area or increased erosion of disturbed peat surfaces. Such processes may lead to a series of positive feedback mechanisms altering the state of the peat retention, and to the hydrological cycling of the system, placing pressure on the bogs' long-term persistence.

Fire is strongly influenced by climate, and increased temperatures and altered rainfall regimes may result in more frequent and intense wildfires. Wildfire occurring within the bogs and fens is arguably among the greatest threat to the integrity and functioning of the ecological community, particularly where changes to hydrology or climatic conditions have dried out the underlying peat.

Other identified risks are less severe but may contribute to changes in character in the longer term when associated with climate change impacts. These include impacts from feral animals and weeds which, although not currently resulting in large-scale changes in the case of weeds, may do so in a drier, less acidic bog system.

Each of these threats is examined in more detail in Appendix G. Table 1 below outlines each threat along with the likelihood of threat occurring, potential consequences to the ecological character of the wetland and associated risk level (including expected timeframe of the risk).

Table 1: Potential impacts and the likelihood of occurrence and consequences for key threats to the Ginini Flats Wetlands Complex (after Wild et al. 2010)

Potential impact(s) to wetland components, processes and/or services	Likelihood	Consequence	Risk	Timing of threat
1. Climate change				
Changes in hydrology, such as lowering of the water table, will influence available water and primary productivity of the ecosystem, which may lead to system imbalance and potential decline of peat creation and storage mechanisms. May lead to invasion by less water-tolerant species. Changes in stream flow and groundwater levels and seasonality may impact on breeding habitat for frogs. Changes in hydrology may lead to reduction of oligotrophic species such as *Sphagnum* and allow other plants to invade, such as grasses and shrubs. Increased CO_2 levels may result in increased primary productivity of *Sphagnum*. Increases in ambient temperature will result in increased peat oxidation and decomposition. Increases in soil temperature may increase evapotranspiration, decreasing available soil moisture. Changes in snow cover depth, duration and melt patterns may result in a reduced snow pack, which will impact water availability in drought. Reduced snow cover reduces insulation and protection from harsh winter conditions for fauna. Changes in snow melt may be reducing groundwater levels and recharge for the bog. Changes in temperature may reduce the frost hollow effect, permitting growth of woody species. Reduction in snow depth and persistence leads to increased impacts of cold, frost conditions on flora and fauna, potentially including: » increasing frost events reducing the potential for recovery from past disturbances » a reduced snow pack, resulting in less-compacted *Sphagnum*, may change hydrological and growth characteristics of the bog acrotelm.	Currently occurring	Moderate to high	High	Short to long term

Potential impact(s) to wetland components, processes and/or services	Likelihood	Consequence	Risk	Timing of threat
2. Fire – increase in intensity or frequency				
Vegetation changes favour fire-tolerant rhizomatous sedges over *Sphagnum* and resultant changes in hydrological processes. Reduced peatbog area and increased dried peat or alpine humus soil area, results in variations in hydrology, nutrient fluxes, acidity and primary productivity. Impacts to adjacent woodland communities. Increased sedimentation from surface runoff of bare areas. Altered hydrology from channelisation. Change in floristics to more fire-tolerant species.	High – greater risk to raised bogs compared with valley bogs	Moderate if frequency is not too high	Moderate	Medium term
3. Altered hydrological regime				
Fluctuating water table levels and cycles of wetting and drying, resulting in decomposition of peats. Fire (see point 2 above) has very significant impacts directly on the peatlands by burning vegetation/peat and also on the catchment especially the flow on hydrology impacts. Lower water table conditions, which are less favourable for *Sphagnum* development and more favourable to other plant species. Increases in run-off will change the erosion risk. Erosion, particularly gully erosion, will change the energy and change the hydrology of the wetland. Hydrological changes will impact Corroboree frog breeding pool habitat.	Moderate (based on modelling)	Moderate to high	Moderate	Medium term
4. Invasive species				
4.1 Feral animal activity Changes in hydrological regime due to pig (and potentially deer) wallowing in pools. Potential disturbance of corroboree frog breeding pools, egg nests and non-breeding habitat by pigs. Creation of bare areas in herbfields due to pigs rooting for tubers. Channelling of bogs, altering hydrology.	Currently occurring	Low to moderate	Low	Short term, ongoing

Potential impact(s) to wetland components, processes and/or services	Likelihood	Consequence	Risk	Timing of threat
4.2 Weed invasion Competition and exclusion of native flora. Blackberry invasion may alter frog breeding habitat.	Conifer risk is moderate if seed bank has persisted following fires. The risk for other species is moderate.	Low to moderate	Low	Medium-term
4.3. Chytrid fungus Decline in population and/or loss of the Northern Corroboree Frog (*Pseudophryne pengilleyi*).	High – already occurs within wetland	High – has already resulting in a decline in population since early 1980's	High	Ongoing
5. Changes in upper catchment infrastructure				
Existing road infrastructure may cause sediment and turbid water run-off from the Mt Franklin road. The creation of additional infrastructure or upgrading works may exacerbate these impacts. Winter vehicular access to Mt Ginini may exacerbate road impacts.	Moderate	Moderate to low	Low	Long term
6. Impact from recreational and other visitors				
Sphagnum bogs are fragile and low levels of visitor use can have quite significant impacts. Ginini Flats Wetland Complex is close to a public access road (Mt Franklin Road), which increases potential visitor numbers. An informal track to Ginini West has been allowed to overgrow to reduce the impact of recreation on Ginini West, and there are no plans to re-establish the track	Moderate	Moderate to high	Low	Long term+

5. LIMITS OF ACCEPTABLE CHANGE (LAC)

Limits of acceptable change (LAC) is a tool that can be applied to the management of Ramsar sites to help detect changes to ecological character (Davis and Brock in Wild et al. 2010). The LAC framework uses existing data to quantify the natural variability in the systems against which future changes can be assessed. Exceeding or not meeting LAC does not necessarily indicate there has been a change in ecological character within the meaning of the Ramsar Convention. However, exceeding or not meeting LAC may require investigation to determine whether there has been a change in ecological character.

This approach requires an understanding of the critical components of the system and quantitative measures of these components. The application of the LAC framework in the Ginini Flats ECD (Wild et al. 2010) has found there are many knowledge gaps for these critical components and processes, making setting such limits challenging. Due to this lack of baseline data and an understanding of the natural variability of critical components at Ginini Flats Wetland Complex and the associated difficulties with setting quantifiable limits of acceptable change, the LACs have been qualified with a measure of confidence. Qualitative indicators of hysteresis, or points where an adverse change cannot be remedied, have also been included to provide additional indicators. The LACs provided in the ECD are presented in Table 2 below.

LAC can be updated as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of critical components, processes, benefits or services of the Ramsar wetland.

Table 2: Baseline data, natural variability and limits of acceptable change for critical components of ecological character of the Ginini Flats Wetland Complex (Wild et al. 2010)

Theme component /Process	Ramsar Nomination criteria and supporting baseline data	Limits of acceptable change to ecological character	Qualifying statement	Level
Abiotic				
Hydrology	1,2,3,4 and 9 Observational evidence of functioning including presence of pools and wetted peat layers.	**LAC 1** Qualitative evidence of reductions in functionality of hydrology such as breaking of pools, development and persistence of erosion pavements or hydrophobic peat surfaces following fire disturbance for a period of greater than five years.	No data were available for the time of listing meaning that site specific data are of insufficient quality and quantity to determine statistically supported LACs. Therefore, this LAC is set to be qualitative and judgement based. The five year threshold for lack of recovery is based on recovery observations following the 1998 and 2003 fires in numerous Victorian peatlands documented by Tolsma and Shannon (2007).	Low

Theme component /Process	Ramsar Nomination criteria and supporting baseline data	Limits of acceptable change to ecological character	Qualifying statement	Level
Nutrient and Carbon Recycling	1, 2 and 3 Peat extent mapping and some depth mapping	**LAC 2** Greater than 20% change in extent (9.8 +/– 0.5 ha) of peat surfaces and evidence of oxidation.	No data were available on peat extent or depth at the time of listing. The baseline extent of approximately 50ha mapped in 1999 by Hope et al., 2009 was used in lieu of other data. However, site specific extent and temporal change data remain of insufficient quality and quantity to determine a statistically supported LAC. The 20% change level is an arbitrary figure based on mapping error tolerances and the precautionary principle.	Low
Biotic				
Vegetation/ *Sphagnum* and Peat Accumulation	1, 2 and 3 Short-term extent and depth mapping	**LAC 3** Greater than 20% change in extent (9.8 +/– 0.5 ha) and a lack of recovery five years following disturbance (e.g. fire) that removes arcotelm or acrotelm and catotelm **LAC 4** Peat accumulation of less than 3.5cm per century or growth of *Sphagnum* spp. less than 30cm/yr. Loss of *Sphagnum* spp. propagules for recruitment following a large disturbance event ongoing for a period of five years.	No data were available on *Sphagnum*, vegetation or peat accumulation rates at the time of listing. The baseline extent of approximately 50ha mapped in 1999 by Hope et al., 2009 was used in lieu of other data. Site specific data is of insufficient quality and quantity to determine a statistically supported LAC. The 20% change level is an arbitrary figure based on mapping error tolerances and the precautionary principle. Peat accumulation and *Sphagnum* spp. has been recorded for Ginini and other bogs (Clark, 2003). The peat accumulation figure is difficult to measure with sufficient precision in the short-term; therefore more focus should be placed on the *Sphagnum* growth figure. It should be noted that this growth figure is based on pre-compressed *Sphagnum*.	Low

Theme component /Process	Ramsar Nomination criteria and supporting baseline data	Limits of acceptable change to ecological character	Qualifying statement	Level
Vegetation/ *Sphagnum*	1, 2 and 3 Floristic surveys of 'keystone[1]' species. However, these data are short-term and there are too few data points to capture long-term variability.	**LAC 5** Loss, or extended (> 2 seasons) absence of keystone including (but not restricted to): *Sphagnum cristatum, Empodisma minus, Richea continentis, Epacris paludosa, Baloskion australe, Baeckea gunniana, Carex gaudichaudiana, Myriophyllum pedunculatum* and *Poa costiniana* from Ginini Flats Wetland Complex. **LAC 6** Reduction or absence of recruitment of new individuals or ramets for these species.	No data were available for the time of listing meaning that site specific data are of insufficient quality and quantity to determine statistically supported LACs. However, ongoing monitoring and analysis may facilitate future determination of a LAC for relative abundance of keystone species identified by Hope et al., 2009.	Low
Vegetation/ *Sphagnum* and Peat Accumulation	1, 2 and 3 Inferred fire history for the site showing an average interval around 25–30 years	**LAC 7** An increase in fire frequency greater than 25 years or inferred increase in intensity.	There are data on the frequency of fire events in adjacent woodland at Mt Ginini (Zylstra, 2006). It is not certain if Ginini Flats Wetland Complex burnt during all these events and, if so, the severity or extent. However, it is evident that the community can recover from fire events over time. There are no data on past fire intensity or quantitative information for this community in general. Therefore, there is no baseline provided for this variable.	Low

Theme component /Process	Ramsar Nomination criteria and supporting baseline data	Limits of acceptable change to ecological character	Qualifying statement	Level
Northern Corroboree Frog	4 and 9 Abundance Occurrence, pattern and extent of *Sphagnum* pools for breeding	**LAC 8** Absence of calling males in two successive monitoring seasons **LAC 9** Evidence of stochastic declines due to disease or limited breeding site availability **LAC 10** Evidence of no suitable habitat due to closing of pools or collapse of system.	Due to the very low numbers of frogs at the site and the difficulties in measuring and detecting differences (Evans pers.comm. 2009) these population LACs are qualitative and should be interpreted with caution. Site specific quantitative data on habitat is of insufficient longevity to determine natural variability and determine a statistically supported LAC.	Low

6. SITE MANAGEMENT STRATEGIES

The site management strategies for the Ginini Flats Wetlands Complex promote a range of specific management actions that will maintain and, in some cases restore, the ecological character of the site. The site management strategies are designed to:

a) address risks that are having an adverse impact, or are likely to have an adverse impact on ecological character and

b) highlight existing strategies and actions that are consistent with Ramsar 'wise use' principles.

6.1 FIRE MANAGEMENT PLANNING

6.1.1 Fire prevention

The *Emergencies Act 2004* is the relevant law for bushfire management in the ACT and provides for strategic planning. Fire management in the ACT is the responsibility of ACT Emergency Services, which has prepared the ACT Strategic Bushfire Management Plan: Version 3 (SBMP) (ACT Government 2014a). The plan recognises that bogs and fens should be protected from fire and, as far as practicable, land managers must ensure that land is managed in accordance with the applicable reserve management plan prepared under the ACT *Nature Conservation Act 2014*. Where there is inconsistency between the SBMP and a reserve management plan the SBMP prevails. There is no inconsistency between the SBMP and this management plan.

The *Fuel and Fire Suppression Guidelines for ACT Declared Threatened Species and Endangered Ecological Communities* (ACT Government 2008b) *and the 2012–13 Ecological guidelines for fuel and fire management operations* (ESDD 2012) recognise that *Sphagnum* bog and fens are highly fire sensitive and should be excluded from planned burns, and that every practical measure is to be undertaken to protect bogs and fens from burning, including during wildfires.

Similarly the Namadgi National Park PoM specifically recognises the importance of excluding fire from this ecological community (see Namadgi National Park PoM 2010 Actions 98–9 and 114–19).

In terms of ecological thresholds and planned burning, the ACT vegetation communities that form the ACT *Sphagnum* bogs and fens ecological community are considered fire sensitive and in need of protection from fire.

The current Regional Fire Management Plans (2014–2019) do not include ecological burning or prescribed burning for fuel reduction within vegetation communities surrounding areas of *Sphagnum* bogs and fens.

Supply of water for fire suppression activities must also come from an EHNV[7] free supply, such as Cotter, Bendora or Corin Dams, or mains water. The Ecological Guidelines for Fuel and Fire Management Operations (EPD 2012), see below, prescribes that all water used for fire suppression in the Cotter River Catchment EHN Exclusion Zone should be sourced from potable supplies, or be extracted from the Cotter River above Cotter Dam, to prevent EHN virus being introduced to the catchment. Keeping the Cotter River above the dam free of EHNV is important for a range of threatened fish species.

In the case of widespread wildfires it may be impossible to protect all bogs and fens in the Namadgi National Park. The Ginini Flats Wetland Complex Ramsar site has the highest priority for wildfire protection because it is listed in formal conservation agreements, particularly international agreements, supports populations of the Northern Corroboree Frog and is a site of on-going research. Protection of the listed ecological community will always be a high priority because of its legal status, including under the EPBC Act.

7 Epizootic Haematopoietic Necrosis Virus

Excerpt from Ecological Guidelines for fuel and fire management operations (ESDD 2012):

4. EHN Virus Exclusion Zone

4.1 All prescribed burn operations in the 'Cotter River Catchment EHN Exclusion Zone' should minimise the potential for introduction of the EHN virus.

4.2 All water used for fire suppression in the Cotter River Catchment EHN Exclusion Zone should be sourced from potable supplies, or be extracted from the Cotter River above Cotter Dam, to prevent EHN virus being introduced to the catchment.

4.3 All drafting equipment used in EHN infected waters (the rest of the ACT) should be sterilized in a chorine solution*2 before being used in Cotter Catchment, to prevent EHN virus being introduced.

4.4 Where possible fire water storage units (tankers, buoy-walls etc) should be sterilised using chlorine before entering the Cotter Catchment, to prevent EHN virus being introduced.

6.1.2 Rehabilitation and management of fire affected bogs

The 2003 fire burned almost all the bog areas and fens with the burnt area in individual mires ranging from 55–100% (Carey et al. 2003). The large fens recovered quickly, resprouting six weeks after the fire. Following assessment of the impact of the fire on bog hydrology, a program of bog rehabilitation commenced. Rehabilitation work on burned bogs involved techniques to:

» re-wet areas

» stabilise eroded flow lines by slowing flow and increasing water spreading

» create pools

» transplant *Sphagnum* clumps

» fill/stabilise incised streams

» shade areas of *Sphagnum* hummocks (Good 2006).

Experimental work began to assess whether recolonisation of *Sphagnum* could be enhanced by simple interventions suitable for broadscale application. Experimental treatments included: fertiliser, transplanted *Sphagnum* moss, fertiliser and transplanted moss, and no treatment. Treatments were tested with and without horizontal shade and vertical shade.

The success of the rehabilitation measures has been monitored for ten years (until 2013), and should continue to be monitored, at a longer interval, given that full recovery of the bogs is likely to take longer than 20 years.

Discussion with experts and Namadgi National Park staff involved in the bog rehabilitation program resulted in the following recommendations for any future bog rehabilitation:

1. Priority bogs for rehabilitation are those:

» that are high in catchment or in a critical hydrological position (such as perched on a slope)

» where hydrological function can be returned and/or sustained, and

» that are reasonably accessible

2. works should only be considered if there is a commitment to maintain them for a minimum of ten years.

It is important that the knowledge gained over the past decade of bog rehabilitation efforts is retained. A final report on the 2003 fire bog-restoration works and experiments, and the results until 2013, has not yet been collated. It should include what has been done (techniques and locations), what was successful, and make recommendations for further actions if required.

MANAGEMENT STRATEGY: FIRE MANAGEMENT PLANNING	
OBJECTIVE	**ACTIONS**
Prevent fire from entering the Ginini Flats Wetland Complex so the values of the ecological community are protected.	1. Incorporate appropriate management guidelines for fire suppression in the ecological community, as outlined in the ACT Ecological Guidelines for Fuel and Fire Management Operations into the current ACT Strategic Bushfire Management Plan and regional fire management plans (e.g. for Bimberi Nature Reserve). All future fire management plans will continue to protect the Ginini Flats Wetland Complex from planned fire and wildfire.
Prevent the transfer of Epizootic Haematopoietic Necrosis Virus (EHNV) into the Ginini Flats Wetlands Complex.	2. Source the supply of water for fire suppression in or near Ginini Flats from an EHNV free supply such as Cotter, Bendora or Corin dams or mains water supply and include this requirement in all future fire management plans.
Maintain the Ginini Flats Wetland Complex as a functioning ecosystem through rehabilitation and monitoring of burned areas.	3. Develop and implement targeted management responses for fire affected areas (e.g. an immediate post-fire risk assessment, and through restricting access in the post-fire recovery period). 4. Maintain accurate fire history via mapping of extent, frequency, severity (or intensity) and regeneration. 5. Continue monitoring the 2003 fire bog rehabilitation program at five yearly intervals (e.g. in 2018 and 2023). 6. Finalise the report on the 2003 bog restoration works, including recommendations, and undertake further actions if required.

6.2 AMELIORATION OF HYDROLOGICAL CHANGES

The hydrology and water balance of the Ginini Flats Wetland Complex are fundamental to the vegetation communities, fauna habitats and the development and integrity of the peatland on site. Any changes in the hydrological regime due to drought, climate change, fires or changes in the catchment (for example clearing for infrastructure, groundwater extraction, drainage works) have the potential to influence water table levels and water balance within the wetland, and hence the peatlands and vegetation communities.

MANAGEMENT STRATEGY: AMELIORATION OF HYDROLOGICAL CHANGES	
OBJECTIVE	**ACTION**
Maintain and, where feasible and desirable, improve the hydrological function of the Ginini Flats Wetland Complex.	7. Prepare a report reviewing the rehabilitation techniques employed in the post-2003 fire restoration works and research, and assess their effectiveness in terms of hydrological processes. Develop recommendations for ongoing rehabilitation works, and for strategies and indicators to guide where and when such rehabilitation should occur in the future if similar fire impacts occur. 8. Apply the ACT Hydrogeological Landscapes project case study outcomes (Appendix H) to better elucidate current threats to catchment hydrology within Ginini Flats Wetland Complex and develop strategies to minimise risks to ecosystems. The strategy may include monitoring, such as survey of soil moisture and ground water movement, and impact mitigation. 9. Protect water quality in all streams by minimising the impact of erosion caused by management infrastructure and use (such as fire trails, road works and creek crossings). This includes applying a high standard of soil erosion control measures and keeping any new works to an absolute minimum.

6.3 PROTECTION AND REHABILITATION OF PEATLAND

Peat bogs such as Ginini Flats are important components of aquatic and terrestrial systems as they are able to influence ecosystem function by storage of organic matter, alteration of hydrology and interception or transformation of nutrients. Peatlands influence downstream water quality and represent a long-term saturated zone that would not otherwise occur if the area was composed of the native mineral soil. The stored peat biomass also represents long-term storage of both micro-nutrients (metals) and macro-nutrients (carbon, nitrogen and phosphorous). Peatlands also play a role in global carbon storage over millennia, and have the potential to release some of this store under a changing climate (Charman, cited in Wild et al. 2010).

Peatlands are the product of complex interactions between biotic factors (growth rate, decomposition, exclusion of other plants) and abiotic conditions (water supply, temperature, topography). The distinct hydrological functioning and carbon cycling of the Ginini Flats Wetland Complex results in conditions well suited to growth of the dominant bog species, *Sphagnum cristatum*. In turn, this species modifies local conditions to give it a competitive advantage over other plants, making the bog environment acidic, nutrient poor, cool and anoxic (van Breemen, cited in Wild et al. 2010).

MANAGEMENT STRATEGY: PROTECTION AND REHABILITATION OF PEATLAND	
OBJECTIVE	**ACTIONS**
Maintain and enhance the *Sphagnum* bogs and fens ecological communities and peat formation processes that occur on site.	10. Continue to conduct systematic vegetation surveys, mapping and long-term monitoring to support research that assists in identifying specific management requirements for bogs and fens species and communities, including responses to: (a) planned and unplanned fire; (b) climate change; and (c) impacts of threats such as introduced species. 11. Restrict access to the Ginini Flats bogs and fens except for research and management purposes. 12. Restrict the use of heavy machinery for fire suppression purposes or any other reason in the immediate catchment of the wetlands.
Protect the peat deposits under the *Sphagnum* bogs and fens in the Ginini Flats Wetland Complex from degradation or destruction.	13. Continue post-fire rehabilitation work to assist the natural regeneration of the Ginini Flats *Sphagnum* bogs following the 2003 fires, and adapt management according to the results of monitoring and assessment. 14. Rehabilitate damaged areas of the *Sphagnum* bogs and fens ecological community on the site (e.g. from fire, historic grazing, infrastructure damage, areas containing erosion tunnels, flow line incisions and bog collapse).

6.4 INVASIVE SPECIES MANAGEMENT AND CONTROL

Pest animal management is a core responsibility of Namadgi National Park management. Targeted pest animal management programs are essential to maintain bog and fen biodiversity, protect the ecosystem service of high quality water provision, assist in ecological restoration, and protect landscapes and recreational amenity from disturbance and degradation.

Because bogs and fens occur as relatively small patches within the overall landscape of Namadgi National Park, the most effective programs for reducing the impacts of feral animals on the ecological community should be conducted at the landscape scale.

6.4.1 Pest animals

MANAGEMENT STRATEGY: INVASIVE ANIMAL MANAGEMENT AND CONTROL	
OBJECTIVE	**ACTIONS**
Minimise the impact of invasive animals on the ecological values of the Ginini Flats Wetland Complex (consistent with national and regional invasive animal plans, where applicable).	15. Ensure that the co-operative invasive fauna management programs developed for Namadgi National Park address the management of feral pigs, feral horses and other pest animals within the Ginini Flats Wetland Complex. Continue delivering, monitoring and evaluating existing pest management programs for pigs and feral horses in Namadgi National Park. Invasive animal management programs should include consultation with stakeholders and neighbours and accord with the ACT Vertebrate Pest Management Strategy and threatened species action plans. 16. Where management planning is absent, establish a program to monitor for the presence and impact of goats, cattle, deer, foxes, cats, rabbits and European wasps that are not currently actively managed. 17. Develop pest management programs specifically for any new pest animal species likely to have an impact on the wetlands.

6.4.2 Weeds

Monitoring of the larger of the ACT bogs and fens following the 2003 fire found that willows had appeared in a number of the bogs and fens; these were removed. New occurrences were noted in 2013 in Nursery Swamp. In 2013 a large stand of mature willows was discovered in NSW bushland west of Cotter Source Bog and removed by Parks and Conservation Service staff and willows have also been found and removed from Ginini West; continued monitoring and removal of seedlings is required.

Blackberries have been found and controlled by the Parks and Conservation Service in ridges surrounding the Cotter Source Bog and ongoing control is required at Gibraltar Bog. Blackberries are also a significant threat at other ACT bogs and ongoing monitoring and management is required.

Weed invasion is a factor in grasslands surrounding the Ginini Flats Wetland Complex. Following the 2003 fire, weeds such as Sheep Sorrel (*Acetosella vulgaris*), thistles (*Carduus* spp.) and cat's ear (*Hypochaeris* spp.) were recorded in burned areas of bogs. These weeds declined in abundance as regeneration of native species occurred. Sweet Vernal Grass (*Anthoxanthum odoratum*) is present in the Ginini West and Cheyenne wetlands, on the Ginini ski run, in the grasslands around Snowy Flat on the western edge opposite Pryor's Pines and all along the Mt Franklin Road. It remains a significant problem. Orange Hawkweed (*Hieracium aurantiacum*) is of potential concern for invasion into the surrounding grasslands. There is a seed source of this weed in the west of Namadgi National Park, and the grasslands surrounding the bogs and fens will be a prime location for their establishment should seeds reach these areas. Mouse-ear Hawkweed (*Hieracium pilosella)* has been found at Nursery Swamp. African Lovegrass (*Eragrostis curvula*), widespread in the region, may also be spread by recreational users and vehicles into surrounding grasslands. Monitoring and management of such weeds should continue to be a part of the weed program of Namadgi National Park.

MANAGEMENT STRATEGY: WEEDS MANAGEMENT AND CONTROL	
OBJECTIVE	**ACTIONS**
Minimise the impacts of weeds (woody and non-woody) on the Ginini Flats Wetland Complex (consistent with national and regional weed management plans, where applicable).	18. Pest plant management programs developed for Namadgi National Park will address the management of weeds within the Ginini Flats Wetland Complex. Continue delivering, monitoring and evaluating existing pest plant management programs in Namadgi National Park. 19. In conjunction with action 18, establish an ongoing weed monitoring and mapping program in the immediate catchment area to track the extent of weed species of concern and the effectiveness of weed management programs. Adapt weed management to the findings.

6.4.3 Pathogens

Infection of amphibians with chytrid fungus is listed as a key threatening process under the EPBC Act and the Australian Government has prepared a threat abatement plan for infection of amphibians with chytrid fungus resulting in chytridiomycosis (DEH, 2006). The plan aims to minimise the impact of this pathogen on amphibian populations by preventing further spread of the fungus and decreasing the impact of infection on currently affected populations. Objectives and actions to achieve these aims are outlined in the threat abatement plan.

The spread of the Epizootic Haematopoietic Necrosis Virus (EHNV), which is a virus of some fish species, can be halted by ensuring that hygiene protocols are followed by all persons entering the *Sphagnum* bogs and fens.

MANAGEMENT STRATEGY: PATHOGEN MANAGEMENT AND CONTROL	
OBJECTIVE	**ACTIONS**
Minimise the impacts of pathogens/diseases on the Ginini Flats Wetland Complex (consistent with national and regional disease management plans).	20. Hygiene protocols should be followed by all people entering the Ginini Flats Wetland Complex. 21. A. Assess the latest science on the chrytid fungus and other pathogens to assist minimising their impact. B. Where possible, identify, prevent, eradicate, contain or control pathogens and diseases where they threaten the ecological community.

6.5 PROTECT AND MONITOR THREATENED AND OTHER FAUNA

Action Plan No. 6: Northern Corroboree Frog (*Pseudophryne pengilleyi*) (second edition), outlines the necessary actions to protect the species. The objective of the action plan is to maximise the long-term survival of viable, natural populations at sites across its geographical range in the ACT (ACT Government, 2011). Strategies to achieve this include: protection of the habitats and sites critical to the species' survival; increasing community awareness of the need to protect the species and its habitat; and a captive breeding and release program.

This management plan addresses the objectives to protect Northern Corroboree Frog habitat listed in the action plan, including protecting the habitat from:

- the impacts of construction and maintenance of access tracks
- fire and the impacts of fire management and suppression activities
- the impacts of feral animals, weeds and pathogens.

Milner et al. 2015 recommends on-going monitoring of the Broad-toothed Rat (*M. fuscus*) is required to determine whether ACT populations are experiencing the longer-term declines that appear to have occurred in other areas. The 2015 study provides baseline information on habitat parameters and an index of population size of *M. fuscus* and introduced predators and competitors against which future changes can be assessed and key threatening processes can be monitored.

The interdependence of plants and animals in the Ginini Flats Wetland Complex's ecosystem also warrants assessment and monitoring of other native fauna on the site.

MANAGEMENT STRATEGY: PROTECTING THREATENED FAUNA SPECIES	
OBJECTIVE	**ACTION**
Maintain and improve habitat for the Northern Corroboree Frog and other native fauna species.	22. Continue implementing the Northern Corroboree Frog Action Plan. Assess and monitor populations of other fauna species at the site, including the Broad-toothed Rat (*M. fuscus*).

6.6 MANAGING RECREATION AND VISITOR IMPACTS

Some of the *Sphagnum* bogs in the Ginini Flats Wetland Complex are still recovering from the impact of the 2003 fire and must be protected from additional pressure, including the impact of visitors. Unfortunately, the wetlands are close to public access roads. Visitor impacts that are likely to have a negative effect on the *Sphagnum* bogs include trampling of *Sphagnum* moss and spreading of weed seed and possibly pathogens. Trampling in sensitive vegetation such as *Sphagnum* moss has shown significant impact after only 30 passes, and recovery from that level of impact has taken 3–5 years (Whinam et al. 2003). Walkers have been found to be significant in spreading weed seeds in Kosciusko National Park (Mount and Pickering 2009).

The most effective way to manage visitor impacts on *Sphagnum* bogs is to avoid having visitors enter them.

Management of visitor impacts on the bogs can be achieved through education (including signs), avoiding directing people into bog areas and removing (or not maintaining) access tracks to bogs. While visitors require a permit to camp in the upper Cotter Catchment (south of Corin Dam), the permit conditions do not currently provide information about the fragility of the bogs.

Researchers require a permit to work in Namadgi National Park. Search and rescue exercises, and orienteering and rogaining events require permits. The informal track to Ginini West has been allowed to rehabilitate and should not be re-established. It is preferable that access to Ginini West (by researchers and other persons) is via navigation across country using a map or GPS rather than following a defined track.

Recreation facilities should not be developed close to the Ginini Flats Wetland Complex unless an environmental assessment demonstrates no impact.

MANAGEMENT STRATEGY: RECREATION AND VISITOR MANAGEMENT	
OBJECTIVES	**ACTIONS**
Recreation within the Ramsar site is managed to conserve and protect sensitive vegetation communities of the site.	23. Promote awareness about the Ramsar site and its vulnerability to damage by recreational activities to user groups through various media and interpretation methods, e.g. signage. 24. Include information about avoiding entering *Sphagnum* bogs in the Ginini Flats area in camping permits for the Upper Cotter Catchment area.
Recreation and visitor use do not negatively affect the Ginini Flats Wetland Complex.	25. Develop best practice guidelines for visitors to the ecological community and ensure these are followed. 26. Avoid trampling impacts by implementing measures to restrict access to Ginini Flats bogs and fens. 27. When permitted, access to Ginini West (by researchers and other persons) is via navigation across country using a map or GPS rather than following a defined track.

6.7 MANAGING INFRASTRUCTURE CHANGES AND MAINTENANCE

Schedule 4 of the *ACT Planning and Development Act 2007* specifies that any proposal with the potential to have a significant impact on land reserved for the purpose of a wilderness area, national park, nature reserve or special purpose reserve requires an environmental impact assessment or an environmental significance opinion from the Conservator of Flora and Fauna that the proposal is not likely to have a significant adverse environmental impact.

The EPBC Act is applicable to the ACT *Sphagnum* bogs and fens ecological community because:

» they are part of the Alpine *Sphagnum* Bogs and Associated Fens nationally endangered ecological community

» the Northern Corroboree Frog is a threatened species

» Namadgi National Park is included in the Australian Alps National Parks and Reserves listing in the National Heritage List

» the Ginini Flats Wetland Complex is a Ramsar site.

All these are matters of national environmental significance under the EPBC Act, which requires that any action which may have a significant impact on a matter of national environmental significance should be referred to the Commonwealth Minister for the Environment, who will determine whether the action requires EPBC Act assessment and approval. The Commonwealth and ACT governments have a bilateral agreement under the EPBC Act regarding environmental impact assessment (DEWHA 2009).

MANAGEMENT STRATEGY: INFRASTRUCTURE CHANGES AND MAINTENANCE	
OBJECTIVE	**ACTIONS**
Protect hydrology and water quality by avoiding and/ or minimising impacts of infrastructure and road and track construction and maintenance.	28. Avoid any new infrastructure, road and track construction and maintenance works within the catchment of the Ginini Flats Wetland Complex. 29. Where unavoidable construction or maintenance takes place, minimise the impact of erosion by applying a high standard of soil erosion control measures. 30. Construct improvements to river crossings on tracks near or within the Ginini Flats Wetland Complex catchment in a way that does not affect their natural drainage.

6.8 AMELIORATION OF CLIMATE CHANGE IMPACTS

Habitat protection is considered the optimal action for assisting the majority of species to adapt to climate change within budgetary limitations (Steffen & Hughes 2013). *Sphagnum* bogs and fens are protected by virtue of their location within Namadgi National Park and related ACT legislation and policies. The ecological community is also protected under Commonwealth legislation.

To limit the negative impacts of climate change, ecosystem resilience needs to be maximised by managing threats such as weeds, pest animals and fire. Predicted climate change is likely to increase these threats, and a proactive approach to manage them is vital.

In 2009, the Research and Planning unit of ACT Parks Conservation and Lands, with the assistance of the Australian National University (mapping), mapped the bogs and fens of the ACT to provide a baseline assessment of their condition, against which future changes in their characteristics could be assessed. The project's report, *Sphagnum* Bog Mapping and Recovery Plan: Technical Report 20 (Macdonald, 2009) made recommendations for establishing long-term climate change monitoring sites at Ginini Flats Wetland Complex Ramsar site:

> "Establish base line and long-term monitoring of the key functions of bogs (filtration, water storage, peat hydrology, water release rates, carbon sequestration) with respect to climate variables and rehabilitation activities. Once established, monitoring of bog functionality will provide feedback on the impacts of climate change and bog functional response so that actions may be implemented to reduce losses of bog ecosystem services."

Uncertainties regarding the local effects of climate change mean that development of precise management responses is not possible. However, appropriate responses include:

- incorporating available knowledge about climate change into assessment of the potential effects of management actions, monitoring of high risk species and ecological communities (e.g. Northern Corroboree Frog, *Sphagnum* bogs and fens) and encouraging research into the effects of climate change on the biota of Namadgi National Park
- minimising threats other than climate change that can place stress on species and ecological communities (e.g. fire, pest animals, weeds and pathogens)
- evaluating ways to minimise the effects of climate change on high risk species and ecological communities.

As a small jurisdiction, it is not possible for the ACT to address climate change and its impacts in isolation. A collaborative approach across the Australian Alps and Southern Tablelands region will be most effective in addressing the impacts of climate change.

Implementing all other actions in this management plan to manage and reduce the impacts of threats will contribute to making the ecological community more resilient to climate change. These actions are crucial to maintaining the extent and condition of the ecological community.

MANAGEMENT STRATEGY: AMELIORATION OF CLIMATE CHANGE IMPACTS	
OBJECTIVE	**ACTIONS**
Maximise ecosystem resilience to climate change by integrating findings from monitoring and research into site management.	31. Establish a long-term climate change monitoring site in the immediate vicinity of the Ginini Flats Wetland Complex to better understand the impacts of climate change on the wetland. Continue to collaborate with other agencies (e.g. Icon Water, Australian Alps national parks) in measuring the impacts of climate change on bogs, fens and affected biota in the vicinity of the Ginini Flats Wetland Complex. 32. Incorporate the knowledge gained from monitoring and assessment into management actions that maximise ecosystem resilience of the site. 33. Further develop and use climate models to identify threats to the site from climate change impacts in different parts of the landscape to identify where control of invasive plants and animals will be most critical. Develop a climate change impact conceptual model of risks to the site and revise regularly as impacts and feedback mechanisms are identified. 34. Identify characteristics of the ecological community on the site that may make some patches more resilient to UV-B (e.g. greater shrub cover, aspect, shading proximity, snow cover duration). Consider and model these variables in rehabilitation/restoration triage spatial fire protection planning. Monitor effects of UV-B and, if possible, develop management responses.

6.9 ABORIGINAL AND EUROPEAN CULTURAL HERITAGE VALUES

Significant gaps in knowledge and understanding relating to Aboriginal use of Namadgi are apparent due to the fact that archaeological research has tended to be opportunistic rather than systematic. Anthropological research has been extremely limited. There is an opportunity for greater involvement of the local Aboriginal community in the management and promotion of the park now that the Ngunnawal community is re-establishing ties to the area.

The fabric of many of Namadgi's cultural heritage places is fragile, vulnerable and expensive to maintain but resources for the maintenance of such places are limited.

There is the opportunity to use the skills, knowledge and volunteer labour of community groups to help conserve heritage places.

Efforts to protect Namadgi's natural values need to be undertaken with an awareness of the potential impacts of activities on the cultural values of the park's heritage places.

The Ramsar Site and the values of the wetlands are poorly known and recognised (ACT Government 2001).

MANAGEMENT STRATEGY: PRESERVING ABORIGINAL AND EUROPEAN CULTURAL HERITAGE VALUES	
OBJECTIVE	**ACTIONS**
Identify, conserve and protect Aboriginal and European cultural heritage sites in and surrounding the Ginini Flats Wetland Complex and, where appropriate, interpret and promote the sites to retain and foster community associations and an appreciation of the past.	35. Encourage and support further research to identify and assess the significance of Aboriginal sites in and surrounding the Ginini Flats Wetland Complex.

6.10 EDUCATION AND COMMUNICATION STRATEGIES

6.10.1 Education and Interpretation

Off-site interpretation of the *Sphagnum* bogs and fens is currently passive; information is provided in a display at the Namadgi National Park Visitor Centre, and on interpretation/information signs at the Mt Ginini car park. While the information sign covers the Ginini Flats Wetland Complex it does not provide directions to them. This interpretation panel is located so people heading south along the Mt Franklin Road, where bogs occur near the road, are informed about the values provided by bogs. However, the panel omits to explain how fragile or how easily damaged the bogs are and the importance of not entering them.

Much effort has already gone into public education to raise awareness of the Northern Corroboree Frog and the captive breeding program at Tidbinbilla Nature Reserve. It is vital that the public is aware that the species' key habitat is endangered and that its long-term conservation depends on quality habitat. However, conservation of healthy ecological communities goes beyond conserving a single species to ensure survival of all relevant species and effective ecosystem services. It is important that visitation is not encouraged when communicating about the ACT's *Sphagnum* bogs and fens.

There are various interpretation opportunities provided by the *Sphagnum* bogs and fens, for example to interpret the post-2003 fire rehabilitation work and research done in Namadgi National Park and across the Australian Alps.

6.10.2 Neighbours

There is a history of the Parks and Conservation Service working with the Australian Alps National Parks Cooperative Management Program to conserve the *Sphagnum* bogs and fens across the Australian Alps; this developed after the 2003 fires. The Australian Alps Liaison Committee (AALC) (which includes representatives from alpine parks in NSW, VIC, ACT and the Commonwealth Government), commenced a mire restoration program in 2003 which was implemented through the 'Alps Mire Restoration and Research Group'. To ensure knowledge transfer between researchers and on-ground staff, the group held a series of workshops between 2003 and 2009 on *Sphagnum* bog rehabilitation techniques and approaches (Good et al. 2010). Recently, the Australian Alps Water Catchments Reference Group has moved to investigate the feasibility for developing alps-wide monitoring procedures and data collection guidelines to enable easier cross border data sharing and cooperative management.

MANAGEMENT STRATEGY: EDUCATION AND COMMUNICATION STRATEGIES	
OBJECTIVE	**ACTIONS**
Communicate effectively with partners, stakeholders and the community.	36. Develop and implement a Ginini Flats Wetland Complex Ramsar Site Communication, Education and Public Awareness Plan.
Through expanded education opportunities, the community supports conservation measures to prevent the decline of the Ginini Flats Wetland Complex.	37. Incorporate interpretation about *Sphagnum* bogs and fens, their role in conservation and habitat provision, and the need for protection into programs that focus on the Northern Corroboree Frog. 38. Explore further opportunities for providing the public with additional information about the Ramsar site, including through additional and improved interpretive signage at key locations e.g. Mount Ginini carpark and entrances to backcountry walking tracks, without improving site access.

6.10.3 Community involvement including volunteers

Volunteers have assisted in the monitoring of weeds such as willows in the bogs, although there has been relatively little community involvement in the management of the ecological community. Given its sensitivity to visitor impacts such as trampling, and the potential to spread the EHNV, all activities have been under the direct supervision of Parks and Conservation Service rangers.

MANAGEMENT STRATEGY: MANAGEMENT OF VOLUNTEER ACTIVITIES	
OBJECTIVE	**ACTIONS**
Promote regional consistency in volunteer activities.	39. Continue to involve volunteers in as many aspects of management implementation as possible, providing safe, supported and engaging opportunities. 40. Continue involvement in the Australian Alps National Parks Water Catchments Reference Group to ensure a regionally consistent approach to management and monitoring of *Sphagnum* bogs and fens.
Volunteer activities do not negatively affect the *Sphagnum* bogs and fens.	41. Ensure park staff directly supervise all volunteer assisted management programs in or near the Ginini Flats Wetland Complex. Restrict numbers for volunteer activities to the minimum number needed to carry out the work safely.

6.11 MANAGING RESEARCH AND MONITORING

Research and monitoring are fundamental to the management of the Ginini Flats Wetland Complex. The results of research and monitoring will help reduce knowledge gaps, detect management triggers, assess limits of acceptable change and identify potential changes in ecological character.

Research activities have the potential to damage the *Sphagnum* bogs through trampling, spread of weed seeds and pathogens and, depending on the activity, to physically alter components of the bogs and peat functionality. The values of any research should be carefully weighed against any potential impacts, with detrimental impacts avoided or minimised.

MANAGEMENT STRATEGY: MANAGING RESEARCH AND MONITORING	
OBJECTIVE	**ACTIONS**
Undertake and support research and monitoring that builds knowledge and understanding of the Ginini Flats Wetland Complex, including their constituent components and species, and leads to effective management and conservation of the ecological community.	42. Prepare an inventory (including a bibliography) of past and current surveys, monitoring and research at Ginini Flats Wetland Complex. 43. Analyse survey, monitoring and research requirements and priorities and prepare a research and monitoring strategy for Ginini Flats that identifies and addresses current knowledge gaps. See Table 3 below (extracted from the approved Ecological Character Description) for guidance. 44. Identify and develop an agreed method for determining baseline condition of the site (consider flora, fauna and non-biotic indicators; using information contained in the approved Ecological Character Description). 45. Update the Limits of Acceptable Change, as identified in the 2010 ECD, as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of critical components, processes, benefits or services of the Ramsar wetland. 46. Continue to support and conduct systematic vegetation surveys, mapping and long-term monitoring to support research that assists in identifying specific management requirements for species and communities within the Ginini Flats Wetland Complex. 47. The Conservator for Flora and Fauna must monitor the implementation of the Ramsar wetland management plan and report to the Minister about the wetland management plan at least once every five years.

Table 3: Monitoring programs recommended in Wild et al. 2010

Monitoring programs are designed to inform management. In the case of Ramsar sites, monitoring programs are designed to inform management actions directed at maintaining the ecological character of the site.

The ECD for the Ginini Flats Wetland Complex (Wild et al. 2010) outlined the following monitoring needs for key components and threats at the site, which should be considered in future research and monitoring programs.

Component/ process	Objective	Indicator or variable for measurement	Frequency	Priority
Hydrology				
Magnitude, duration and seasonality of inflows and outflows	To determine the water balance of the site and establish limits of acceptable change parameters	Surface and groundwater inflows and outflows through catotelm and acrotelm	Seasonally	Medium
Water quality				
Magnitude, duration and seasonality of water quality parameters	Determine if there are changes in water quality parameters	TP,TN, pH, turbidity	Seasonally	Medium
Nutrient and carbon cycling				
Peat formation and retention	To determine if peat levels are increasing, stabilising or decreasing	Depth of peat, emissions of oxidating peats	Bi-annually	Medium
Biota				
Amphibians	To continue current monitoring program to determine status of the population	Total numbers of calling males and habitat parameters (availability of pools)	Annually during breeding season	High
Sphagnum	Establish baseline for *Sphagnum* recovery	Plot based following Clark (1980)	Five yearly	Medium
Vegetation	Baseline and set limits of acceptable change	Extent and condition of vegetation communities (aerial photography)	Bi-annual or disturbance event based	Medium
Macro-invertebrates 2	Establish baseline data and set limits of acceptable change	Number of taxa Presence/absence of families (Compare with Suter et al., 2002 for reference)	Annually in spring and autumn	Medium
Fish and crayfish	Determine status/ persistence of *Galaxius olidus* and *Euastacus reiki* in the Upper Cotter Catchment.	Abundance (or presence/ absence) of G. olidus and *Euastacus reiki*	Bi-annual to annual	Medium
Birds	Species abundance and composition	Presence of threatened or migratory species	Bi-annual or event based	Medium
Feral pigs	Continue baseline data collection and detect population changes	Total abundance of animals Evidence-based counts of disturbance impacts (e.g. number of rootings per ha)	Bi-annual or event based	Medium

7. MANAGEMENT ACTIONS, RESOURCES AND RESPONSIBILITIES

The prescribed management actions for the Ginini Flats Wetland Complex will maintain and, in some cases, restore the ecological character of the site. The following table (Table 4) consolidates all proposed management objectives and actions, identifies responsibility and sets priorities for implementation.

Table 4: Consolidated Management Objectives and Actions

Management strategy and objective	Action 1) Existing resources 2) new resources needed	Limits of acceptable change[1]	Priority and Responsibility
Fire Management			
Prevent fire from entering the Ginini Flats Wetland Complex so the values of the ecological community are protected.	1. Incorporate appropriate management guidelines for fire suppression in the ecological community, as outlined in the ACT Ecological Guidelines for Fuel and Fire Management Operations, into the current ACT Strategic Bushfire Management Plan and regional fire management plans (e.g. for Bimberi Nature Reserve). All future fire management plans will continue to protect the Ginini Flats Wetland Complex from planned fire and wildfire (1).	LAC 7 An increase in fire frequency greater than 25 years or inferred increase in intensity.	**HIGH** Land custodian in consultation with ESA
Prevent the transfer of Epizootic Haematopoietic Necrosis Virus (EHNV) into the Ginini Flats Wetland Complex.	2. Source the supply of water for fire suppression in or near Ginini Flats from an EHNV free supply such as Cotter, Bendora or Corin dams or mains water supply and include this requirement in all future fire management plans (1).		**HIGH** Land custodian
Fire Rehabilitation			
Maintain the Ginini Flats Wetland Complex as a functioning ecosystem through rehabilitation and monitoring of burned areas.	3. Develop and implement targeted management responses for fire affected areas (e.g., an immediate post-fire risk assessment, and through restricting access in the post-fire recovery period) (1) & (2). 4. Maintain accurate fire history via mapping of extent, frequency, severity (or intensity) and regeneration (1) & (2). 5. Continue monitoring the 2003 fire bog rehabilitation program at five yearly intervals (e.g. in 2018 and 2023) (1) & (2). 6. Finalise the report on the 2003 bog restoration works, including recommendations, and undertake further actions if required (1) & (2).	LAC 1 Qualitative evidence of reductions in functionality of hydrology such as breaking of pools, development and persistence of erosion pavements or hydrophobic peat surfaces following fire disturbance for a period of greater than five years.	**MEDIUM** EPSD - Parks and Conservation

Management strategy and objective	Action 1) Existing resources 2) new resources needed	Limits of acceptable change[1]	Priority and Responsibility
Hydrological Change			
Maintain and, where feasible and desirable, improve the hydrological function of the Ginini Flats Wetland Complex.	7. Prepare a report reviewing the rehabilitation techniques employed in the post-2003 fire restoration works and research, and assess their effectiveness in terms of hydrological processes. Develop recommendations for ongoing rehabilitation works, and for strategies and indicators to guide where and when such rehabilitation should occur in the future if similar fire impacts occur (2).	**LAC 1** Qualitative evidence of reductions in functionality of hydrology such as breaking of pools, development and persistence of erosion pavements or hydrophobic peat surfaces following fire disturbance for a period of greater than five years.	**HIGH** EPSD Conservation Research
	8. Apply the ACT Hydrogeological Landscapes project case study outcomes (Appendix H) to better elucidate current threats to catchment hydrology within Ginini Flats Wetland Complex and develop strategies to minimise risks to ecosystems. The strategy may include monitoring, such as survey of soil moisture and ground water movement, and impact mitigation (2).		EPSD Conservation Policy AND land custodian
	9. Protect water quality in all streams by minimising the impact of erosion caused by management infrastructure and use (such as fire trails, road works and creek crossings). This means applying a high standard of soil erosion control measures and keeping any new works to an absolute minimum (1).		Land custodian
Protecting Peatlands			
Maintain and enhance the *Sphagnum* bogs and fens ecological communities and peat formation processes that occur on site.	10. Continue to conduct systematic vegetation surveys, mapping and long-term monitoring to support research that assists in identifying specific management requirements for bogs and fens species and communities, including responses to: (a) planned and unplanned fire; (b) climate change; and (c) impacts of threats such as introduced species (1).	**LAC 5** Loss, or extended (> 2 seasons) absence of keystone including (but not restricted to): *Sphagnum cristatum*, *Empodisma minus*, *Richea continentis*, *Epacris paludosa*, *Baloskion australe*, *Baeckea gunniana*, *Carex gaudichaudiana*, *Myriophyllum pedunculatum* and *Poa costiniana* from Ginini Flats Wetland Complex. **LAC 6** Reduction or absence of recruitment of new individuals or ramets for these species.	**HIGH** EPSD Conservation Research
	11. Restrict access to the Ginini Flats Wetland Complex except for research and management purposes (1).		Land custodian Conservator of Fauna & Flora
	12. Restrict the use of heavy machinery for fire suppression purposes or any other reason in the immediate catchment of the wetlands (1).		Land custodian

Management strategy and objective	Action 1) Existing resources 2) new resources needed	Limits of acceptable change[1]	Priority and Responsibility
Protect the peat deposits under the *Sphagnum* bogs and fens in the Ginini Flats Wetland Complex from degradation or destruction.	13. Continue post-fire rehabilitation work to assist the natural regeneration of the Ginini Flats *Sphagnum* bogs following the 2003 fires, and adapt management according to the results of monitoring and assessment (1).	**LAC 2** Greater than 20% change in extent (9.8 +/– 0.5 ha) of peat surfaces and evidence of oxidation.	**MEDIUM** Land custodian
	14. Rehabilitate damaged areas of the *Sphagnum* bogs and fens ecological community on the site (e.g. from fire, historic grazing, infrastructure damage, areas containing erosion tunnels, flow line incisions and bog collapse) (2).	**LAC 3** Greater than 20% change in extent (9.8 +/– 0.5 ha) and a lack of recovery five years following disturbance (e.g. fire) that removes arcotelm or acrotelm and catotelm **LAC 4** Peat accumulation of less than 3.5 cm per century or growth of *Sphagnum* spp. less than 30 cm/yr. Loss of *Sphagnum* spp. propagules for recruitment following a large disturbance event ongoing for a period of five years.	Land custodian
Invasive animals			
Minimise the impact of invasive animals on the ecological values of the Ginini Flats Wetland Complex (consistent with national and regional invasive animal plans, where applicable).	15. Ensure that the co-operative invasive fauna management programs developed for Namadgi National Park address the management of feral pigs, feral horses and other pest animals within the Ginini Flats Wetland Complex. Continue delivering, monitoring and evaluating existing pest management programs for pigs and feral horses in Namadgi National Park. Invasive animal management programs should include consultation with stakeholders and neighbours and accord with the ACT Vertebrate Pest Management Strategy and threatened species action plans (1). 16. Where management planning is absent, establish a program to monitor for the presence and impact of goats, cattle, deer, foxes, cats, rabbits and European wasps that are not currently actively managed (2). 17. Develop pest management programs specifically for any new pest animal species identified in the existing and future monitoring programs (2).	**LAC 1** Qualitative evidence of reductions in functionality of hydrology such as breaking of pools, development and persistence of erosion pavements or hydrophobic peat surfaces following fire disturbance for a period of greater than five years.	**HIGH** Land custodian

Management strategy and objective	Action 1) Existing resources 2) new resources needed	Limits of acceptable change[1]	Priority and Responsibility
Weeds			
Minimise the impacts of weeds (woody and non-woody) on the Ginini Flats Wetland Complex (consistent with national and regional weed management plans, where applicable).	18. Pest plant management programs developed for Namadgi National Park will address the management of weeds within the Ginini Flats Wetland Complex. Continue delivering, monitoring and evaluating existing pest plant management programs in Namadgi National Park (1). 19. In conjunction with action 18, establish an ongoing weed monitoring and mapping program in the immediate catchment area to track the extent of weed species of concern and the effectiveness of weed management programs. Adapt weed management to the findings (2).	**LAC 1** Qualitative evidence of reductions in functionality of hydrology such as breaking of pools, development and persistence of erosion pavements or hydrophobic peat surfaces following fire disturbance for a period of greater than five years.	**MEDIUM** Land custodian EPSD Conservation Research & Land custodian
Pathogens			
Minimise the impacts of pathogens/ diseases on the Ginini Flats Wetland Complex (consistent with national and regional disease management plans).	20. Hygiene protocols should be followed by all people entering the Ginini Flats Wetland Complex (1). 21A. Assess the latest science on the chrytid fungus and other pathogens to assist minimising their impact (1). 21B. Where possible, identify, prevent, eradicate, contain or control pathogens and diseases where they threaten the ecological community (1).		**MEDIUM** Land custodian EPSD Conservation Research Land custodian
Threatened Fauna			
Maintain and improve habitat for the Northern Corroboree Frog and other native fauna species.	22. Continue implementing the Northern Corroboree Frog Action Plan. Assess and monitor populations of other fauna species at the site, including the Broad-toothed Rat (*M. fuscus*) (1).	**LAC 8** Absence of calling males in two successive monitoring seasons **LAC 9** Evidence of stochastic declines due to disease or limited breeding site availability **LAC 10** Evidence of no suitable habitat due to closing of pools or collapse of system.	**MEDIUM** EPSD Conservation Research AND land custodian

Management strategy and objective	Action 1) Existing resources 2) new resources needed	Limits of acceptable change[1]	Priority and Responsibility
Recreation and visitors			
Recreation within the Ramsar site is managed to conserve and protect sensitive vegetation communities of the site.	23. Promote awareness about the Ramsar site and its vulnerability to damage by recreational activities to user groups through various media and interpretation methods, e.g. signage (2). 24. Include information about avoiding entering *Sphagnum* bogs in the Ginini Flats area in camping permits for the Upper Cotter Catchment area (2).	**LAC 1** Qualitative evidence of reductions in functionality of hydrology such as breaking of pools, development and persistence of erosion pavements or hydrophobic peat surfaces following fire disturbance for a period of greater than five years.	**LOW** Land custodian EPSD - Natural Environment Land custodian with EPSD Natural Environment
Recreation and visitor use do not negatively affect the Ginini Flats Wetland Complex.	25. Develop best practice guidelines for visitors to the ecological community, and ensure these are followed (1). 26. Avoid trampling impacts by implementing measures to restrict unauthorised access to bogs (1). 27. When permitted, access to Ginini West (by researchers and other persons) is via navigation across country using a map or GPS rather than following a defined track (1).		**LOW** Land custodian
Infrastructure and maintenance			
Protect hydrology and water quality by avoiding and/or minimising impacts of infrastructure and road and track construction and maintenance.	28. Avoid any new infrastructure, road and track construction and maintenance works within the catchment of the Ginini Flats Wetland Complex (1). 29. Where unavoidable construction or maintenance takes place, minimise the impact of erosion by applying a high standard of soil erosion control measures (1). 30. Construct improvements to river crossings on tracks near or within the Ginini Flats Wetland Complex catchment in a way that does not affect their natural drainage (1).	**LAC 1** Qualitative evidence of reductions in functionality of hydrology such as breaking of pools, development and persistence of erosion pavements or hydrophobic peat surfaces following fire disturbance for a period of greater than five years.	**LOW** Land custodian

Management strategy and objective	Action 1) Existing resources 2) new resources needed	Limits of acceptable change[1]	Priority and Responsibility
Climate Change			
Maximise ecosystem resilience to climate change by integrating findings from monitoring and research into site management	31. Establish a long-term climate change monitoring site in the immediate vicinity of the Ginini Flats Wetland Complex to measure the impacts of climate change on the wetland. Continue to collaborate with other agencies (e.g. Icon Water, Australian Alps national parks) in measuring the impacts of climate change on bogs, fens and affected biota in the vicinity of the Ginini Flats Wetland Complex (2).	**LAC 1** Qualitative evidence of reductions in functionality of hydrology such as breaking of pools, development and persistence of erosion pavements or hydrophobic peat surfaces following fire disturbance for a period of greater than five years.	**HIGH** EPSD Conservation Research /land custodian
	32. Incorporate the knowledge gained from climate monitoring and assessment into management actions that maximise ecosystem resilience of the site (2).		EPSD Natural Environment
	33. Further develop and use climate models to identify threats to the site from climate change impacts in different parts of the landscape to identify where control of invasive plants and animals will be most critical. Develop a climate change impact conceptual model of risks to the site and revise regularly as impacts and feedback mechanisms are identified (2).		EPSD Conservation Research
	34. Identify characteristics of the ecological community on the site that may make some patches more resilient to UV-B (e.g. greater shrub cover, aspect, shading proximity, snow cover duration). Consider and model these variables in rehabilitation/ restoration triage spatial fire protection planning. Monitor effects of UV-B and, if possible, develop management responses (2).		EPSD Conservation Research
Cultural Heritage			
Identify, conserve and protect Aboriginal and European cultural heritage sites in and surrounding the Ginini Flats Wetland Complex and, where appropriate, interpret and promote the sites to retain and foster community associations and an appreciation of the past.	35. Encourage and support further research to identify and assess the significance of Aboriginal sites in and surrounding the Ginini Flats Wetland Complex (2).		**LOW** EPSD Heritage in consultation with land custodian

Management strategy and objective	Action 1) Existing resources 2) new resources needed	Limits of acceptable change[1]	Priority and Responsibility
Education and communication			
Communicate effectively with partners, stakeholders and the community.	36. Develop and implement a Ginini Flats Wetland Complex Ramsar Site Communication, Education and Public Awareness Plan (2).		**LOW** EPSD Natural Environment/ Land custodian
Through expanded education opportunities, the community supports conservation measures to prevent the decline of the Ginini Flats Wetland Complex.	37. Incorporate interpretation about *Sphagnum* bogs and fens, their role in conservation and habitat provision, and the need for protection into programs that focus on the Northern Corroboree Frog (1). 38. Explore further opportunities for providing the public with additional information about the Ramsar site, including through additional and improved interpretive signage at key locations e.g. Mount Ginini carpark and entrances to backcountry walking tracks, without improving site access. (2).		**MEDIUM** Land custodian in consultation with EPSD Conservation Research Land custodian with funding by EPSD Natural Environment
Volunteer activities			
Promote regional consistency in volunteer activities.	39. Continue to involve volunteers in as many aspects of management implementation as possible, providing safe, supported and engaging opportunities (1). 40. Continue involvement in the Australian Alps National Parks Water Catchments Reference Group to ensure a regionally consistent approach to management and monitoring of *Sphagnum* bogs and fens (1).		**MEDIUM** Land custodian
Volunteer activities do not negatively affect the *Sphagnum* bogs and fens.	41. Ensure park staff directly supervise all volunteer assisted management programs in or near the Ginini Flats Wetland Complex. Restrict numbers for volunteer activities to the minimum number needed to carry out the work safely (1).		**MEDIUM** Land custodian

Management strategy and objective	Action 1) Existing resources 2) new resources needed	Limits of acceptable change[1]	Priority and Responsibility
Research and monitoring			
Undertake and support research and monitoring that builds knowledge and understanding of the Ginini Flats Wetland Complex, including constituent components and species, and leads to effective management and conservation of the ecological community.	42. Prepare an inventory (including a bibliography) of past and current surveys, monitoring and research at Ginini Flats Wetland Complex (2). 43. Analyse survey, monitoring and research requirements and priorities and prepare a research and monitoring strategy for Ginini Flats that identifies and addresses current knowledge gaps. See Table 3 (extracted from the approved Ecological Character Description) for guidance (2). 44. Identify and develop an agreed method for determining condition of the site (consider flora, fauna and non-biotic indicators, using information contained in the approved Ecological Character Description) (2).		**HIGH** EPSD Conservation Research with assistance by EPSD Natural Environment
	45. Update the Limits of Acceptable Change, as identified in the 2010 ECD, as new information becomes available to ensure they more accurately reflect the natural variability (or normal range for artificial sites) of critical components, processes, benefits or services of the Ramsar wetland (2). 46. Continue to support and conduct systematic vegetation surveys, mapping and long-term monitoring to support research that assists in identifying specific management requirements for species and communities within the Ginini Flats Wetland Complex (1).		EPSD Conservation Research
	47. The Conservator for Flora and Fauna must monitor the implementation of the Ramsar wetland management plan and report to the Minister about the wetland management plan at least once every five years (1).		EPSD Natural Environment

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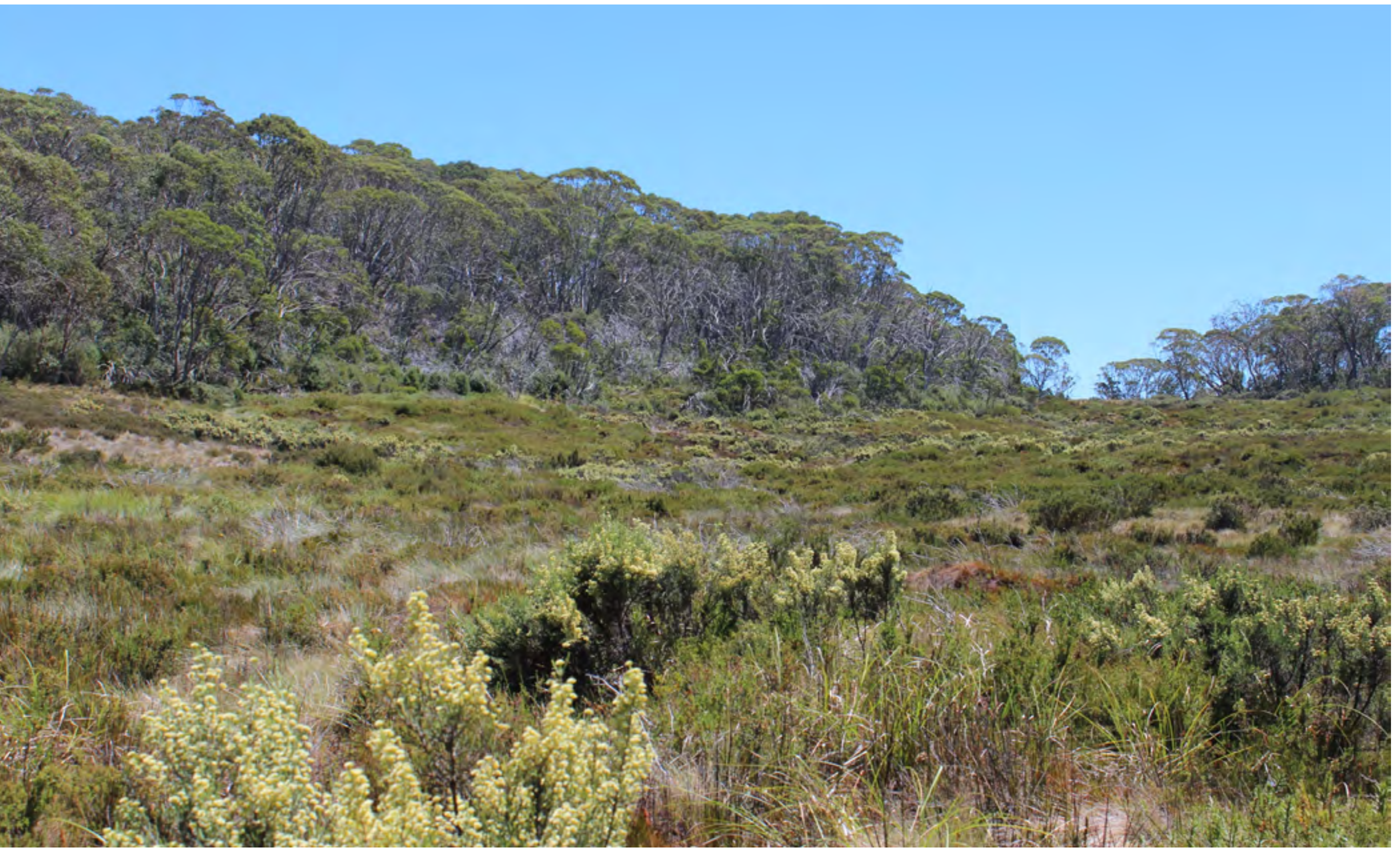

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9. GLOSSARY

Acrotelm
The surface layer of peat, which contains an oscillating water table with variable water content and is subject to periodic air entry, has high hydraulic conductivity and is rich in microbes (Ingram in Wild et al. 2010).

Catotelm
The lower layer of peat, which is constantly saturated and has no air entry, poor hydraulic conductivity and is poor in microbes (Ingram in Wild et al. 2010).

Ecological character
The combination of the ecosystem components, processes and benefits/services that characterise the wetlands at a given point in time.

Hydrophobic
Used to describe soils or peat that has become water shedding where water infiltration does not occur.

Oligotrophic
An oligotrophic plant can live in an environment that offers very low levels of nutrients.

Restiads
A group of monocotyledonous plants in the family *Restio*naceae including *Restio* spp. *Baloskion* spp. and *Empodisma minus* in this instance.

Turbidity
Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates.

10. APPENDIX

APPENDIX A – RAMSAR WETLAND MANAGEMENT PRINCIPLES

This management plan follows the format recommended by *Ramsar Handbook 18 - Managing wetlands* (Ramsar 2010), and is informed by the following documents:

- Ramsar listing of the site (1996)
- Ramsar Information Sheet (1995)
- Conservation advice for the endangered Alpine *Sphagnum* Bogs and Associated Fens Ecological Community (Australian Government 2008)
- Alpine *Sphagnum* Bogs and Associated Fens ecological community National Recovery Plan (Department of the Environment 2015)
- Hydrogeological Landscapes for the Australian Capital Territory (Muller et al. 2016)
- Ginini Flats Wetlands Ramsar Site: Plan of Management (ACT Government 2001)
- Ginini Flats Wetland Complex Draft Management Plan (DEHWA 2010), and
- Ginini Flats Wetland Complex Ramsar site ecological character description (Wild et al. 2010).

The latter provides a baseline description against which to measure changes in the ecological character of the site.

Schedule 6 of the Environment Protection and Biodiversity Conservation Regulations 2000 (Cwlth) – 'Managing wetlands of international importance' outlines the following general principles for wetland management:

- the primary purpose of management of a declared Ramsar wetland must be to describe and maintain the ecological character of the wetland, and to formulate and implement planning that promotes the conservation of the wetland and the wise and sustainable use of the wetland for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem
- wetland management should provide for public consultation on decisions and actions that may have a significant impact on the wetland
- wetland management should make special provision, if appropriate, for the involvement of people who have a particular interest in the wetland and may be affected by the management of the wetland
- wetland management should provide for continuing community and technical input.

Management planning should be done in accordance with the following:

- At least one management plan should be prepared for each declared Ramsar wetland.
- A management plan for a declared Ramsar wetland should:
  - A. describe its ecological character;
  - B. state the characteristics that make it a wetland of international importance under the Ramsar Convention;
  - C. state what must be done to maintain its ecological character;
  - D. promote its conservation and sustainable use for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem;
  - E. state mechanisms to deal with the impacts of actions that individually or cumulatively endanger its ecological character, including risks arising from;
    1. physical loss, modification or encroachment on the wetland; or
    2. loss of biodiversity; or
    3. pollution and nutrient input; or
    4. changes to water regimes; or
    5. utilisation of resources; or
    6. introduction of invasive species; and
    7. state whether the wetland needs restoration or rehabilitation;
    8. if restoration or rehabilitation is needed — explain how the plan provides for restoration or rehabilitation;
    9. provide for continuing monitoring and reporting on the state of its ecological character;
    10. be based on an integrated catchment management approach;
    11. include adequate processes for public consultation on the elements of the plan;
    12. be reviewed at intervals of not more than 7 years.

APPENDIX B – RELEVANT LEGISLATION AND POLICIES

B2.1 International treaties and agreements

The Convention on Wetlands of International Importance, signed in Ramsar, Iran, in 1971.

As a signatory of the Ramsar Convention on Wetlands, Australia has a number of obligations relating to the management of its designated Wetlands of International Importance, or Ramsar sites. These obligations are described in Articles 3.1 and 3.2 of the Convention as follow (Ramsar 1994)

Article 3.1:

> "The Contracting Parties shall formulate and implement their planning so as to promote the conservation of the wetlands included in the List, and as far as possible the wise use of wetlands in their territory."

Article 3.2:

> "Each Contracting Party shall arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the List has changed, is changing or is likely to change as the result of technological development, pollution or other human interference. Information on such changes shall be passed without delay to the organization or government responsible for the continuing bureau duties specified in Article 8."

The Ramsar Convention interprets the above obligations as a commitment by signatory governments to retain the 'ecological character' of their listed sites. For this reason, gaining a detailed understanding of the ecological character of a Ramsar site is a fundamental tool for guiding management actions.

Other international treaties and agreements that influences the management of the Ginini Flats Wetland Complex Ramsar site:

» the Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment (JAMBA), formed in 1974

» the Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment (CAMBA), formed in 1986

» the Agreement between the Government of Australia and the Republic of Korea for the Protection of Migratory Birds and their Environment (ROKAMBA), signed in 2007

» the Convention on the Conservation of Migratory species of Wild Animals (the Bonn Convention), signed in 1991

B2.2 National legislation and policy

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) came into force in July 2000, and enables improved management of Ramsar wetlands through the application of consistent management principles and more robust Australian Government/State arrangements. It also establishes a stronger and more efficient process for assessing actions that are likely to have a significant impact on Ramsar wetlands. The EPBC Act regulates actions that will or are likely to have a significant impact on the ecological character of a Ramsar wetland. The Act recognises that Ramsar Wetlands of International Importance (and listed threatened and migratory species) are matters of National Environmental Significance; introduces an environmental assessment and approval regime for actions that are likely to have a significant impact on Ramsar wetlands (and listed threatened and migratory species) and provides for improved management of Ramsar wetlands. The EPBC Act also establishes a framework for managing Ramsar listed wetlands through the Australian Ramsar Management Principles (EPBC Act 1999, s335), which are set out in Schedule 6 of the Environment Protection and Biodiversity Conservation Regulations 2000. These principles are intended to promote national standards of management, planning, environmental impact assessment, community involvement, and monitoring, for all of Australia's Ramsar wetlands in a way that is consistent with Australia's obligations under the Ramsar Convention. Under Australia's obligations to the Ramsar convention, every Ramsar site needs an individual plan of management in place, to be reviewed at intervals of at least seven years, as stated in the EPBC Act.

Other national legislation and policy that influences management of the Ramsar site:

» Approved Conservation Advice for the Alpine *Sphagnum* Bogs and Associated Fens ecological community (Approved conservation advice under s266B of the *Environment Protection and Biodiversity Conservation Act 1999*) (Australian Government 2008)

» National Water Initiative (NWI) (Australian Government 2004)

» National Framework and Guidance for Describing the Ecological Character of Australian Ramsar Wetlands. Module 2 of the National Guidelines for Ramsar Wetlands (Department of Environment, Water, Heritage and the Arts (DEWHA) 2008)

» Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000)

» Threat Abatement Plan for Predation, Habitat Degradation, Competition and disease Transmission by Feral Pigs (Department of the Environment and Heritage 2005, currently under review)

» 'Memorandum of Understanding In relation to the Co-operative Management of the Australian Alps national parks' (Australian Alps Liaison Committee 1986).

» Alpine *Sphagnum* Bogs and Associated Fens ecological community National Recovery Plan (Department of the Environment 2015)

» The National Capital Plan (Cwlth)

B2.3 Territory legislation and policy

Nature Conservation Act 2014

This Act provides the main legislative backing for the ACT Government's management of reserved lands, covering the protection and conservation of native plants and animals. In so doing, the Act confers powers on the Conservator to control activities on reserved land. For Ramsar Wetlands, this is managed through Parks and Conservation Service (PaCS) as the direct management agency. Part 8.4 of the Act specifically deals with the process of drafting a Ramsar management plan. The Act prescribes that a Ramsar management plan must provide detail on how the Ramsar wetland, and its surrounding area, is to be managed to preserve and protect the ecological character of the wetland. The Conservator may prepare a draft Ramsar wetland management plan. In preparing a draft Ramsar wetland management plan, the Conservator must consult the Commonwealth Minister responsible for administering the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth); and if the Ramsar wetland is located on unleased land or public land—the custodian of each area of land where the wetland is located. The Conservator must also undertake public consultation on the draft plan. After considering submissions, the Conservator must submit the draft management plan and associated public submissions to the Minister for approval. Once approved by the Minister, a Ramsar management plan must be notified under section 198 of the Act. If a Ramsar wetland management plan is in force under s198, the conservator and land custodian must take reasonable steps to implement the plan. The conservator must monitor the effectiveness of the Ramsar wetland management plan and report to the Minister about the wetland management plan at least once every 5 years.

The Namadgi National Park Plan of Management 2010

The Namadgi National Park Plan of Management 2010 has been prepared under the Planning and Development Act 2007 and policies in the Territory Plan (ACT) and the National Capital Plan (Commonwealth). The plan aims to protect in perpetuity the natural and cultural values (including hydrological values) of the park from a range of pressures that have the potential to impact adversely on those values. With regard to natural heritage, Namadgi is part of the Australian Alps bioregion, conserving environments from the higher altitude alpine and subalpine mountain peaks to relatively low elevation grassy valleys. The plan contains objectives and policies for the conservation of significant landscapes and native flora and fauna; management of pest species; ecological restoration; and management of the wilderness area in the park. The Namadgi National Park PoM specifically recognises the significance of Ginini Flats Wetland Complex, as it is included in the List of Wetlands of International Importance in recognition of its significant ecological characteristics. The Ginini Flats management plan is supported with additional management actions in the Namadgi National Park PoM to reflect changed circumstances since the 2003 bushfire (ACT Government 2010).

Other Australian Capital Territory legislation and policy that also applies to the Ginini Flats Wetland Complex Ramsar site and which will have to be considered where applicable when implementing management actions at the site:

- *Environment Protection Act 1997*
- *Heritage Act 2004*
- *Planning and Development Act 2007*
- *Plant Diseases Act 2002*
- *Pest Plants and Animals Act 2005*
- *Water Resources Act 2007*
- ACT Strategic Bushfire Management Plan (ACT Government 2014a)
- Threatened species Action Plan No. 6 for the Northern Corroboree Frog (Pseudophryne corroboree) (ACT Government 2011)
- Namadgi National Park Feral Horse Management Plan 2007 (ACT Government 2007a)
- Interim Recreation Strategy (Mackay 2004)
- ACT Nature Conservation Strategy 2013 – 2023 (ACT Government 2013)
- ACT Pest Animal Management Strategy 2012-2022 (ACT Government 2012a)
- Lower Cotter Catchment Strategic Management Plan (ACT Government 2007b)
- Territory Plan (ACT Government 2008a)
- ACT Water Strategy 2014–44 (ACT Government 2014b)
- AP2: A new climate change strategy and action plan for the Australian Capital Territory (ACT Government 2012b)

APPENDIX C - ECOSYSTEM COMPONENTS AND PROCESSES

C3.1 Key components, ecosystem processes and interactions

A summary of critical components and processes influencing the ecological character of Ginini Flats Wetland Complex at time of listing are provided in the table below (Wild et al. 2010, pp. iv - v).

Table 5: Key components and ecosystem processes at the time of listing for Ginini Flats Wetland Complex Ramsar site

Component/ Process	Summary Description
Biophysical setting	The geology underlying Ginini Flats consists of intensively deformed granitic rocks of Silurian age that are overlain by Ordovician aged metasediments, which are extensively folded and composed of quartz arenite, siltstone and slate, with occasional hornfels beds. Water flowing through interstitial spaces over the granitoids is forced closer to the surface at the edge of the metasediments, resulting in seepages and spring lines. The combination of these processes results in conditions suitable for the continuous growth of *Sphagnum* and other wetland plants that have been recognised as significant in this subalpine environment.
Hydrology	Ginini Flats Wetland Complex is located at the headwaters of the Ginini Creek which forms the base of a small catchment of 410 ha that rises from 1520 m ASL to a maximum elevation at the summit of Mt Ginini of 1762 m ASL. Ginini Flats Wetland Complex has relatively high rainfall (circa 1250 mm/yr).
Peat formation	Peatlands form in areas with cool temperatures, positive water balance and usually more than 500 mm annual precipitation and are characterised by production of organic matter in excess of decomposition resulting in net accumulation. The development of peat layers result in alteration of surface and ground water inflows and outflows. This peat is comprised of two main layers, the surface, living Acrotelm that experiences fluctuations in water levels and the lower, anaerobic Catotelm which is typically saturated.
Vegetation	The peatland development at the site has been extensive, both in the drainage basin and on the slopes, providing a variety of vegetation types within the wetland complex including *sphagnum* bogs, wet heath and wet grassland (or fen). On top of the living *Sphagnum* layer there is substantial variation in vegetation composition in the bog complex, including a mosaic of bog, wet heath, wet herbfield, sedgeland, dry heath and tall wet heath along a gradient of reducing water availability, surrounded by subalpine woodland.
Water quality	The surface water within the Ginini Flats Wetland Complex is unpolluted and slightly acidic, and has low conductivity and very low turbidity. Limited amounts of sediment are likely to be transported to the Ginini Flats Wetland Complex as the result of disturbance of the surrounding catchment. There is the potential for some erosion through slope retreat on the steeper slopes, however this is a small area of the catchment for the wetlands.
Frogs	At the time of Ramsar designation in 1996, the Northern Corroboree Frog (*Pseudophryne pengilleyi*) was recognised to be an important value of Ginini Flats Wetland Complex and the site was believed to hold one of the largest known populations of this species. Currently, *P. pengilleyi* is listed as Vulnerable on the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, Vulnerable on Schedule 2 of the NSW *Threatened Species Conservation Act 1995*, and Endangered on the IUCN Red List.

Component/ Process	Summary Description
Mammals, birds and reptiles	At the time of listing in 1996, the Ginini Flats Wetland Complex supported a range of wetland habitats including *sphagnum* bog, wet herbfield and wet heath. Vertebrate fauna species that have been recorded in the area, are wetland dependent and are expected to have been present around the time of listing include broad-toothed rat, Latham's snipe, alpine water skink and mountain swamp skink.
Fish	The native mountain Galaxias (*Galaxias olidus*) inhabits the small streams that bisect the Ginini Flats Wetland Complex. There is no evidence that exotic fish species have colonised aquatic habitat within Ginini Flats Wetland Complex.
Invertebrates	Ginini Flats Wetland Complex contains a number of habitats that support invertebrates. There is a lack of baseline ecological information on macroinvertebrates associated with Ginini Flats Wetland Complex, although the body of research suggests that the invertebrate fauna of bog environments in Australia is highly diverse given the heterogeneity of habitats found within them.

C3.2 Key ecosystem services

Ecosystem services have been defined under the Ramsar Convention as benefits to humanity derived from functional wetland ecosystems (Ramsar 2005). The *Sphagnum* bogs and fens ecological community is known to provide significant habitat for a number of endemic and threatened flora and fauna species. The persistence of this ecological community is likely to be critical to the survival of a number of these species. *Sphagnum* vegetation and the underlying peat organosols have a significant water-holding capacity, which is important in modulating water flow and maintaining the hydrology of surrounding environments (Ashton & Williams, cited in Department of Environment 2015). The manner in which bog and fen communities gradually release water from the spring snow melt is also critical to the survival of numerous other ecological communities (Good, cited in DOE 2015).

Intact areas of *Sphagnum* act as a natural filter for nutrients, pathogens and sediments, thus, playing an important role in maintaining water quality throughout catchments (McDougall, cited in DOE 2015).

A number of key ecosystem services are provided by the Ginini Flats wetlands, including:

» Regulating services - benefits obtained from the regulation of ecosystem processes such as climate regulation, water regulation and natural hazard regulation;

» Supporting services - necessary for the production of all other ecosystem services such as water cycling, nutrient cycling and habitat for biota;

» Cultural services – benefits people obtain through spiritual enrichment, recreation, education and aesthetics.

The key ecosystem services provided by the Ginini Flats Wetland Complex are further described in Table 6 below.

Table 6: Key ecosystem services provided by Ginini Flats wetlands (Wild et al. 2010)

Ecosystem service or benefit category	Description
Provisioning services – products obtained from the ecosystem such as food, fuel and fresh water	
Wetland products	The wetland complex is part of the Cotter River Catchment, which is a primary water supply source for Canberra the capital city of Australia.
Regulating services – benefits obtained from the regulation of ecosystem processes such as climate regulation, water regulation and natural hazard regulation	
Climate regulation	Peat may be a significant carbon sink depending on climatic and hydrological conditions. However, peat can also act as a carbon source under warmer conditions, which promote peat decline. Predictions by Whinam and Chilcott (2002) suggest that such decline is likely.
Maintenance of hydrological regimes	Localised flattening of hydrological curve through the retention and slow release of moisture over a period of days.
Erosion protection	Protection of soil surface from frost heave and accelerated erosion processes.
Water quality maintenance	Filtration of water, buffering of nutrients and sediments.
Hazard reduction	Flood control through limited flattening of the hydrological curve (as outlined above)
Supporting services – services necessary for the production of all other ecosystem services such as water cycling, nutrient cycling and habitat for biota. These services will generally have an indirect benefit to humans or a direct benefit over a long period of time.	
Biodiversity	Supports a significant sub-set of regional flora species and an ecologically-significant vegetation community. Supports a number of regionally significant and, nationally and internationally threatened species and vegetation communities. Supports a significant population of a threatened amphibian species (northern corroboree frog).
Soil formation	Supports peat soil formation and the accumulation of organic matter.
Nutrient cycling	Provides buffer capacity and removal or conversion of up to 90 per cent of nitrates
Cultural services – benefits people obtain through spiritual enrichment, recreation, education and aesthetics	
Spiritual and inspirational	The wetland is likely to have been used on-route to traditional harvest sites (Mt Gingera) for Bogong moths by Aborigines.
Recreation and tourism	Winter cross-country or back country skiing in the surrounding grassland and woodland areas, summer walking and spring wildflower viewing.
Scientific and educational	Scientific studies on the Northern Corroboree Frog and provision of eggs for captive breeding program. Numerous paleological studies of vegetation, climate and fire histories in peat sediments. Medium-term monitoring of restoration trials of post-fire recovery techniques in *sphagnum* bogs.

APPENDIX D – GEOPHYSICAL VALUES

10.11.1 D4.1 Geology

The geology underlying Ginini Flats consists of intensively deformed granitic rocks of Silurian age that are overlain by Ordovician aged metasediments, which are extensively folded and composed of quartz arenite, siltstone and slate, with occasional hornfels beds. Water flowing through interstitial spaces over the granitoids is forced closer to the surface at the edge of the metasediments, resulting in seepages and spring lines. The combination of these processes results in conditions suitable for the continuous growth of *Sphagnum* and other wetland plants that have been recognised as significant in this subalpine environment (Wild et al. 2010).

10.11.2D4.2 Climate

The climate of Ginini Flats Wetland Complex is characterised as subalpine, with cold winters and cool summers. The mean annual minimum is 3.4 °C and the mean annual maximum temperature is 11.7 °C. The diurnal range of winter temperatures is generally about half that of summer due to the passage of cold fronts and the greater extent of radiation cooling on the more frequent clear nights. Extremes in both maximum and minimum temperatures occur, including heat wave periods in summer when sequences of days over 35 °C have been recorded, particularly in January or February (BoM, cited in Wild et al. 2010). The average annual rainfall is in the vicinity of 1250 mm; around half of the rainfall of many other *sphagnum* bog sites in the Australian Alps (Wild et al. 2010). This rainfall also includes snowfall events which occur between June and September; although snow can fall outside these months.

The area is subject to south-westerly and westerly weather systems, which frequently result in blizzard-like conditions to the mountain range and are the most common snow-producing systems in Australia. Cold southerly patterns occur infrequently and are associated with very heavy snow falls (Davis, cited in Wild et al. 2010). These weather systems deposit snow on the predominantly easterly and south easterly slopes at Ginini Flats and Cheyenne Flats which, as lee slopes, are areas of snow accumulation and slow thaw (Billings & Mooney, cited in Wild et al. 2010). Ginini West has a more westerly aspect so snow cover is likely to be of shorter duration. Within these areas snow depth patterns and persistence also vary depending on the ground conditions. For example, rocks and shrubs can result in irregular distribution of snow and uneven melting, contributing to differences in microclimatic conditions such as the length of growing season, soil microclimate, patterns of snow thaw and water availability, and exposure to wind and frosts (Billings & Mooney, Mark & Bliss, cited in Wild et al. 2010).

The lack of persistent snow cover leads to harsh conditions as snow provides substantial insulation for vegetation in the colder periods (Billings & Moody, cited in Wild et al. 2010). This lack of insulating snow cover also leads to a high prevalence of frost heave. Frost heave occurs when soil moisture freezes, forming needle ice that can heave seedlings out of the soil, leading to vegetation loss and the erosion of soil surfaces. If moisture is present, temperatures only need to cool to as little as –2 °C for frost heave to develop in some clay soils (Lawler, cited in Wild et al. 2010). Data recorded by McPherson (cited in ACT Government, 2001) showed average ground temperature at Mt Ginini to be –0.5 °C in July, indicating that the incidence of frost heave is likely to be high in winter and spring.

D4.3 Hydrology and water quality

Ginini Flats Wetland Complex is located at the headwaters of the Ginini Creek, part of the Middle Cotter Catchment within the Cotter River Catchment (the primary water supply for the city of Canberra). The Cotter River Catchment extends over 481 square kilometres and includes three sub-catchments: the Upper Cotter (Corin Dam Catchment), Middle Cotter (Bendora Dam Catchment to Corin Dam) and the Lower Cotter (Cotter Dam Catchment to Bendora Dam)(Wild et al. 2010). Ginini Creek forms the base of a small catchment of 410 hectares that rises from 1520 m ASL to a maximum elevation at the summit of Mt Ginini of 1762 m ASL. The hydrological functions of the *Sphagnum* bogs and fens of the Ginini Flats wetlands are an important component of the overall high water quality in the Cotter Catchment.

The 2003 fire burned most of the bogs and fens in the ACT, and this is an important consideration for current and future management of these communities. The *Sphagnum* bog peats, which had dried out prior to the fire because of severe drought, were burnt to varying degrees. Fire damage led to the development of stream incision and the draining of some peatlands. The peats in most of the fens retained sufficient moisture to prevent them being burned. Rehabilitation to assist, and research on, *Sphagnum* bog recovery from fire has occurred since 2003 (Macdonald 2009).

The surface water within the Ginini Flats Wetland Complex is unpolluted and slightly acidic, and has low conductivity and very low turbidity (Wild et al. 2010). Limited amounts of sediment are likely to be transported to the Ginini Flats Wetland Complex as the result of disturbance of the surrounding catchment. There is the potential for some erosion through slope retreat on the steeper slopes, however this is a small area of the catchment for the wetlands.

The Ginini Flats Wetland Complex occurs within two Hydrogeological Landscape (HGL) units (see Text box below for description of HGL), namely the Bimberi HGL and the Piccadilly HGL (see Figure 3).

The Bimberi HGL extends in a north-south strip in the west of the ACT in the Namadgi National Park. The HGL covers an area of 80 km^2 and receives 1000 to 1700 mm of rain per annum. The Bimberi HGL includes Ginini East and Cheyenne Flats, all part of the Ginini Flats Wetland Complex Ramsar site.

The Picadilly HGL extends along the western margin of the ACT to the northern edge of the ACT and to the catchment areas of Corin and Bendora Dams. The HGL covers an area of 277 km^2 and receives 750 to 1600 mm of rain per annum. The Picadilly HGL includes West Ginini, part of the Ginini Flats Wetland Complex Ramsar site.

ACT HYDROGEOLOGICAL LANDSCAPES

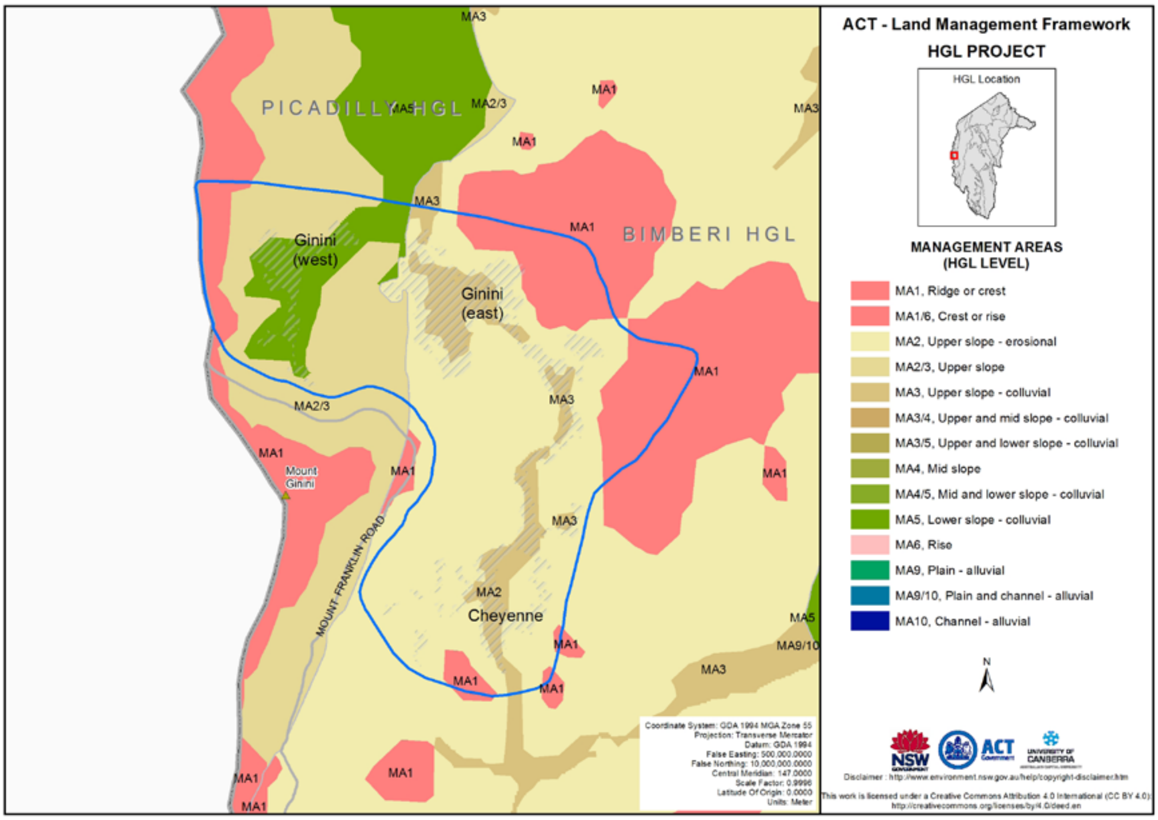
Hydrogeological Landscapes (HGL) have been developed to characterise and manage the quality and distribution of water on the surface and in the shallow sub-surface of the landscape (Muller et al. 2016). Hydrological landscape units integrate information on lithology, bedrock structure, regolith (including soils), landforms and contained hydrologic systems. The HGL unit (or area) therefore represents a landscape component that captures many hydrological parameters including water flow (surface, shallow lateral and groundwater flow), storage and quality that can be used to support a range of natural resource management (NRM) applications including wetland classification and assessment of hydrological vulnerability. HGL maps and associated management recommendations have been produced for the ACT Government by the NSW Office of Environment and Heritage (OEH) and NSW Department of Primary Industries (DPI). The maps and document result from a series of salinity projects OEH is undertaking to better understand how dryland salinity manifests in the landscape and how salinity may be best managed. As a component of the ACT HGL project, wetland mapping, classification and assignment of wetland condition was carried out for wetlands across the ACT.

At the local scale the HGL mapping hierarchy identifies management areas. Management areas are defined as areas of land within a HGL that can be managed in a uniform manner. They enable the link between landscape and targeted management and they operate at the scale of landform facets (crest, upper slopes, footslopes, floodplains etc.) (NCST, cited in Muller et al. 2016). For ease of comparison, management areas have been standardised (Table below). The management areas are based in part on the terminology used in the Australian Soil and Land Survey Field Handbook (NCST, cited in Muller et al. 2016).

HGL Management Area Description:

HGL Management Area	Description
MA 1	Crest or ridge
MA2	Upper slope – erosional
MA3	Upper slope – colluvial
MA4	Mid slope
MA5	Lower slope – colluvial
MA6	Rises
MA 7	Saline site
MA 8	Structurally controlled saline sites
MA 9	Alluvial plains
MA 10	Alluvial channels

Figure 4: HGL units and management areas for Ginini Flats



D4.4 Peat formation

The peat deposit in the *Sphagnum* bogs is critical to the hydrodynamic functioning of the community. In developed peatlands the accumulating dead peatbeds become the predominant substrate for water flow through the wetland. The living peat plants form an open structure that allows the passage of excess water. Overall, for peatlands to function there needs to be a net balance of inflow and outflow that maintains waterlogged conditions within the peat. Peatlands retain large amounts of water, with peat being more than 95% water by weight. Bogs in general have the effect of reducing the water outflow compared to bog inflow because of evapotranspiration (Western et al. 2009).

Peatlands form in areas with cool temperatures, positive water balance and usually more than 500 mm annual precipitation and are characterised by production of organic matter in excess of decomposition resulting in net accumulation (Wild et al. 2010). They are the product of complex interactions between biotic factors (growth rate, decomposition, exclusion of other plants) and abiotic conditions (water supply, temperature, topography). These interactions often develop over many thousands of years (over 3 000 years for Ginini Flats Wetland Complex, see below), with hydrological conditions being considered one of the fundamental driving forces in both the formation and degradation of peatlands (Wild et al. 2010).

Peat formation measured at the Ginini Flats wetlands shows peat accumulation of 0.7–3.3 cm/100 years (Clark, cited in Wild et al. 2010), indicating the very slow nature of the accumulation of peat in the ACT environment. Dating of ACT peat deposits shows: the oldest at Cotter Source Bog, 9040 years; and the youngest at Ginini, 3200 years (Costin, cited in Wild et al. 2010; Hope et al. 2009).

These peatlands contain a valuable record of past climates and vegetation changes. Conservation of this record is vital for future research in this area; the greatest threat to it is fire.

D4.5 Land and soil capability

Soil and Land Degradation Management descriptions for the Australian Capital Territory (ACT) have been developed by the NSW Office of Environment and Heritage (OEH) and NSW Department of Primary Industries (DPI). They are a component of the broader ACT Hydrogeological Landscapes (HGL) project undertaken for the ACT Government (Muller 2016). The Soil and Land Degradation Management descriptions describe the nature and consequences of soil degradation in the ACT and identify management issues and potential actions relevant to specific parts of the landscape (management areas). Descriptions have been prepared for each ACT HGL unit.

Land capability is the inherent physical capacity of the land to sustain a range of land uses and management practices in the long term without degradation to soil, land, air and water resources (Dent & Young cited in Muller et al. 2016). Failure to manage land in accordance with its capability risks degradation of resources on- and off-site, leading to a decline in natural ecosystem values, agricultural productivity and infrastructure functionality. Land capability assessment for the Bimberi and Piccadilly HGL units (Figure 4) produced the following results:

Ginini West – **Extremely low capability land:** Limitations are so severe that the land is incapable of sustaining any land use apart from nature conservation. There should be no disturbance of native vegetation

Ginini East and Cheyenne Flats – **Very low capability land:** Land has severe limitations that restrict most land uses and generally cannot be overcome. On-site and off-site impacts of land management practices can be extremely severe if limitations not managed. There should be minimal disturbance of native vegetation.

In addition to the above capability classification, each Management Area has been classified into Soil Regolith Stability Classes (Murphy cited in Muller et al. 2016). Soil regolith stability is an expression of combined soil and substrate erodibility and sediment delivery potential. The soil regolith stability class is a useful predictor of how likely a soil is to cause turbidity in surface waters and long-distance sedimentation down the catchment, if the soil is disturbed. Soil regolith stability for the Ginini Flats area is indicated in Figure 5.

Figure 5: Land and soil capability

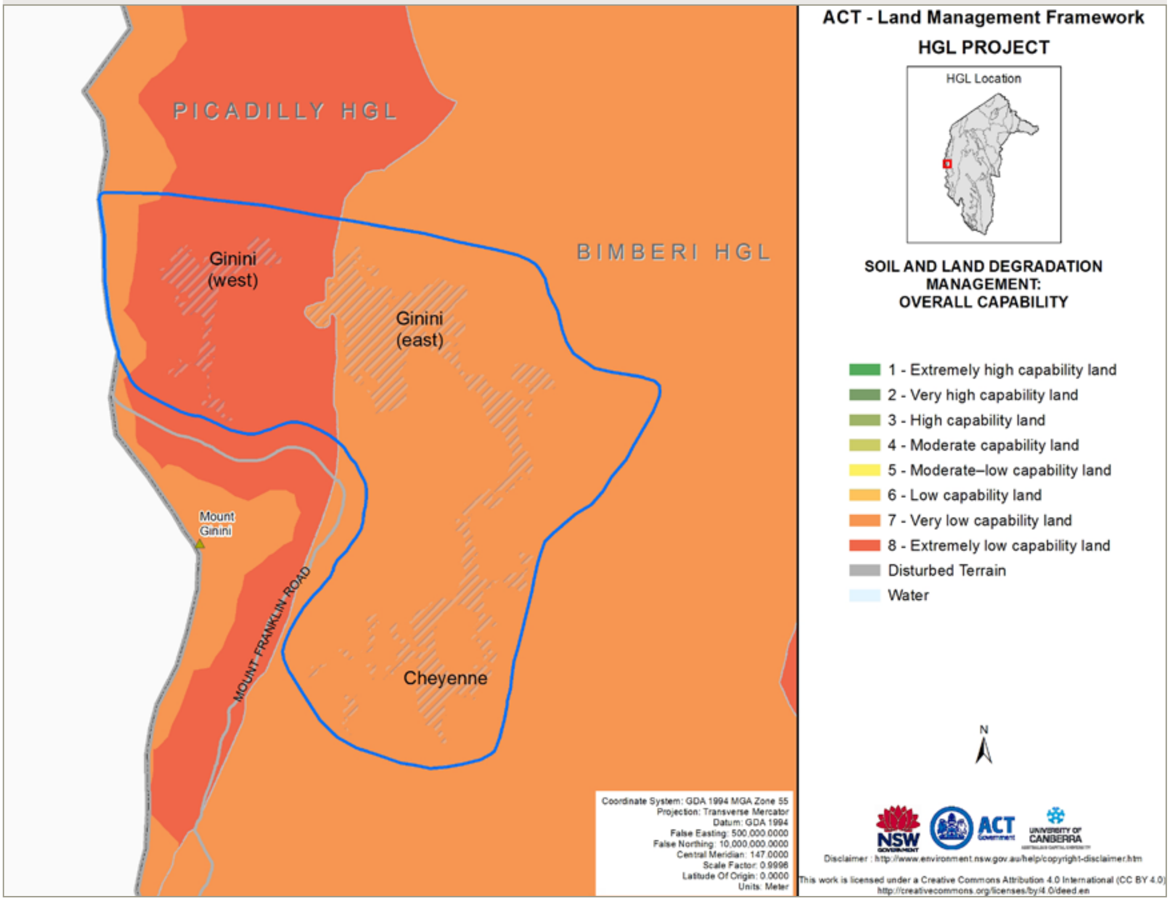
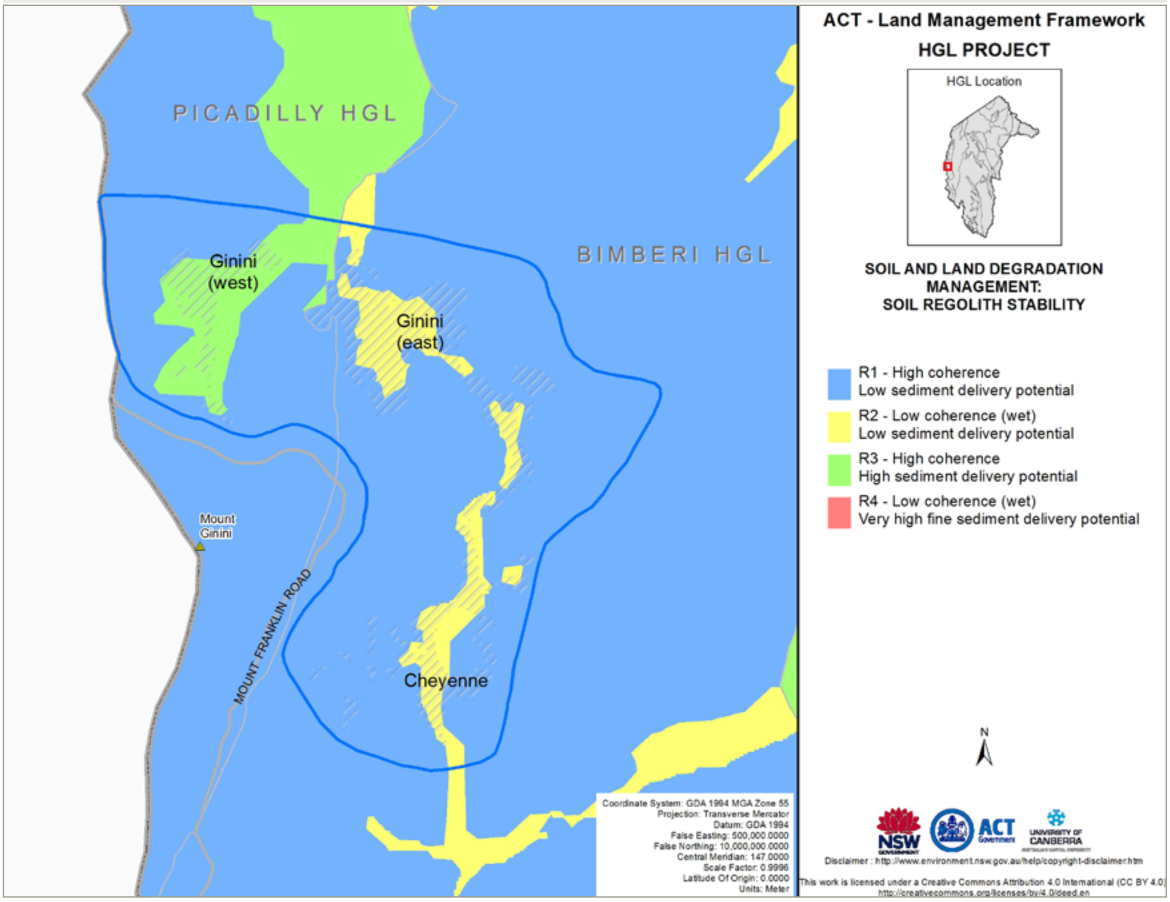


Figure 6: Soil regolith stability



APPENDIX E - BIODIVERSITY VALUES

E5.1 Vegetation

The Ginini Flats Wetland Complex falls within the Australian Alps IBRA[8] bioregion, which contains only one subregion (Australian Alps), occurring across the Alps in NSW, Victoria and the ACT. The Ginini Flats Wetland Complex is an extensive mosaic of Alpine *Sphagnum* bogs and associated fens, wet heath and wet grassland communities. The Alpine *Sphagnum* Bogs and Associated Fens ecological community is usually defined by the presence or absence of *Sphagnum* spp. on a peat substratum. The Alpine *Sphagnum* bogs and fens ecological community is described by the listing information for the nationally endangered ecological community Alpine *Sphagnum* Bogs and Associated Fens (DEWHA 2009). A more recent description can be found in the classification and mapping of Alpine vegetation undertaken by Mackey et al. (2015).

The vegetation at Ginini Flats Wetland Complex was first described by Clark (cited in Wild et al. 2010) and later classified by Helman and Gilmour (cited in Wild et al. 2010). These classifications were used by Hope et al. (2009) to map the bogs (see Table 3 and Figure 3 below).

Hope et al., cited by Wild et al. (2010), identified three classifications of bogs, based on their topographic setting, that occur within the Ginini Flats Wetland Complex:

1. slope bog and fens are found at breaks of slope on valley slopes indicating groundwater supply
2. headwater bogs occur at the head of small streams, often surrounded by heath of woolly teatree (*Leptospermum lanigerum*) and other shrubs
3. valley floor bogs and fens occur on the floor of valleys, often with meandering incised streams dammed by peat ponds.

All three types of *sphagnum* bogs at Ginini Flats are dominated by large hummock forming mosses, predominantly *Sphagnum cristatum*, and other water-loving, oligotrophic plants including a covering of shrubs and restiads. *Sphagnum* spp. is a slow growing moss species that forms extensive wetland communities and has been recorded to increase in length by up to 30 cm in a growing season at Ginini Flats (before compression from snow pack).

The peatland development at the site has been extensive, both in the drainage basin and on the slopes, providing a variety of vegetation types within the wetland complex including *sphagnum* bogs, wet heath and wet grassland (or fen). On top of the living *Sphagnum* layer there is substantial variation in vegetation composition in the bog complex, including a mosaic of bog, wet heath, wet herbfield, sedgeland, dry heath and tall wet heath along a gradient of reducing water availability, surrounded by subalpine woodland (Wild et al. 2010).

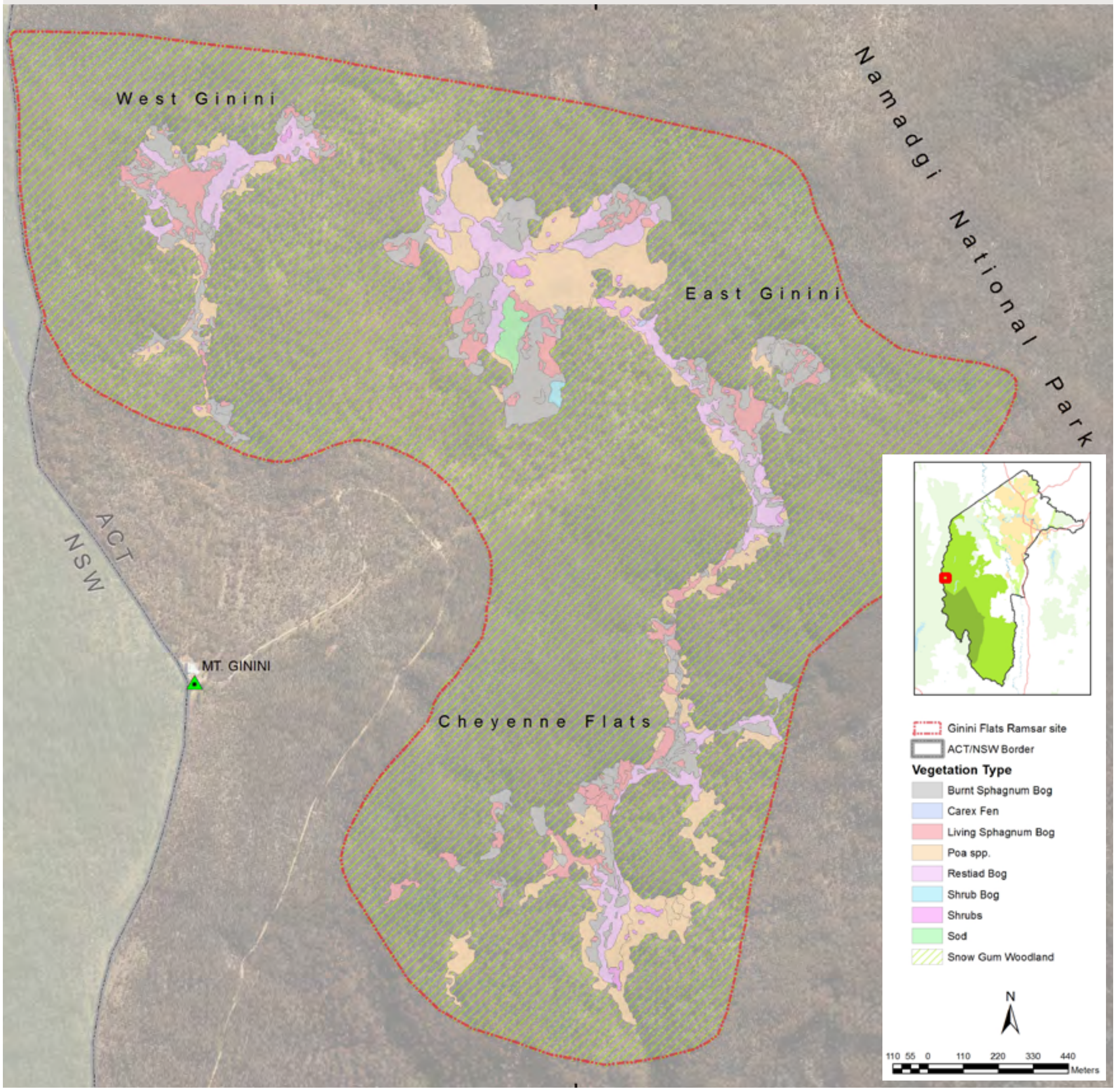
The other predominant vegetation community within the Ramsar site boundary (which follows catchment boundaries) is snow gum (*Eucalyptus pauciflora* ssp. *pauciflora* and ssp. *debeuzevillei*) woodland with a grassy ground cover (*Poa* spp.) or a shrubby understorey dominated by *Bossiaea foliosa*, *Oxylobium ellipticum* and *Daviesia ulicifolia* (Wild et al. 2010). The woodland structure is indicative of past fire events (1939 and 1944), displaying relatively even-aged mallee habits where trees have re-sprouted from lignotubers. The understorey varies from low shrubs to grassy areas. This community occurs on alpine humus soils on the well-drained surrounding slopes of the catchment that drain into the wetland proper. There are also pockets of snow gum woodland within the wetland, with one such patch between west Ginini Flats and east Ginini Flats having an understorey of *Tasmannia xerophila* and *Poa* spp (Wild et al. 2010).

8 Interim biogeographic regionalisation of Australia

Table 7: Vegetation communities and dominant species which comprise the Ginini Flats Wetland Complex

Vegetation community (Helman and Gilmour 1985)	Mapping Unit (Hope et al. 2009)	Mapped Extent (ha)	Dominant species
Bog	*Sphagnum* bog	44.4	*Sphagnum cristatum, Richea continentis* and *Baloskion australe*
Wet herbfield	*Poa*	19.4	*Poa costiniana, P. clivicola and Arthropodium milleflorum*
Wet heath	Shrub bog	0.2	*Epacris paludosa, Baeckea gunniana* and *Callistemon pityoides*
Sedgeland	Carex fen	0.03	*Carex gaudichaudiana and Ranunculus spp.*
Tall wet heath	Shrubs	1	*Leptospermum lanigerum and Sphagnum Cristatum*
Dry heath	Not mapped	Approx 345	*Bossiaea foliosa, Oxylobium alpestre* and *Helipterum anthemoides*
Snow gum woodland	n/a	n/a	*Eucalyptus pauciflora ssp. debeuzevillei*
Source: Wild et al. 2010, p24			

Figure 7: Ginini Flats Vegetation Map



The interface of wetland communities and the open woodland is characterised by dry heaths of *Bossiaea foliosa* and *Oxylobium alpestre*, which may represent the edge of cold air drainage pools where mean temperatures reduce primary productivity and the development of sufficient woody tissue to support snow gums resulting in an 'inverted tree line' (Bell & Bliss, cited in Wild et al. 2010). Wetter areas and gullies have tall wet heath communities dominated by dense stands of *Leptospermum lanigerum*, which may have an understorey of *Sphagnum*.

Wet herbfield communities, which may also be classified as grasslands, also occur on the periphery of the bog communities at Ginini Flats. This community includes *Poa* tussock grasses (*Poa costiniana*, and *P. clivicola*) and small epacrid shrubs (*Epacris microphylla* and *E. brevifolia*).

Sedgeland communities are dominated by the rhizomatous sedge *Carex gaudichaudiana* on peat to alpine humus soils and can be viewed as an alternative state community where, at the time, *Sphagnum* cannot grow. These communities are more correctly classified as fens because the water table is, on average, at the soil surface (Whinam & Hope, cited in Wild et al. 2010). This results in open pools supporting *Gonocarpus micranthus* and the aquatic milfoil *Myriophyllum pedunculatum*. This community is viewed as inseparable to *Sphagnum* bogs in the EPBC Act (1999) listing which are incorporated into the Endangered Alpine *Sphagnum* Bogs and Associated Fens community.

The *Sphagnum* bog complex and wet heath communities form a mosaic, which includes the shrub species *Richea continentis*, *Epacris paludosa*, *Baeckea gunniana*, *Callistemon pityoides* and *Grevillea australis* growing on hummocks and hollows of *Sphagnum*. The restiads *Empodisma minus* and *Baloskion* austral grow between and over the *Sphagnum* hummocks, which are around 50 cm higher than adjacent hollows, resulting in a variable surface appearance of the bog. *Empodisma minus* fen occurs on the drier edges and shrub growth (particularly of the myrtaceous shrubs *Baeckea* and *Leptospermum*) often concentrates along drainage channels.

E5.2 Fauna

At the time of listing in 1996, the Ginini Flats Wetland Complex supported a range of wetland habitats including *sphagnum* bog, wet herbfield and wet heath. Vertebrate fauna species that have been recorded in the area (ACT Government 2001) are wetland dependent and are expected to have been present around the time of listing include:

» the Northern Corroboree Frog (*Pseudophryne pengilleyi*)

» Broad-toothed Rat *(Mastacomys fuscus*)

» Latham's snipe (*Gallinago hardwickii*)

» Alpine Water Skink (*Eulamprus kosciusko*)

» Mountain Swamp Skink (*Niveoscincus rawlinsoni*).

E5.2.1 Amphibians

The Northern Corroboree Frog

The Northern Corroboree Frog (*Pseudophryne pengilleyi*) is an endangered species in the ACT and is listed as critically endangered under the EPBC Act. Northern Corroboree Frogs use two types of habitat: in the summer they breed in pools and seepages associated with *Sphagnum* moss, wet tussock grasslands and wet heath, and in the winter the frogs shelter under logs and in leaf litter in subalpine woodland and heath adjacent to the breeding area (ACT Government 2011).

At the time of Ramsar designation in 1996, the *P. pengilleyi* was recognised to be an important value of Ginini Flats Wetland Complex and the site was believed to hold one of the largest known populations of this species. The population of northern corroboree frogs has declined significantly since the 1980s across its entire range. At Ginini Flats Wetland Complex, the frog was once estimated to be the largest vertebrate biomass and had the largest aggregations of the species in its range. By 1992, populations of northern corroboree frogs in the ACT had declined significantly, with less than 10 per cent of the population size of the early 1980s, and have continued to be at very low levels since. This low population size was the state of *P. pengilleyi* at the time of listing of Ginini Flats Wetland Complex, with less than 15 calling males being recorded at this location (Wild et al. 2010). *P. pengilleyi* is listed as Vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999*.

It is listed as Critically Endangered in NSW and Endangered in the Australian Capital Territory. Action Plan No. 6: Northern Corroboree Frog (*Pseudophryne pengilleyi*) (ACT Government 2011), outlines the necessary actions to protect the species.

Other amphibian species

Activities that are listed under Action Plan No. 6 to protect the Northern Corroboree Frog will also assist other frog species, such as Verreaux's Alpine Tree Frog (*Litoria verreauxii alpine*). The Alpine Tree Frog has been recorded in the Brindabella and Bimberi Ranges associated with large pools in *Sphagnum* bogs and fens, used during the breeding and tadpole stages of development (Gillespie, Osborne & McElhinney 1995). The species is listed as vulnerable under the EPBC Act, and as endangered under the NSW *Threatened Species Conservation Act 1995*. In recent decades, Verreaux's Alpine Tree Frog has, with the Northern Corroboree Frog, experienced pronounced population declines, which are most likely due to the introduced amphibian chytrid fungus. Surveys undertaken during spring and summer of 1996–97 targeted known locations in the Bimberi Range and Snowy Mountains, as well as sites in Victoria (Hunter et al. 1997; Osborne et al. 1999). These surveys demonstrated that the species had undergone a dramatic decline throughout its range, had apparently disappeared from the alpine zone and was extremely rare in subalpine areas.

Broad-toothed Rat

The Boad-toothed Rat *(Mastacomys fuscus*) is recognised nationally as a declining species and was listed in 2016 as a threatened species under the EPBC Act 1999. In New South Wales *M. fuscus* is classified as vulnerable, with one of the two populations, Barrington Tops, classified as endangered. In Victoria the species is classified as threatened however in the ACT, where there is paucity of information on the species, *M. fuscus* has no special protection status (Milner et al. 2015). *M. fuscus* occurs in a range of habitats where there is dense vegetation cover, including wet herbfield and wet heath habitats at the Ginini Flats Wetland Complex. The broad-toothed rat is herbivorous and feeds mainly on grasses but does also eat the leaves of herbs, seeds and fungi (Green and Osborne, 1994). A recent survey of potential habitat in Namadgi National Park (Milner et al. 2015) detected *M. fuscus* in relative abundance across Ginini East, West, and Cheyenne Flats. Milner et al. (2015) reports that on average, *M. fuscus* scats were found in 26.5% of quadrats examined. The survey also found that relative abundance of *M. fuscus* decreased significantly if evidence of disturbance by feral animals was present. Across its range, the species is identified as being at extreme risk to global warming due to shifts in the composition and distribution of alpine vegetation communities (Milner et al. 2015).

E5.2.3 Latham's Snipe

Latham's Snipe (*Gallinago hardwickii*) is listed as a migratory species protected under international agreements (JAMBA, CAMBA, ROKAMBA, Bonn) as well as a marine species under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. Latham's Snipe breeds in Japan and migrates to Australia for the spring and summer months. It forages in mud for aquatic invertebrates. The *Sphagnum* bog, wet herbfield and wet heath habitats within the Ginini Flats Wetland Complex are likely to be suitable for Latham's Snipe, particularly where there are open mud areas for foraging and dense low vegetation for shelter. Latham's snipe have been recorded in five out of the sixty-six surveys that have been carried out within 10 kilometres of the Ginini Flats Wetland Complex between 1998 and 2006. All five records of Latham's Snipe are from late January and early February in 2002, when a total of seven birds were observed through three sightings of single birds and two sightings of two birds (Wild et al. 2010).

E5.2.4 Alpine Water Skink

Eulamprus kosciusko is a moderately large skink that grows to 20 cm and is widespread in the Australian Alps. They are confined to areas of *sphagnum* bog, wet heath and, to a lesser extent, wet herbfield (Green and Osborne 1994). Alpine Water Skinks have been observed to shelter in burrows made by freshwater crayfish (*Euastacus* species). They feed on small invertebrates (for example flies, grasshoppers, spiders and moths) and are viviparous, with females giving birth to between two and five live young in late summer (Green & Osborne 1994). This species is believed to occur within or adjacent to Ginini Flats Wetland Complex although there has been little research undertaken (ACT Government 2001).

E5.2.5 Mountain Water Skink

Pseudemoia rawlinsoni (referred to in the RIS and previous Management Plan for the site as *Niveoscincus rawlinsoni* and *Leiolopisma rawlinsoni*) is a small skink, approximately 100 mm long, with glossy olive scales (Green & Osborne 1994). These skinks are locally common in swampy habitats including *sphagnum* bog, wet heath and wet herbfield (Green & Osborne 1994). This species is believed to occur within or adjacent to Ginini Flats Wetland Complex although there has been little research undertaken on reptiles in the area (ACT Government 2001).

E5.2.6 Fish

The Mountain Galaxias (*Galaxias olidus*) has been recorded within streams in the Ginini Flats wetlands. It feeds on both terrestrial and aquatic invertebrates and may itself be predated by Alpine Water Skinks (Green & Osborne 1994). There is no evidence that exotic fish species have colonised aquatic habitat within Ginini Flats Wetland Complex.

Fish within the small streams associated with *Sphagnum* bogs and fens can be affected by the Epizootic Haematopoietic Necrosis Virus (EHNV) which causes mortality in threatened fish species.

E5.2.7 Invertebrates

Ginini Flats Wetland Complex contains a number of habitats that support invertebrates. There is a lack of baseline ecological information on macroinvertebrates associated with the site, although the body of research suggests that the invertebrate fauna of bog environments in Australia is highly diverse given the heterogeneity of habitats found within them.

A number of notable invertebrate species have been recorded within Ginini Flats Wetland Complex. Of the terrestrial species, *Polyzosteria viridisma* (metallic bog cockroach) is confined to the Snowy Mountains and Brindabella Ranges alpine areas, and has been observed in Ginini Flats (Australian Nature Conservation Agency; Green & Osborne cited in Wild et al. 2010). Osborne (cited in Wild et al. 2010) notes that a number of species, whilst reasonably common to the Australian alpine environment, are at their most northern limit at the Ginini Flats Wetland Complex, within somewhat isolated populations. Species include: *Acripeza reticulata* (mountain grasshopper), *Yeelanna* sp. (spotted grasshopper), *Kosciuscola tristis* (alpine chameleon grasshopper) and various species of *Lycosa* (alpine wolf spiders).

Of the aquatic species, the Namadgi National Park Plan of Management (ACT Government 2010) states that the spiny freshwater crayfish (*Euastacus* rieki) is present within the Namadgi National Park alpine areas, including bog environments. Given the shallow pools with woody debris substrates and streams with overgrown woody shrubs, it is possible that this species occurs within the Ginini Flats Wetland Complex, although this requires confirmation.

Despite the potential for a wide range of invertebrate species, given the lack of data specific to the site the actual ecological condition of invertebrate fauna at the time of listing is not known. Despite this lack of knowledge on ecological condition, it is acknowledged that the invertebrate fauna of the Ginini Flats Wetland Complex form an important food source for *Pseudophryne pengilleyi* (northern corroboree frog), *Galaxias olidus* (mountain galaxid) and other invertebrates such as *Lycosa* sp. (alpine wolf spiders).

E5.2.8 Feral animals

Past disturbance to the site include livestock grazing, although livestock grazing has been minimal with the last official grazing in the area occurring in 1909, and possibly during a period of drought in 1920 (Clark, cited in Wild et al. 2010).

Feral pigs have been observed in the Ginini Flats Wetland Complex (Wild et al. 2010). Feral pigs disturb large areas of herbfield in their search for food such as insect larvae and tubers. Pigs also wallow in bog pools and can disturb the breeding pools used by the corroboree frogs that breed in the area.

Foxes (*Vulpes vulpes*) are found in the area and pose a threat to vulnerable species in the wetlands such as the broad-toothed rat and Latham's snipe (Wild et al. 2010).

Feral horses have damaged bogs and fens in Namadgi National Park historically. They were removed from Namadgi National Park in the 1980s, but since the late 1990s small numbers have entered from the neighbouring Kosciuszko National Park, and trampled areas of bog in the western part of the upper Cotter Catchment (ACT Government 2007).

APPENDIX F - SOCIAL AND CULTURAL VALUES

F6.1 Aboriginal cultural heritage

Evidence of Aboriginal life in Namadgi National Park can be found in a continuing oral tradition, findings of archaeological surveys and recorded observations of the region's first European settlers. Amongst the contemporary local Aboriginal community, the Canberra and Namadgi National Park region is recognised as the traditional territory of the Ngunnawal people (Navin Officer 2008).

Up until the early 1990s not many Aboriginal sites were known in the high mountain areas where the alpine *Sphagnum* bogs occurred. Many more places, including rock shelters, art sites, tool making sites and artefact scatters were known from the more accessible lower elevation country of the valley bottoms and fens. There is evidence (Argue 1995) of extended occupation in the Cotter, Orroral, Gudgenby and Naas River valleys at elevations around 1000 metres above sea level, continuing up to Nursery Swamp (1100 m ASL), Boboyan and Grassy Creek (1200 m ASL) and Rotten Swamp (1450 m ASL).

Flood (1980) reported five Aboriginal campsites above the winter snowline (1525 mASL) in the Brindabella and Bimberi Ranges. These places are all close to *Sphagnum* bogs: at Blackfellows Gap (1525 m ASL), near Little Ginini (1647 m ASL), Mt Gingera (1647 m ASL), Mt Bimberi (1891 m ASL) and Brumby Flat (1738 m ASL). Each is a small site with less than 20 artefacts, and interpreted as seasonal, with Bogong Moths (*Agrostis infusa*) and Yam Daisies (*Microseris lanceolata*) abundant in the area. Flood's general inference was that Aboriginal people visited the upland areas seasonally and in small groups (predominantly male) for Bogong Moth collection and ceremony.

In early 2013, during a wildfire in the immediate vicinity of Ginini Flats, a fire suppression line was cleared within the Ginini catchment to protect the bog from fire. Prior to restoration of the cleared line, a survey was conducted for any Aboriginal artefacts and a grinding stone was located not far from the bog (Collins 2013).

These more recent surveys have considerably expanded knowledge of the importance of the *Sphagnum* bogs in Aboriginal life. However, limited survey work has been carried out in the mountainous areas of Namadgi National Park overall, and it is likely that more sites would be found, if surveys were undertaken.

F6.2 European cultural heritage

The European cultural heritage relevant to the Ginini Flats Wetland Complex area includes the pastoral period, skiing, forestry and research.

F6.2.1 Pastoralism

Early European settlement of the region began after the exploration expeditions by Charles Throsby (1821) and Mark Currie (1823). By 1839 around one-quarter of the land that is now Namadgi National Park had been claimed by squatters (including the Upper Cotter) and in 1844 the first pastoral run was taken up at Gudgenby, with other runs taken up in the Cotter River Valley soon after (ACT Government 2010). Stock routes are likely to have developed along traditional Aboriginal routes, linking areas to surrounding valleys and high plains. The *Sphagnum* bogs and fens were important water resources for the pastoral industry.

In the 1860s–80s there was intensive use of subalpine pastures from south of Mt Kosciuszko to the Mt Scabby area, with lighter use of woodlands and 'plains' north of Mt Scabby in drought years. There was a severe drought across the region in 1885, and in 1889 'snow lease' arrangements were established under the Crown Lands Act 1884 (NSW). Routes through the southern part of the ACT were used to take cattle to the snow leases in the Tantangara and Coolamon areas of what is now Kosciuszko National Park (Rotten Swamp was named because the 'ground' was not good for cattle). This access continued until snow leases ceased in Kosciuszko National Park in 1972 (ACT Government 2001).

Protecting the Cotter Catchment as the main source of water for the national capital resulted in grazing leases being terminated and freehold land resumed in the catchment between 1911–13. One short period of grazing was allowed for drought relief in the 1920s (ACT Government 2001). A significant difference between the good condition of Ginini Flats wetlands in the early 1950s (following protection from grazing impacts in 1913) and the degraded condition of the *Sphagnum* bogs in the NSW Alps (still experiencing significant impacts from high country grazing practices which was stopped in 1958) was noted.

F6.2.2 Forestry

From the early days of Canberra, arboreta were established in the ACT to test for species most appropriate for urban landscape use, and that would be economically viable in the development of local softwood production (Chapman & Varcoe 1984).

The Mt Ginini Arboretum, established in 1959 at the highest elevation (over 1700 m ASL), was removed in 1974 because of the spread of exotic species into the natural environment, including into an area close to the Ginini Flats wetlands; management of wildings from this arboretum continued well into the late 1990s.

Native hardwood forestry was an active industry in the Cotter Valley from the 1930s. While this did not occur in areas near *Sphagnum* bogs and fens (other than at Blundells Flat), roads were established with the intention of continuing up the valley for forestry vehicle access. Concern about the impact of forestry on the water supply halted further expansion in 1962.

F6.2.3 Skiing

Skiing was popular in the Brindabella Mountains in the 1940s–50s. A ski run was cleared on the east side of Mt Ginini by the Royal Military College Duntroon for their Ginini Ski Lodge. These facilities were demolished in 1969, although the ski run remained clear and the lower portion was used for access to the Stockyard Arboretum until it was closed and rehabilitated under the recommendations of the Ginini Flats Wetlands Ramsar Site Plan of Management 2001 (ACT Government 2001).

F6.2.4 Cultural heritage of scientific research

A two metre deep, 50 metre long trench was cut into Ginini West Flat by the Australian Forestry School (a cooperative venture between the Commonwealth and the states) in 1938 for a study of peat profiles. Also, *Sphagnum* from West Ginini was cut for use in filters in vehicle gas production during World War II (ACT Government 2001). Both these activities affected the integrity of the bog peat and resulted in the 2003 fire having a much more detrimental impact on the section of the bog where these activities occurred.

The relatively undisturbed nature of the *Sphagnum* bogs in the ACT has made them important places for scientific research on the dating and palaeobotany of bogs and fens (Hope 2003), and provides a reference for comparison of condition for more highly disturbed bogs elsewhere in the Australian Alps. The ACT *Sphagnum* bogs and fens are considered highly significant from a conservation perspective as they contain pollen and charcoal deposits that provide a botanical and climatic timeline dating back to the late Pleistocene. This type of geological record is important in providing a picture of past climatic conditions, which assists understanding of ongoing climate change and its effects.

Osborne and others have been involved in researching subalpine frogs in the Brindabella Mountains over the last 45 years, especially the endangered Northern Corroboree Frog (*Pseudophryne pengilleyi*) (Osborne 1995; ACT Government 2011). The species' breeding habitat is associated with pools and seepages in *Sphagnum* bogs, as well as wet tussock grasslands and wet heath.

Hone's research on control of feral pigs in montane and subalpine regions of the ACT, as part of a landscape scale control program, has significant implications for the conservation and management of the *Sphagnum* bogs (Hone 2002).

Assessing the effects of fire following the 2003 fire, and testing rehabilitation techniques for *Sphagnum* bogs, is providing information that will facilitate long-term conservation (Carey et al. 2003; Hope, Wade & Whinam 2003; Good et al. 2010; Whinam et al. 2010).

APPENDIX G KEY THREATS

Ginini Flats Wetland Complex is within a National Park and at the top of the catchment and is therefore protected from many developmental and upper catchment impacts. However, alpine and subalpine vegetation is particularly susceptible to environmental change, due in part to the restricted growing season of the alpine and subalpine regions, but also the very fragile nature of some systems, particularly the Alpine *Sphagnum* Bogs and Associated Fens ecological community. In the Ecological Character Description (ECD): Ginini Flats Wetlands report Wild et al. (2010) identified fire, climate change, pest animals and weeds, and infrastructure, development and recreation impact as likely threats or threatening activities for this site. Each of these threats is detailed further below. Table 6 outlines each threat along with the likelihood of threat occurring, potential consequences to the ecological character of the wetland and associated risk level (including expected timeframe of the risk).

G7.1 Climate change

Scientists are already observing significant changes to the natural cycles, behaviour and distribution of plants and animals in response to climate change. The ongoing impacts on biodiversity are expected to be serious, even with only a small increase of 1–2° C in average temperature. Species with restricted climatic ranges, small populations and limited ability to migrate, are most likely to suffer dramatic declines or local extinction as suitable habitat disappears in the ACT (ESDD 2012).

Predicted impacts of climate change in the ACT (Steffen & Hughes 2013) include:

» higher temperatures, particularly higher minimum temperatures

» a significant increase in the number of extreme-heat days

» higher evaporation from overall higher temperatures

» increased winds in summer months

» drier average seasonal conditions

» decline in rainfall and reduction in run-off

» increased frequency and intensity of storm, extreme rainfall events and flooding, and fire

» more frequent and more severe drought

» increased atmospheric CO_2.

Climate change poses potential serious threats to ecosystem resilience of *Sphagnum* bogs and fens through changes to the distribution and prevalence of invasive species and disease with consequent impacts on biodiversity. These threats may significantly affect the functioning of the bogs and fens.

Increased frequency and magnitude of fire may have multiple negative impacts on the region's biodiversity through ecosystem destruction and alteration, including changes to species distribution and abundance, and increased establishment of invasive species after a fire (Steffen & Hughes 2013).

Stresses to alpine and subalpine ecosystems can be caused by direct factors such as reduced snow cover, as well as indirect effects such as reduction in water quality and quantity (in the ecosystem and downstream), all of which can lead to species decline.

Recent observed changes in the ACT climate that will affect bogs and fens include:

» long-term temperature increases, particularly in the last ten years

» declining snow in the alpine regions of the ACT – 30% since 1954 (Steffen & Hughes 2013).

Ginini Flats Wetland Complex is situated at the northern extreme of the climatic range for *sphagnum* bog wetlands in the Australian Alps. Climate change has the potential to alter all critical components and processes (for example hydrology, peat formation, vegetation, habitat availability, water quality, groundwater recharge), and thus the services that characterise the ecological character of the wetland.

A warmer drier climate will affect catchment hydrology and water supply and the subalpine *Sphagnum* bogs may contract, (ACT Government 2010). This may occur through:

» changes in snow cover depth and duration resulting in reduced snow pack, which will affect water availability in drought, decrease pools for frog breeding and result in less compacted *sphagnum* (Clark 1980), which in turn may change hydrological and growth characteristics of the peat layers

- changes in snow melt, reducing groundwater levels and bog recharge
- lowering of water tables, which will influence available water and the primary productivity of the ecosystem (Grover 2006,) and may lead to system imbalance and potential decline of peat creation and storage mechanisms.

Climate change may also affect the bogs and fens through:

- increased CO_2 levels resulting in increased primary productivity of *Sphagnum* and woody plants
- changes in hydrology leading to reduction of species such as *Sphagnum* and invasion by other plants
- increase in soil temperature, increasing evapotranspiration and decreasing available soil moisture (Grover 2001)
- changes in temperature, reducing the frost hollow effect and permitting growth of woody species in formerly treeless areas
- reduction in snow depth and persistence, increasing the impacts of cold and frost conditions on plants and animals, with the potential for frost heave to reduce recovery from past disturbances.

Modelled wetland vulnerability to climate change

Hydrogeological Landscapes (HGL) have been developed to characterise and manage the quality and distribution of water on the surface and in the shallow sub-surface of the landscape (Muller et al. 2015). Hydrological landscape units integrate information on lithology, bedrock structure, regolith (including soils), landforms and contained hydrologic systems. HGL maps and associated management recommendations have been produced for the ACT Government by the NSW Office of Environment and Heritage (OEH) and NSW Department of Primary Industries (DPI) (see also Appendix D). As a component of the ACT HGL project, wetland mapping, classification and assignment of wetland condition was carried out for wetlands across the ACT. This included an assessment of wetland hydrological vulnerability to climate change.

The hydrological vulnerability assessment shows outcomes for 3 climate change scenarios. The consensus scenario is a mean of all 12 climate models used for the NARCliM Project, and is the currently recommended model ensemble outputs to be used by NSW OEH (Muller et al. 2016). The ACT EPD selected a best case scenario which uses only the CCCMA31_R2 model output, and a worst case scenario which uses only the EACHAM5_R3 model outputs. For each HGL Unit, a weighted mean was calculated for current annual and seasonal volume (mm) of precipitation, surface water and groundwater recharge. Weighted percent change for annual and seasonal precipitation, surface water and groundwater recharge was calculated for the near future time period. The weighted values are based on the percent cover of individual gridded values from the source data layer within a HGL Unit in relation to the total area of that HGL Unit. As mentioned elsewhere, the Ginini Flats Wetland Complex occurs within two HGL areas, namely the Bimberi HGL and the Piccadilly HGL.

Results of modelling change in mean annual water source volumes and seasonality of delivery across the Bimberi and Piccadilly HGL units (Muller et al. 2016):

- In the consensus scenario precipitation levels see a non-significant decrease
- In the best case (wetter) scenario precipitation levels see a non-significant to slight increase but a slight to moderate change in seasonality
- In the worst case (drier) scenario precipitation levels see a slight to moderate decrease but no change in seasonality.

These trends continue across the scenarios for surface and groundwater (Muller et al. 2016):

- For the consensus scenario surface and groundwater see non-significant to moderate decreases in annual volumes with predominantly no change in seasonality.
- In the best case scenario surface water sees moderate to very substantial annual increases and non-significant to very substantial annual increases for groundwater, but experiences slight to substantial changes in seasonality of surface water.
- In the worst case scenario surface water sees moderate to substantial annual decreases and slight to very substantial annual decreases for groundwater, but experiences no change in seasonality.

Relating the magnitude of annual and seasonal change to wetland hydrological vulnerability produced the following results (Muller et al. 2016) (see also Figures 7 – 9 below):

» In the consensus scenario the Ginini West wetland, which falls within the Piccadilly HGL unit is indicated as highly vulnerable. Cheyenne and Ginini East, which falls within the Bimberi HGL unit, is indicated as not vulnerable.

» In the best case (wetter) scenario, the whole Ginini Flats area (covered by both HGL units) is indicated as vulnerable.

» In the worst case (drier) scenario, the whole Ginini Flats area (covered by both HGL units) is indicated as highly vulnerable.

Figure 8: Hydrological Vulnerability to climate change - consensus scenario

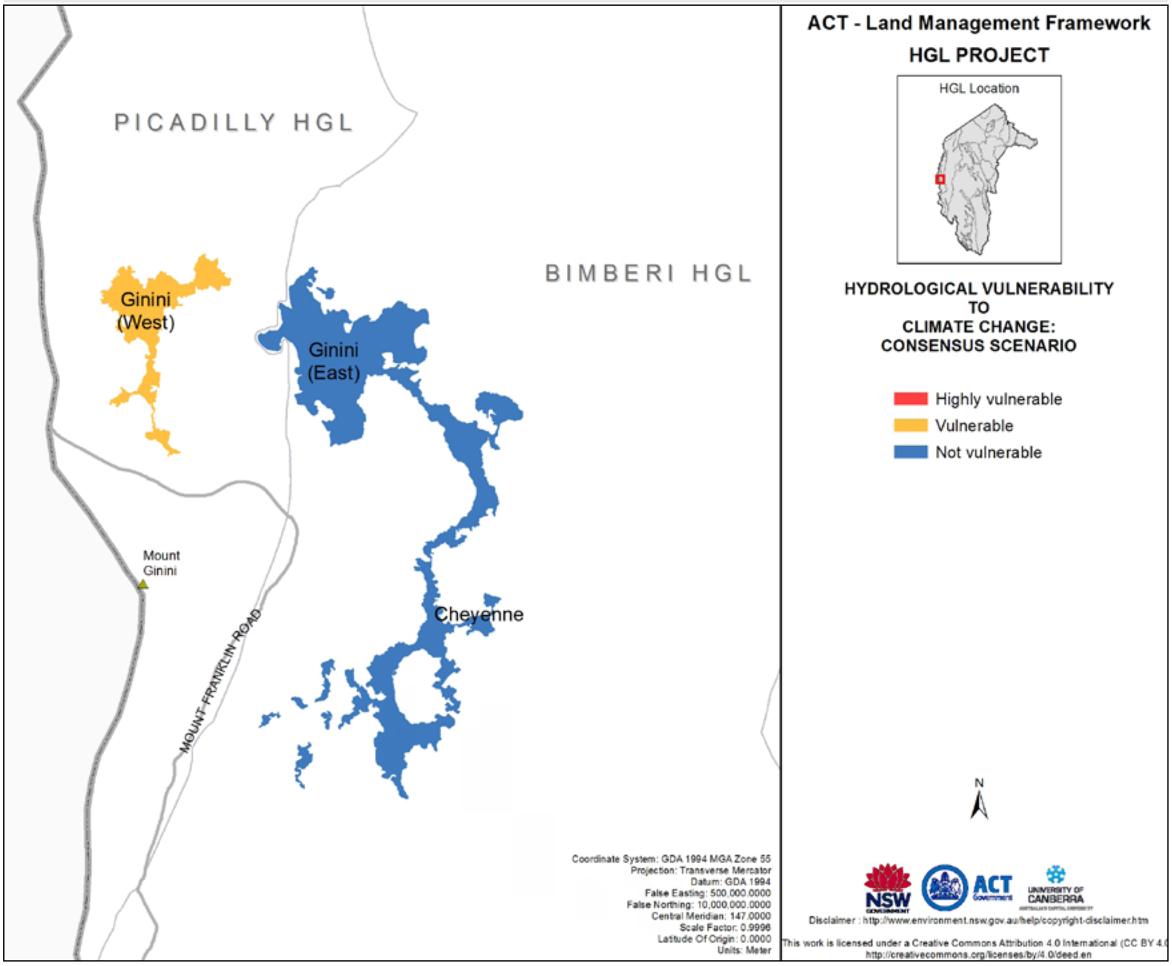


Figure 9: Hydrological vulnerability to climate change - wetter scenario

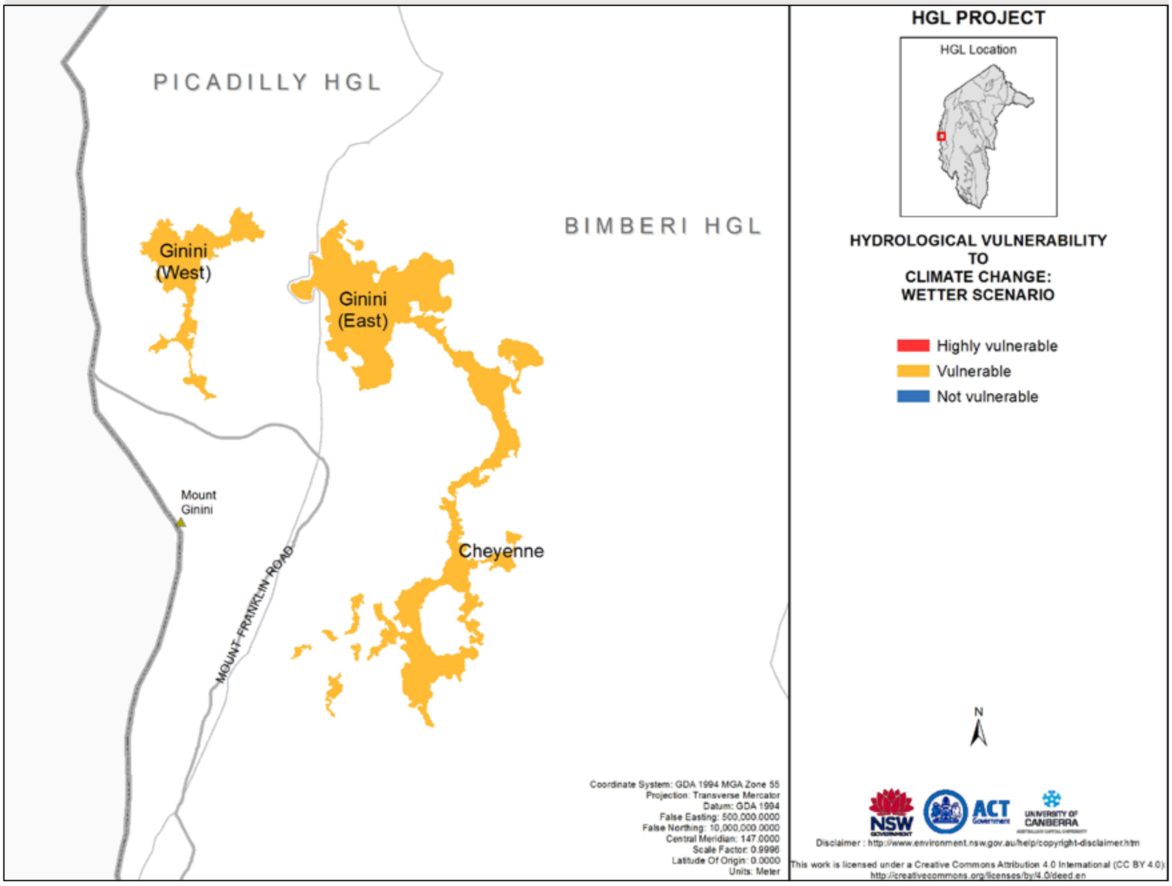
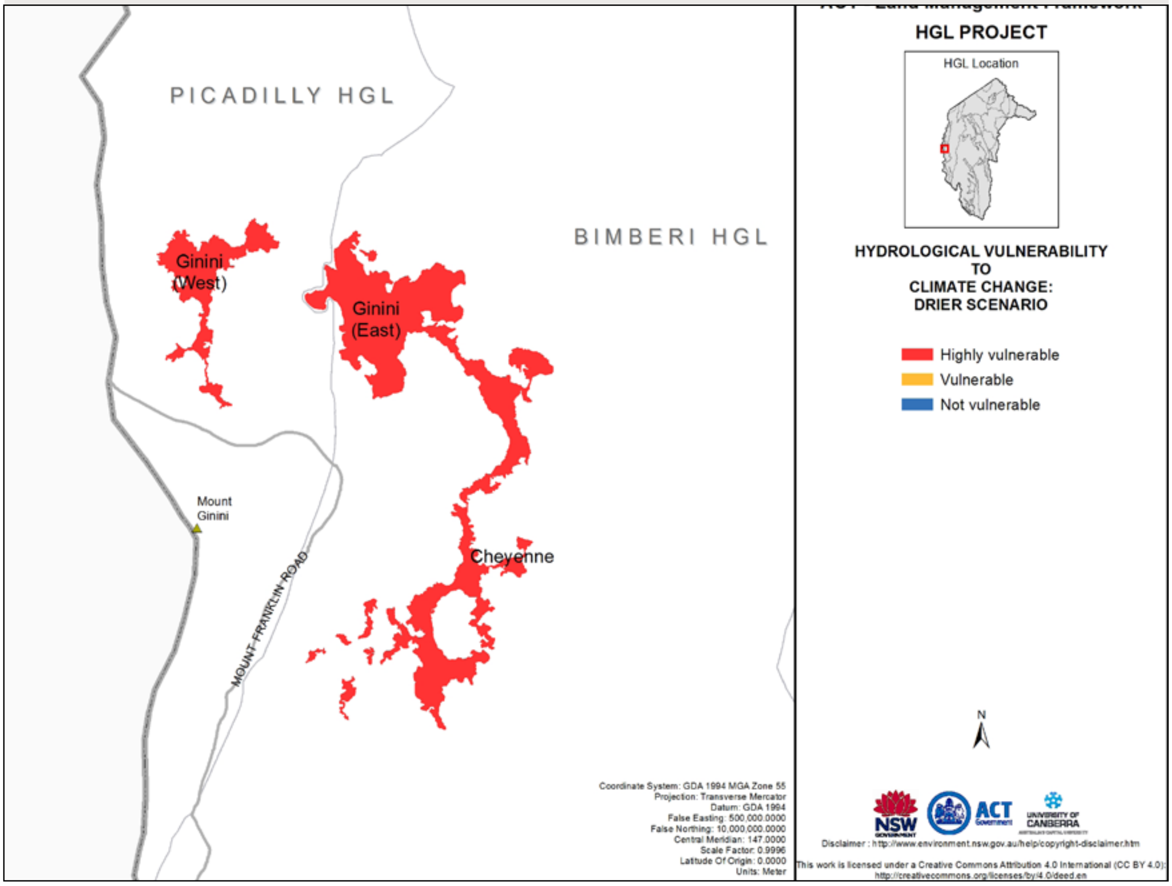


Figure 10: Hydrological vulnerability to climate change - drier scenario



G7.2 Fire

Fire is a feature of the Australian landscape. The available peat core records show the presence of fire throughout the development of the ACT bogs and fens over the last 14 000 years, and indicate that they are resilient to burning provided the underlying peat is moist (Hope et al. 2003). Fire has probably been responsible for the loss of some bogs, which have then redeveloped over time. Fire in the ACT, both past and future is strongly influenced by climate variability: for example, El Niño events dry out the landscape, increasing the spread of fires and their penetration into normally moist environments. Fire results in changes to vegetation, peat formation, hydrology and water quality. Whilst some impacts are short term (for example water quality) many are medium term (for example decades) and have the potential to significantly affect the ecological character of the wetland.

The fire history of the surrounding snow gum woodland has been determined by dendrochronological evidence by Banks (1989) and shows a high frequency of events of moderate to high intensity with an increase in frequency between 1850 and 1950 with up to ten fires per decade recorded in the woodland. This frequency has subsequently declined post 1970 with around two fires per decade in that period. Fires burned in the mountains of the ACT in 1851, 1875, 1899, 1918, 1925, 1939 and 1944 (Wild et al. 2010). It is not known to what extent the Ginini Flats Wetland Complex was burnt in these fire events because ash and other deposits do not remain evenly in the strata. However, given general fire behaviour in bogs burning the drier areas it is likely that edges of the bog were impacted in these past fires (Wild et al. 2010). Prior to this, major fires were less frequent and were likely to have occurred around every 50 years (Banks 1989); the extent of their impact on bogs and fens is not known.

Wildfire occurring within the bogs and fens is arguably among the greatest threat to the integrity and functioning of the ecological community, particularly where changes to hydrology or climatic conditions have dried out the underlying peat. In 2003, following ten years of drought, a fire lit by lightning strikes burned 90% of Namadgi National Park. Nearly all bogs and fens in the ACT were burned to some degree, ranging from patchily burned surface vegetation through to areas of severely burned peat.

The three *sphagnum* bogs which comprise the Ginini Flats Wetland Complex were all burnt with up to 30 centimetres of peat destroyed in some parts and severe damage to a large proportion of the *Sphagnum*. Around 45 per cent of the surface of Ginini west and east bogs were badly burnt in the fires with around 50 per cent (22 ha) of the *sphagnum* bog as a whole burnt (Carey et al. 2003). In some areas the fire-sterilised peats have not regenerated with bog species and they have remained dry with water passing under the peat (Wild et al. 2010). Recovery of the bogs will only occur over the medium to long term (20 years or more) and some areas may not recover, given that the conditions conducive to bog formation are now marginal in south-eastern Australia due to changing climate (Hope 2003).

The greatest risk to bogs and fens is if a peat fire is ignited; such fires often continue to smoulder for weeks or months as they slowly burn through the dry peat. Avoiding a peat fire is a high priority. During drought periods, monitoring of the dryness of peatbeds in major bogs and fens will provide information to help set priorities for fire protection within the multiple demands of wildfire management.

In a severe fire in bog and fen peatlands, the fire will generally proceed slowly and take a long time to consume the vegetation. A fire team may be able to put out spot fires and break fire fronts to achieve a mosaic burn. Protecting 'islands' of intact bog will enhance overall mire recovery after fire. A buffer of riparian vegetation needs to be protected to maintain stream integrity. By contrast, fens do not need special measures unless the fen has dried out (Hope et al. 2009).

G7.3 Invasive Species

G7.3.1 Feral animals

Large vertebrate pests, such as feral cattle, horses, pigs, deer and goats, are a significant threat to the hydrological values and function of the ecological community. These animals cause impacts such as: tracking and compaction of peats leading to channelling of water and stream incision, with the consequent drying of the surrounding peat, draining of pools and death of *Sphagnum* (Whinam and Chilcott 2002); and disturbance of Northern Corroboree Frog breeding pools and egg nests (Osborne 1991).

Pig wallowing and rooting in bogs has been observed in Namadgi National Park, and deer wallowing in the Victorian Alps (Gill et al. 2004), with similar impacts. Feral pig rooting and digging by rabbits in the woodlands and herbfields surrounding bogs is likely to affect Northern Corroboree Frog habitat, and may lead to increased sedimentation of the bogs and fens. While intact sites with good vegetation cover are resistant to weed establishment, opening up of the vegetation cover by feral animal trampling, wallowing, rooting and digging provides the opportunity for weed species to establish. A recent survey of the broad toothed rat in alpine bogs and fens habitat in Namadgi National Park found evidence of disturbance by feral animals across quadrants surveyed in Cheyenne Flats (4%), Ginini West (13%) and Ginini East (18%) (Milner et al. 2015). Of the observed disturbance by feral animals, evidence of feral pigs was most common, followed by fox and rabbit.

Feral pigs have been observed in the Ginini Flats Wetland Complex (Wild et al. 2010, Milner et al. 2015). Feral pigs disturb large areas of herbfield in their search for food such as insect larvae and tubers. Pigs also wallow in bog pools and can disturb the breeding pools used by the corroboree frogs which breed in this area. Feral pigs established populations in Namadgi National Park in the early 1960s (Hone 2002). The ACT Parks and Conservation Service has conducted a successful feral pig control program over the past 25 years. Maintaining low pig numbers is vital to limit feral pig damage to bogs and fens and surrounding woodlands. Any improvements in management techniques for feral pigs should be considered for use in the landscapes that contain the ecological community. Park managers should continue to support research into feral pig management and incorporate findings into the management program.

Feral horses have damaged bogs and fens in Namadgi National Park historically. Small numbers of feral horses enter the park from the Kosciuszko National Park and are a particular concern if they are present in the sensitive subalpine wetlands that provide an important hydrological function for Canberra's water supply. A feral horse management plan (ACT Government, 2007) is being implemented to reduce the impacts on the ecological community and its hydrological function.

As part of this program, aerial monitoring is carried out twice a year which also identifies any potential impacts from deer, cattle, pigs and goats. It is imperative that such a program remains active as long as horses are in the area.

Feral goats have been controlled in Namadgi National Park: in the early 1980s over 300 were removed from the Cotter River side of the Tidbinbilla Range; in the late 1990s a small number were located in, and then removed from, the landscape surrounding the Cotter Source Bog. However, because Namadgi National Park has a long border and goats continue to populate surrounding lands, it is vital to monitor for, and control any new incursions into areas where the bogs and fens are located.

Cattle have entered Namadgi National Park – and specifically bogs and fens – during very dry periods. These are usually domestic herds that have broken through fences seeking both feed and water. Because of their impact on the integrity of bogs and fens, it is important to prevent such incursions and, if they do occur, remove cattle promptly. Past disturbances to the site include livestock grazing. Livestock grazing has been minimal with the last official grazing in the area occurring in 1909, and possibly during a period of drought in 1920 (Wild et al. 2010).

Feral deer are an emerging threat, and three species are known to be present in Namadgi National Park: Sambar Deer have been seen in the middle and upper Cotter catchments; Red and Fallow Deer occur in low numbers in the east. Deer have the potential to damage the integrity of bogs, as noted in the Victorian Alps where there is a record of a deer wallow in a bog (Gill et al. 2004). The ACT Parks and Conservation Service has developed a strategy for the monitoring and management of feral deer (ACT Gov, 2014c). At this stage, there is no systematic impact monitoring in the bog communities. However, a priority action for implementation of the strategy is to develop a management program for high priority areas. Protection of bogs and fens from deer should be considered in this context.

Foxes are likely to have a negative impact on small mammals that inhabit the bogs, including the Broad-toothed Rat *(Mastacomys fuscus)*, and potentially the Water Rat (*Hydromys chrysogaster*) in the larger fens on the montane valley floors. They are also known to eat crayfish in bogs. The impact of such predation is unknown. Monitoring of Broad-toothed Rat populations in bogs indicates recovery since the 2003 fire, however evidence of foxes continue to be found at the site (Milner et al. 2015). As part of research into feral pig baiting techniques in 2005–07 there was some fox management in the Cotter Catchment (Trish Macdonald, pers. comm. 2013). Monitoring of fox density is important and management of foxes should continue if there is an increase in the number of foxes and/or a fall in the number of Broad-toothed Rats.

Feral cats have been observed throughout Namadgi National Park, and have been seen at high altitudes even when the landscape is snow covered. Their effect on native animals has not been quantified, and there are no practical management methods currently available for their control, however Curiosity™ cat bait uptake trials have recently taken place in Namadgi. Monitoring should be undertaken to quantify the impacts of cats on native animals and, if required, management should be adopted if successful methods become available.

Rabbits are known to inhabit surrounding grasslands and woodlands of the wetland complex (Wild et al. 2010). Extensive rabbit management was carried out in the Nursery Swamp valley in the early 1980s to reduce the severe impact that large numbers were having on the ecosystem: removal of rabbit warrens by blasting significantly reduced the impacts of rabbits for more than 20 years. Warren blasting was also carried out in the 1990s in the grasslands surrounding Rotten Swamp, Cotter Source Bog and Bimberi Peak Bog (Trish Macdonald, pers. comm., 2013). Warren blasting is recognised as a conditionally acceptable control method in the national Model Code of Practice for the Humane Control of Rabbits (ACT Government 2015) to be used when rabbit numbers are low. A significant rabbit population at Cotter Source bog was controlled by Parks and Conservation Service in 2013. Ongoing monitoring of rabbit warrens in the areas surrounding bogs and fens will be carried out, and rabbits managed if necessary.

European wasps are a declared pest animal and are widespread in Namadgi National Park, and occur in the Ginini Flats Wetland Complex (Wild et al. 2010). While little is known about the ecological impact of European wasps, they are a likely threat to native biodiversity, especially to insects and spiders. There is currently no effective landscape-scale control. The extent and intensity of nesting within bogs should be monitored, and consideration given to local control at hot spots through baiting programs similar to those currently used in ACT recreation areas.

There is no evidence that exotic fish species have colonised aquatic habitat within Ginini Flats Wetland Complex (Wild et al. 2010). The Cotter River catchment (for which the Ginini Flats Wetland Complex is part of the headwaters) is one of a few south-east draining catchments that do not support a number of exotic fish species. Carp and redfin are excluded due to the fish barrier created by the Cotter Dam and brown trout are excluded from the mid and upper catchment by the fish barrier created by the Bendora Dam.

G7.3.2 Weeds

Introduction of weed species may occur through the spread of seed by wind, native animals and feral pests, and by vehicles and recreational users. Weeds can compete with and exclude native plants. The weeds of highest priority in bogs and fens are those likely to affect hydrological function.

Willows (*Salix species*) are known to alter water availability within the peat, drying it out. Willows can survive and thrive in the acidic soils and peats of bogs. Monitoring of the larger of the ACT bogs and fens following the 2003 fire found that willows had appeared in a number of the bogs and fens; these were removed. New occurrences were noted in 2013 in Nursery Swamp. In 2013 a large stand of mature willows was discovered in NSW bushland west of Cotter Source Bog and removed by Parks and Conservation Service staff and have also been found and removed from Ginini West (Ben Stevenson, personal communication 2014).

Blackberry (*Rubus fruticosus*), a Weed of National Significance, occurs in parts of Namadgi National Park, and is a potential threat in both bogs and fens. Blackberries degrade the ecological community by displacing native species and reducing habitat for native animals.

Blackberries also provide harbour and seasonal food for foxes, rabbits and pigs, which in turn can disperse seed, acting as vectors to spread infestations. Former Northern Corroboree Frog breeding sites that have been invaded by blackberry in NSW appear to have become unsuitable for the species (ACT Government 2011). Blackberries are present in some of the species' smaller breeding sites in Namadgi National Park.

In general the Ginini Flats wetlands remain relatively undisturbed and free of weed invasion; however, weed invasion is a factor in grasslands surrounding them. Following the 2003 fire, weeds such as Sheep Sorrel (Acetosella vulgaris), thistles (*Carduus* spp.) and cat's ear (*Hypochaeris* spp.) were recorded in burned areas of bogs. These weeds declined in abundance as regeneration of native species occurred. Nodding Thistle was found and removed by Amanda Carey in 2004 from Little Rotten Swamp, Sweet Vernal Grass (Anthoxanthum odoratum) is present in the Ginini West and Cheyenne wetlands, on the Ginini ski run, in the grasslands around Snowy Flat on the western edge opposite Pryor's pines and all along the Mt Franklin Road. It remains a significant problem. Orange Hawkweed (Hieracium aurantiacum) is of potential concern for invasion into the surrounding grasslands. There is a seed source of this weed in the west of Namadgi National Park, and the grasslands surrounding the bogs and fens will be a prime location for their establishment should seeds reach these areas. Mouse-ear Hawkweed (Hieracium pilosella) has been found at Nursery Swamp. African Lovegrass (Eragrostis curvula), widespread in the region, may also be spread by recreational users and vehicles into surrounding grasslands. Monitoring and management of such weeds should continue to be a part of the weed program of Namadgi National Park.

At the time of listing, some peripheral weed invasion was noted on disturbed areas such as roads. In April 2009, field observations showed a persistence of some ruderal weeds such as sheep's sorrel (*Rumex acetosella*), thistles (*Carduus* spp.) and cats ear (*Hypochaeris* sp.) which were also recorded immediately following the fires (Wild et al. 2010). Whilst these have persisted they are expected to decline in abundance as regeneration of native species occurs.

G7.3.3 Pathogens

Pathogens pose a direct threat to the existence of amphibian species and fish within *Sphagnum* bog and fen habitats. The amphibian chrytrid fungus (*Batrachochytrium dendrobatidis*) has had a significant impact on the Northern Corroboree Frog(*Pseudophryne pengilleyi*). At Ginini Flats Wetland Complex, the Northern Corroboree Frog was once estimated to be the largest vertebrate biomass and had the largest aggregations of the species in its range (Osborne cited in Wild et al. 2010). By 1992, populations of northern corroboree frogs in the ACT had declined significantly, with less than 10 per cent of the population size of the early 1980s, and have continued to be at very low levels since. The decline in numbers is believed to be due to chytridiomycosis, a disease caused by infection with the Amphibian Chytrid Fungus), a pathogen that may have been carried to the site by another frog species (Crinia spp.) or a human vector. A study in 2007 found that 14 per cent of the population of the *P. pengilleyi* population was infected with the fungus (Wild et al. 2010).

Epizootic Haematopoietic Necrosis Virus (EHNV) is unique to Australia and characterised by sudden high mortalities of fish, particularly Macquarie Perch, and trout species which can act as vectors. EHNV was first recorded from the Canberra region in 1986. The spread of EHNV has been aided by its relatively resistant characteristics and the ease with which it can be transmitted from one location to another on nets, fishing lines, boats and other equipment. Once EHNV has been recorded from a water body it is considered impossible to eradicate (ESDD 2012). Although not recorded in the Ginini Flats wetlands so far, vigilance is required to ensure it remains free of the virus.

G7.4 Changes to infrastructure

Existing, development and/or use of infrastructure such as roads has the potential to impact the ecological character of the wetland through altered hydrology (increased runoff) and changes to water quality (for example increased sediments and turbidity, introduction of pollutants such as oil (Wild et al. 2010). Such impacts have the potential to impact peat formation, vegetation and habitat availability within the wetland. Existing catchment development includes the historical ski run on the eastern side of Mt. Ginini, where trees have been removed upslope of the wetlands (now disused), the Mt Franklin Road and car park and the weather monitoring infrastructure on the summit of Mt Ginini.

G7.5 Recreation and tourism

Recreational use of the *Sphagnum* bogs and fens is limited: the bogs by their relative isolation; and the fens, though in more heavily visited areas, because they are usually 'wet' and walkers avoid entering them. The *Sphagnum* bogs are fragile and low levels of visitor use can have quite significant impacts. The fens are more robust and are less likely to be affected by visitors.

Park visitors that might enter bogs and fens include bushwalkers, orienteering and rogaining participants, cross-country skiers, researchers, volunteers, search and rescue groups, the Australian Federal Police (AFP) Tactical Response Team and the AFP Rural Patrol team. Management activities that require access to the bogs and fens – including firefighting and control burns, weed management, feral pest management, scientific research, bog rehabilitation and water supply management – have a similar potential to negatively affect the ecological community.

Visitor impacts that are likely to have a negative effect on the *Sphagnum* bogs include trampling of *Sphagnum* moss, spreading of weed seed and possibly pathogens. Trampling in sensitive vegetation such as *Sphagnum* moss has shown significant impact after only 30 passes, and recovery from that level of impact has taken 3–5 years (Whinam et al. 2003). Walkers have been found to be significant in spreading weed seeds in Kosciusko National Park (Mount & Pickering 2009).

Ginini Flats wetlands are close to a public access road (Mt Franklin Road) and are accessible by walkers, including day walkers. Visitors require a permit to camp in the upper Cotter Catchment (south of Corin Dam). The permit conditions of those camping in the upper Cotter Catchment do not currently provide information about the fragility of the bogs.

G7.6 Threats to cultural heritage

Knowledge of Aboriginal use of Namadgi is limited by the fragmentation of oral tradition and kinship groups that followed European settlement of the region and the limited systematic archaeological survey and anthropological research that has been undertaken (ACT Government 2010).

Many of Namadgi National Park's cultural landscapes and historic heritage places were damaged or destroyed by the 2003 bushfire.

Significant gaps in knowledge and understanding relating to Aboriginal use of Namadgi are apparent due to the fact that archaeological research has tended to be opportunistic rather than systematic. Anthropological research has been extremely limited. There is an opportunity for greater involvement of the local Aboriginal community in the management and promotion of the park now that the Ngunnawal community is re-establishing ties to the area.

The fabric of many of Namadgi's cultural heritage places is fragile, vulnerable and expensive to maintain but resources for the maintenance of such places are limited. There is the opportunity to use the skills, knowledge and volunteer labour of community groups to assist with the conservation of heritage places.

Efforts to protect Namadgi's natural values need to be undertaken with an awareness of the potential impacts of activities on the cultural values of the park's heritage places.

The Ramsar Site and the values of the wetlands are poorly known and recognised by the general public (ACT Government 2001).

APPENDIX H - GININI FLATS WETLAND COMPLEX HGL MANAGEMENT – A CASE STUDY

Ginini Flats Wetland Complex: HGL Management Case Study Nicholson A., Cowood A., Wooldridge A. and Muller R. Report to ACT Environment and Planning Directorate, November 2016

H8.1 Overall Principles

The formation of peat requires cool-cold conditions, waterlogging, organic soils and a landscape/ landform position that stores water in an acidic environment. The Hydrogeological Landscape (HGL) framework goes some way to identify the differences, and hence management of the peat forming wetlands in Ginini developed on different geologies.

The West Ginini Wetlands ("peatlands") exist in the Adaminaby Group of Ordovician geologies which is in the Picadilly HGL; whilst the East Ginini and Cheyenne Flats Wetlands ("peatlands") occur in granitic geologies which is in the Bimberi HGL.

Hydrology

There are two groundwater flow systems, a shallow perched system and a local flow system, that provide water to the wetlands. Through- flow (movement of water downslope in shallow regolith) is the major component in an undisturbed landscape. Run-off provides direct flow to the wetlands, and deep recharge to the base of the wetland is a minor component. There is slightly more deep recharge in the Picadilly HGL through fractures than the hard granite rock landscape (Bimberi HGL).

Groundwater pressure from local flow system to bottom of peat, and through-flow maintains the groundwater head at the surface of the wetland. Run-off events and snow melt provide additional water to the wetland. Peat is a storage system for groundwater and run-off, and also moderates run-off from the wetland by slow delivery over time from the wetland. The *sphagnum* in the wetland stores significant water volume (95% of matrix is often water). Small free water areas exist throughout the wetland.

As you go deeper into peat layers, the hydraulic conductivity lessens. There are also clay layers under the peat that act as impermeable or semi permeable layers. The result is that there is a shallow perched system set up within the peat layers. This perched system stores water and also allows for slow output of held water in the peatland, and is ultimately controlled by the height level at the outlet of the wetland ("plug"). Evaporation in the peatlands is reduced by vegetation and *sphagnum*, and also by the colder environment, so that water is retained longer in the environment. The winter period tends to accumulate water in the system, for release into the drier seasonal conditions.

The separation of the two systems (shallow perched / local flow system) and the loss of interconnection due to drought, climate change or loss of control point (i.e. the plug) will perturb the functioning water system, leading to degradation.

Soils and Erosion

The Alpine Humic and Organosol soils of the Ginini area are influenced by altitude and slope. There is an increase in soil depth downslope with humic layers in the topsoils and sodic clays in the subsoils. Sodicity is an issue in both HGLs, but more risk in Picadilly HGL. The Picadilly HGL is steeper and slightly more sodic, so is more susceptible to erosion. It also has lower CEC and often more clay in the profile.

Landscape shape is influenced by geology with bowl forming and rounded landforms in the granitic Bimberi HGL, and more acute landforms in the Picadilly HGL. The rounded Bimberi landscapes are more predisposed to formation of bowl shaped depressions which can become peatlands.

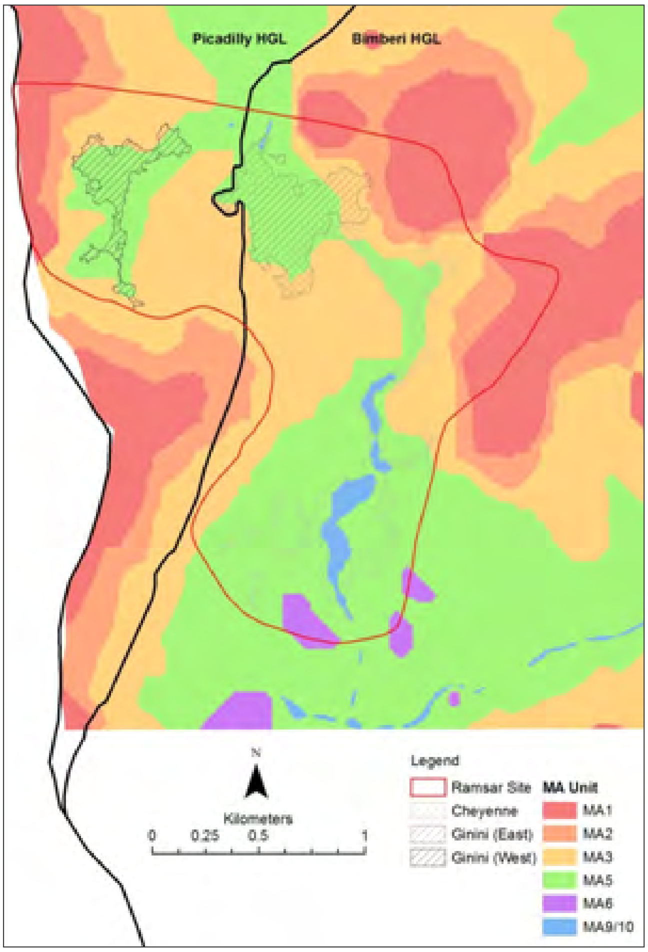
The peat soils are more fibrous and aerobic in the top most layers and become finer and anaerobic at depth. The areas are waterlogged with acidic and reducing conditions. Clay layers exist at 30-40cm to a depth of 1-2 m occasionally. Frost heave in the wetlands is a natural process which increases the "roughness" of the surface.

Erosion particularly, gully erosion will change the energy and hydrology of the wetland. Increases in run-off will change the erosion risk. Increased erosion will:

- Decrease water quality
- Increase sediment delivery
- Increase the risk of tunneling, especially in sodic soils
- Increased risk of channelised flow and sheet erosion.

The wetlands water level is controlled by a "plug" at the catchment outlet which determines the stability of the wetland. This plug can be a rock bar or clay layer. Erosion around this area can have devastating impact on the wetland essentially by draining or lowering the water level in the wetland.

Figure 11: Map of HGL Units and Management Areas for the Ginini Flats Wetland Complex



Burning has very significant impacts directly on the peatlands by burning vegetation/peat and also on the catchment especially the flow on hydrology impacts. The impacts are:

- Burn increases run-off on steep slopes, which increases the sediment load and volume of water reaching the wetland. This changes the hydrology by decreasing the volume of through flow and deep recharge, in favor of increased run-off.
- Burning opens up erosion risk on slopes, but importantly changes the dynamics on the wetland. Increased volumes of run-off increase sheet erosion, formation of channels and erosion around "the plug" leading to dewatering of the wetland.
- Burning decreases organic matter on the slopes leading to the wetland and is exacerbated by fire frequency. This will impact on water storage potential in the slopes leading to the wetland.
- Burning of slopes also increases the delivery of nitrogen and phosphorous to the wetland.

There are subtle differences between the two HGLs, but there are also significant similarities (Table 1, Figure 1 and 2, see also Appendix 1). Management of the wetland is determined by location of Management Areas (Figure 3).

An HGL management framework is detailed in Section 2, including an overview of determined Wetland Function and associated Management Actions. Section 3 further outlines the specific details of the Management Actions. Section 4 summarises identified risks, with Section 5 listing actions to avoid (DLU).

Table 8: Summary of differences and similarities in Bimberi and Picadilly HGL areas

Heading		
	Bimberi HGL – Ginini East/ Cheyenne Flat	Picadilly HGL – Ginini West
1. (MA1 & MA2) - Ridge and steep slope	Alpine humus soils, Organosols Sodic slopes	Alpine humus soils, Organosols Sodic slopes – higher risk
2. (MA2 & MA3) – Colluvial slope	Run-off from area Through-flow Rounded slopes	Run-off from area Through-flow Acute slopes
3. (MA3) – Slope area immediate to the bog	Grasslands (*Poa*) Tea tree Dense vegetation High fire risk - flammable	Grasslands (*Poa*) Tea tree Dense vegetation High fire risk - flammable
4. (MA5) Bowl – Peat bog	Peat bog *Sphagnum* Peat soils More likely to be bowl shaped	Peat bog and open water *Sphagnum* Peat soils Sheet wash and channelized flow Tunnel erosion
5. Shallow perched system	Clay layer 40cm – 2m Responsive to climate Responsive to run-off Groundwater connection	Clay layer 40cm – 1m Responsive to climate Responsive to run-off Groundwater connection
6. Groundwater	Positive groundwater head Responsive to climate Responsive to through-flow	Positive groundwater head Responsive to climate Responsive to through-flow More deep recharge
7. Plug	Granite plug Less likely to erode More stable	Clay, metamorphic contact, or none High erodible Likely to channelize
8. Outlet	Likely to be granite boulders Lower erosion risk Consider granite rock flume	Eroded gully and head cuts High gullying risk Consider constructed structures Masonry flume Sandbags Jute mesh/coir logs

Figure 12: Schematic conceptual model of the East Ginini Wetland.

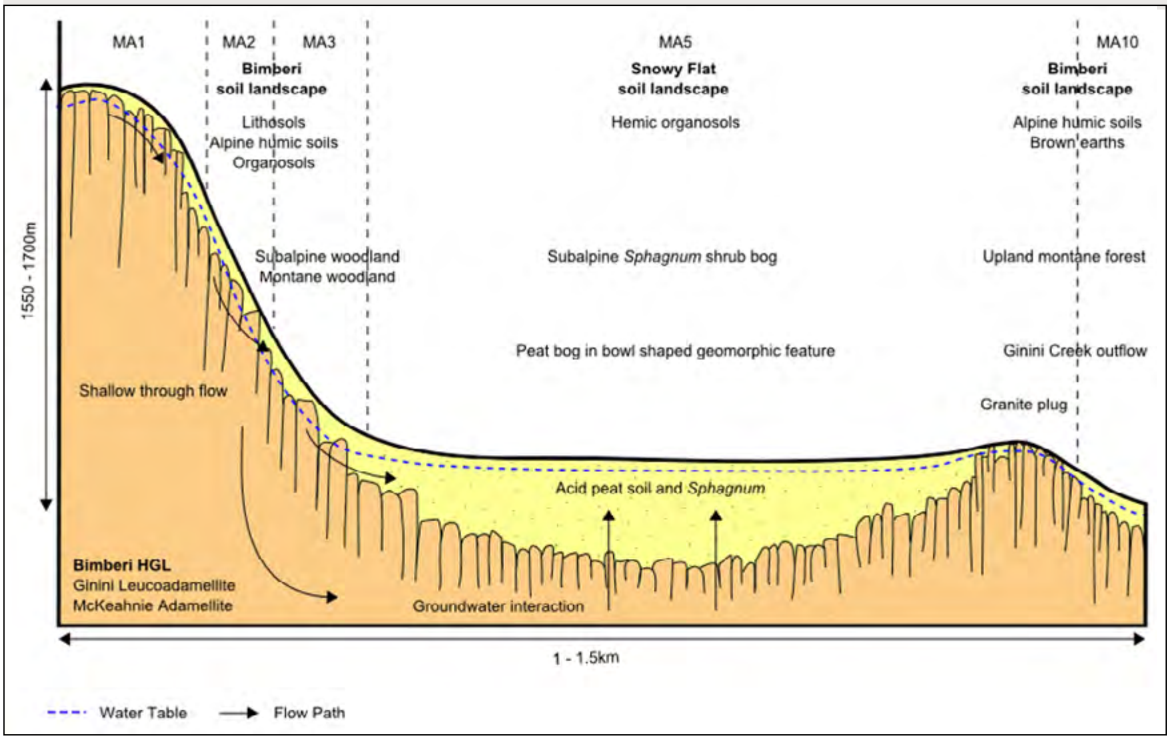
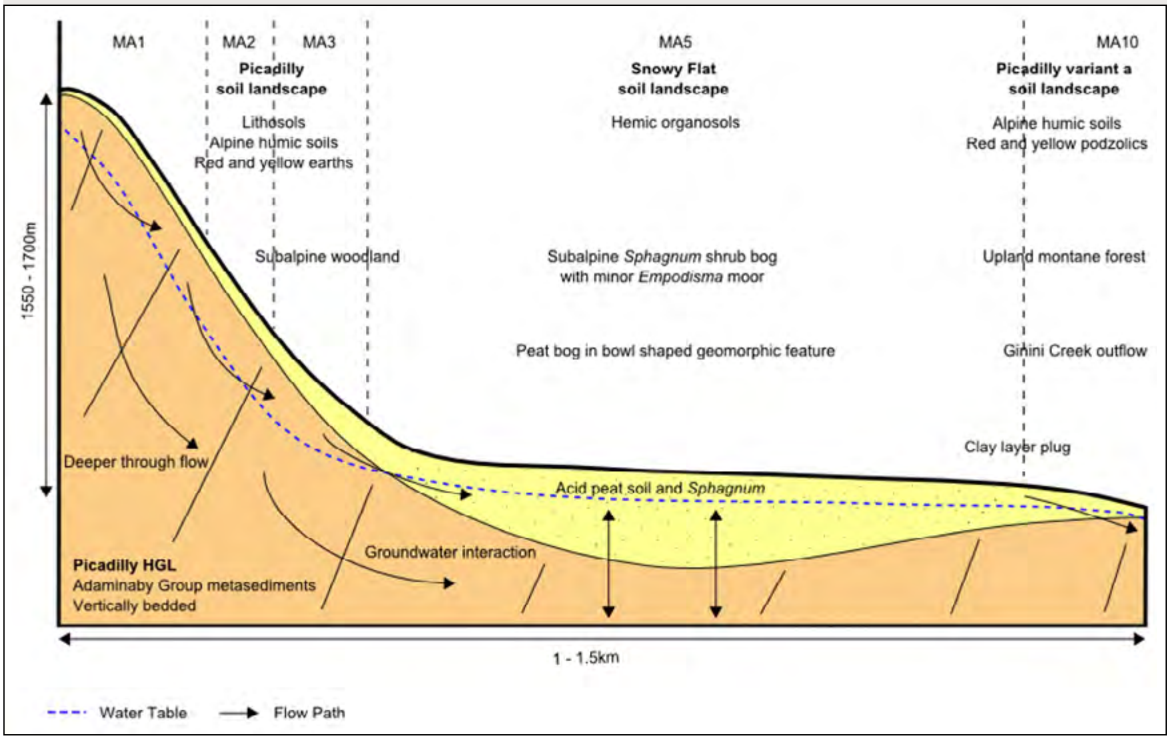


Figure 13: Figure 2: Schematic conceptual model of the West Ginini Wetland.



H8.2 Management Actions

Wetland Functions and Management Actions – HGL Framework

Wetland Function	Bimberi	Picadilly
A. The wetland provides an important water source		A
B. The wetland generates an important water discharge site		
C. The wetland generates an important water recharge site		
D. The wetland provides buffering of surface water events		
E. The wetland supports important biogeochemical processes	E	
F. The wetland receives water quality issues		F
G. The wetland mitigates water quality issues		
H. The wetland generates water quality issues		
I. The wetland has potential to support species habitat	I	I
J. The wetland provides an important species habitat	J	J
K. The wetland supports pest species		
L. The wetland supports cultural values	L	
Wetland Management Actions		
WCF Cultural function		
WCF1 Manage for passive recreation		
WCF2 Manage for active recreation		
WCF3 Maintain indigenous culture	WCF3	
WCF4 Manage wetland for aesthetics		
WCF5 Provide for education and research opportunities	WCF5	WCF5
WFM Fire management		
WFM1 Manage for emergency wetland protection - e.g. foam	WFM1	WFM1
WFM2 Manage fire back burning away from wetland in adjacent vegetation community	WFM2	WFM2
WHM Habitat management		
WHM1 Manage for maintaining current habitat	WHM1	WHM1
WHM2 Manage to improve habitat		
WHM3 Manage to improve habitat for a specific species or community	WHM3	WHM3
WHM4 Manage to improve landscape connectivity and species dispersal		
WHM5 Manage to provide drought refugia	WHM5	WHM5
WHM6 Introduction of new species for improved habitat		
WHM7 Reintroduction of existing species for improved habitat		
WHR Hydrology management		
WHR1 Maintain soil moisture in wetland bogs	WHR1	WHR1
WHR2 Maintain hydrological regime	WHR2	WHR2
WHR3 Buffering wetland with trees to reduce wind evaporation	WHR3	WHR3
WHR4 Increase shading to reduce evaporation in wetlands	WHR4	WHR4
WHR5 Control water level in wetland	WHR5	WHR5

Wetland Function	Bimberi	Picadilly
WHR6 Control extraction of water from wetland		
WHR7 Manage river regulation for wetland habitat – environmental flows		
WHR8 Construction of wetlands with natural materials only		
WHR9 Construction of wetlands with natural materials and man-made materials		
WNM Nutrient management		
WNM1 Planting 'nutrient loving' plants		
WNM2 Harvesting wetland plant material		
WNM3 Management of aquatic plant species		
WNM4 Manage for filtering and retention of nutrients		
WNM5 Manage diffuse effluent input to wetland		
WNM6 Manage point source effluent to wetland		
WNM7 Manage for filtering and retention of organic matter and carbon storage		
WPH pH management		
WPH1 Manage to maintain *sphagnum* peat bogs	WPH1	WPH1
WPM Pest management		
WPM1 Controlled access to manage wetland weed invasion	WPM1	WPM1
WPM2 Manage for reduction in invasive pest species in wetland	WPM2	WPM2
WSA Salinity management		
WSA1 Manage for dilution flows to wetland		
WSA2 Manage for diversion of saline inflow around wetlands		
WSA3 Manage for point source diversion of saline inflow to wetlands		
WSA4 Manage for saline groundwater intrusion		
WSM Sediment management		
WSM1 Manage for filtering and retention of sediment	WSM1	WSM1
WSM2 Manage for erosion control and bank stability	WSM2	WSM2
WSM3 Manage for soil development and decomposition of organic matter	WSM3	WSM3
TA Track and Access		
TA1 Track siting and design	TA1	TA1
TA2 Track drainage		
TA3 Track maintenance and monitoring		
TA4 Track surfacing		
TA5 Controlled access to reduce trafficability (compaction/trampling)	TA5	TA5
AM Animal Management		
AM1 Control total grazing pressure (kangaroos/rabbits)		
AM2 Exclusion fencing		
AM3 Feral animal control	AM3	AM3

H8.3 Specific Wetland Management Actions

With regard to wetlands there are more specific actions which could be applied as indicated below

WCF Cultural function

» WCF3 Maintain indigenous culture:

- The Bimberi wetlands have significant sites at the outlets from the peatlands which indicate long term usage by indigenous communities.

» WCF5 Provide for education and research opportunities:

- There is a range of current and future research that is being undertaken to fill knowledge gaps around climate change impacts, hydrology, water quality and vegetation research.
- There is a long term need for monitoring the behavior and performance of the peatlands (hydrology, peat formation, flora and fauna etc).

WFM Fire management

» WFM1 Manage for emergency wetland protection - e.g. foam:

- The use of fire retardant measures such as foam could be considered provided impact on biota is considered.
- Targeted water bombing of the edges of the peat to stop ingress of fires to the peatlands.

» WFM2 Manage fire back burning away from wetland in adjacent vegetation community:

- It is important that back burning is undertaken surrounding the catchment of the wetlands, **not in the direct sub-catchment of the peatlands**.
- Large changes in hydrology can impact the wetland from burning, particularly increased run-off from steep slopes, which increases the sediment load and volume of water reaching the wetland. This changes the hydrology by decreasing the volume of through flow and deep recharge, in favour of increased run-off.
- Burning opens up erosion risk on slopes, but importantly changes the dynamics on the wetland. Increased volumes of run-off increase sheet erosion, formation of channels and erosion around "the plug" leading to dewatering of the wetland.
- Burning decreases organic matter on the slopes leading to the wetland and is exacerbated by fire frequency). This will impact on water storage potential in the slopes leading to the wetland.
- Burning of slopes also increases the delivery of nitrogen and phosphorous to the wetland.

WHM Habitat management

» WHM1 Manage for maintaining current habitat:

- Management of water regime is of prime importance. Erosion is an active area of management, particularly at the "plug" of the wetland system.

» WHM3 Manage to improve habitat for a specific species or community:

- The habitat of the Northern Corroboree frog is impacted by decline in the peatlands, free water and also by fungal disease.
- Biosecurity actions with regard to fungal contamination need to be undertaken.

» WHM5 Manage to provide drought refugia:

- Actions which direct water from lower slopes including small silt fences to direct run-off water , and weed free straw bales placed on the peatlands to direct water flow, could be used to direct water flow in a triage situation under drier conditions.

WHR Hydrology management

» WHR1 Maintain soil moisture in wetland bogs:

- Slopes vegetation to manage organosols that store water and deliver downslope.
- Redirecting run-off - construction of silt fencing in the catchment using geofabric, shade cloth or coir logs.
- Maintain the integrity of the "plug" area.

» WHR2 Maintain hydrological regime:

- Redirection of run-off on slopes.
- Redirection of water in peatlands by use of straw bales or coir logs.
- Maintain the integrity of the plug area so that catastrophic dewatering does not occur.

» WHR3 Buffering wetland with trees to reduce wind evaporation.

- Encourage fringing shrub and tree regrowth, and repair of post fire damage.

» WHR4 Increase shading to reduce evaporation in wetlands:
  • There have been trials of artificial shading materials with some success.

» WHR5 Control water level in wetland:
  • Control of "plug" by use of natural materials or man-made material to maintain wetland water level.

WPH pH management

» WPH1 Manage to maintain *sphagnum* peat bogs:
  • Fire management and the introduction of large volumes N & P in run-off post fires are a risk to the pH management of wetlands and water quality.

WPM Pest management

» WPM1 Controlled access to manage wetland weed invasion:
  • Weed invasion is a relative low risk due to isolation
  • Foot access from Mt Franklin may need to be controlled as an entry point for seeds brought in by foot traffic.
  • Routine surveillance and removal of weed species.

» WPM2 Manage for reduction in invasive pest species in wetland:
  • Feral pigs with their wallowing, digging for roots and trampling are a significant risk.
  • Baiting, trapping and other removal actions are appropriate, as is routine monitoring.

WSM Sediment management

» WSM1 Manage for filtering and retention of sediment:
  • Careful management of burning and wild fire adjacent to the peatlands.
  • Construction of silt fencing in the catchment using geofabric , shade cloth or coir logs.

» WSM2 Manage for erosion control and bank stability:
  • Control of "plug" by use of natural materials or man-made material to maintain wetland water level. Manmade systems and materials include (Picadilly HGL):
    • Masonary flumes
    • Coir logs
    • Rock gabions
    • Sheet pile drop structures
  • Natural measures, which are more likely to occur in Bimberi HGL include loose rock (granite boulder) flumes, clay infill , coir logs, straw bales or wooden drop structures.
  • Downstream of plug needs to control active gully head migration upstream with man-made or natural methods. The areas should have no effective drop height as this increases the risk of forming gullies that migrate upstream.
  • Channelised flow in peatland can be controlled by use of straw bales and coir logs.
  • Maintenance in vegetative cover will reduce sheet erosion. Importation of clean straw mulch could be considered as a short term remediation method.
  • Vegetation cover also reduces the risk of tunneling.

» WSM3 Manage for soil development and decomposition of organic matter:
  • Maintenance of waterlogged and anaerobic conditions.

TA Track and Access

» TA1 Track siting and design:
  • Siting access tracks to ridge lines only.

» TA5 Controlled access to reduce trafficability (compaction/trampling):
  • Control foot traffic to wetland and vehicular access to proximity of peatlands.

AM Animal Management

» AM3 Feral animal control:
  • Feral pigs with their wallowing, digging for roots and trampling are a significant risk.
  • Baiting, trapping and other removal actions are appropriate, as is routine monitoring.

H8.4 Risk

Climate change presents the greatest risk to the peatlands that is outside the realms of onsite management (Appendix 2). Impacts may be due to:

- » Seasonality in rainfall to more summer dominance
- » Warming temperatures
- » Drop in rainfall

Fire risk is mostly natural wildfire, but also due to back- burning actions. The key message is that burning should not occur in the sub-catchment due to impacts on catchment hydrology.

Erosion risk is confounded by both burning and climate change, but has some element of on – site management that will reduce risk.

H8.5 High hazard land use (DLU)

There are some activities that present high hazard to wetlands. A good example of this inappropriate activity is construction of a trench in Ginini West for research purposes, but the scar on the landscape is visible decades later. Some other examples of high hazard include:

A. Construction of drains to lower water tables

B. Allowing access to wetlands of hard hooved animals

C. Inappropriate burning

D. Poor soil management lading to loss of surface layers

E. Reducing run-off from fresh water catchments.

Table 9: H8.5 Ginini Wetlands

HGL Unit Parameters	Bimberi HGL	Picadilly HGL
Lithology	This HGL comprises mainly granitic rocks. Key lithologies include: » Ginini Leucomonzogranite » Bendora Granodiorite » McKeahnie Monzogranite » Half Moon Peak Monzogranite	This HGL comprises Ordovician metasediments. Key lithologies include: » Adaminaby Group » Tidbinbilla Quartzite » Felsic volcanic and granitic rocks (minor)
Annual Rainfall	1000-1700 mm	750-1600 mm
Regolith and Landforms	Soil generally < 1 m with deeper pockets associated with areas of saprolite along fractures. Less weathered core stones occur at depth. The combination of sandy soil and saprolite provides low potential for salt store. Slope class 10-32% with 1-10% at the top of slopes Elevation 950-1650 m	Soil generally < 1 m with deeper pockets associated with saprolite along fractures. Shallow depth and high rainfall provide low potential for salt store. Slopes generally 10–32%; 32–56% in higher areas. Elevation range is 600–1700 m.

HGL Unit Parameters	Bimberi HGL	Picadilly HGL
Soil Landscapes	The following soil landscapes are dominant in this HGL: Bimberi Tenosols (Alpine Humus Soils) are common on many slopes. Other soil types may be present usually at lower elevation or on exposed western and northerly slopes, but even here, soils could be consider transitional Alpine Humus Soils due to the humic component in their topsoils. Where rock is near the surface Leptic and Clastic Rudosols (Lithosols) may be found. Organosols (Peats) are found on the areas of imperfect drainage which are commonly referred to as bogs, fens or swamps. This HGL occurs at generally high elevations. The cold and relatively high rainfall ensure a greater occurrence of Alpine Humus Soils and Peats than for either Namadgi or Clear Range HGLs.	The following soil landscapes are dominant in this HGL: Picadilly Picadilly (variant A) Tenosols (Alpine Humus Soils) are common on crests and upper slopes. Crests and hillslopes of lower elevation, or in association with subcrop and outcrop, contain Clastic Rudosols (Lithosols). Shallow Yellow and Brown Kandosols (Shallow Red and Yellow Earths) and Red and Brown Chromosols (Red and Yellow Podzolic Soils) are common on midslopes. On the lowest slopes relatively deep Red Kandosols (Red Earths) occur in association with colluvial deposits (e.g. talus). Organosols (Peats) are found in areas of imperfect drainage. Limited floodplains with Stratic Rudosols (Alluvial Soils and unconsolidated sediments). Due to steeper slopes soils in this HGL are shallow and poorly developed. Associated soil types such as Clastic Rudosols (Lithosols) are more common in this HGL than in the related Boboyan HGL. This HGL also has more Tenosols (Alpine Humus Soils) due to higher elevation
Land and Soil Capability	Class 7	Class 7
Land Use	» native forest » water supply » national park	» native forest » forestry (pines) » water catchment
Key Land Degradation Issues	» water erosion » mass movement » soil acidity	» mass movement » water erosion » shallow soil » soil acidity
Native Vegetation	This HGL is situated predominantly within the IBRA7 Australian Alps region, with northern areas within the South Eastern Highlands (Bondo subregion). The HGL is uncleared with vegetation formations comprised mostly of Grassy Woodlands and Wet Sclerophyll Forest on the northern lower elevations. Freshwater wetlands are a common feature on the tops of alpine slopes. Local vegetation is described by Gellie (2005).	This HGL is situated predominantly within the IBRA7 South Eastern Highlands (Bondo subregion) and Australian Alps. The HGL is uncleared with vegetation formations comprised of Wet and Dry Sclerophyll Forest, with areas of Grassy Woodlands and smaller areas of Freshwater Wetlands. In the alps the dominant vegetation becomes Grassy Woodlands and Freshwater Wetlands are more frequent. Local vegetation is described by Gellie (2005).

HGL Unit Parameters	Bimberi HGL	Picadilly HGL
HGL Unit Hydrogeology		
Aquifer Type	Unconfined to semi-confined in fractured rock and saprolite Lateral flow through unconsolidated colluvial sediments on lower slopes and in flow lines	Unconfined to semi-confined in fractured rock and saprolite Lateral flow through unconsolidated colluvial sediments on slopes
Hydraulic Conductivity	Moderate Range: 10-2–10 m/day	Moderate Range: 10-2–10 m/day
Aquifer Transmissivity	Low Range: <2 m2/day	Low Range: <2 m2/day
Specific Yield	Low Range: <5%	Low Range: <5%
Hydraulic Gradient	Moderate Range: 10–30%	Steep Range: >30%
Groundwater Salinity	Fresh Range: <800 µS/cm	Fresh Range: <800 µS/cm
Depth to Watertable	Locally shallow (bogs and fens). Otherwise intermediate Range: <2–8 m	Deep Range: >8 m
Typical Sub-Catchment Size	Small (<100 ha)	Small (<100 ha)
Scale (Flow Length)	Local Flow length: <5 km (short)	Local Flow length: <5 km (short)
Recharge Estimate	Moderate	Moderate
Residence Time	Short (months)	Medium (years)
Responsiveness to Change	Fast (months)	Medium (years)

HGL Unit Parameters	Bimberi HGL	Picadilly HGL
Landscape Functions		
	A. The landscape provides fresh water runoff as an important water source. B. The landscape provides fresh water runoff as an important dilution flow source.	A. The landscape provides fresh water runoff as an important water source. B. The landscape provides fresh water runoff as an important dilution flow source.
Landscape Management Strategies	» Maintain or maximise runoff (10) » Maintain current hydrology (11)	» Maintain or maximise runoff (10) » Maintain current hydrology (11)
Key Management Focus	In a catchment sense, management of the landscape for water supply is the major focus, as well as functioning as a dilution source for the lower landscape and adjoining HGLs. At a landscape level, it is management of the unique wetland systems and the processes that drive the wetland formation that should be a focus. The high altitude wetlands bogs and fens are ecological and biodiverse landscapes. The behaviour or feral pigs and horses are a significant threatening process to wetland areas in this HGL.	This landscape is a major supplier of a large quantity of high quality surface water to the water supply dams in ACT. There are areas of forestry that "compete" for this water resource.
Specific Land Management Opportunities	» Lots of unique native vegetation, including an array of wetland types » Mostly national park » Hydrology is mainly intact.	» Public land – national park » Forested areas have potential for production.
Specific Land Management Constraints	» Fire regime will have a large impact on the hydrology of this HGL » Access and topography limit land management options » It is difficult to limit the access of feral animals to sensitive areas – wetlands.	» Forestry above 850mm limits water yield, and landscape balance between forestry and native vegetation is needed. » Forestry operation requires sound soil management to limit erosion » Fire regime will have a large impact on the hydrology of this HGL » Access and topography limit land management options. » Track construction, location and maintenance are of high importance.

HGL Unit Parameters	Bimberi HGL	Picadilly HGL
Management Area Actions		
	» MA1 (Ridges) » Vegetation for ecosystem function » Maintain and improve existing native vegetation to protect current landscape hydrology (VE8)	» MA1 (Ridges) » Vegetation for ecosystem function » Maintain and improve existing native woody vegetation to reduce discharge (VE3) » Maintain and improve existing native vegetation to protect current landscape hydrology (VE8)
	» MA2 (Upper Slope – Erosional) » Vegetation for ecosystem function » Maintain and improve existing native vegetation to protect current landscape hydrology (VE8)	» MA2/3 (Upper Slope – Erosional & Colluvial) » Vegetation for ecosystem function » Maintain and improve existing native woody vegetation to reduce discharge (VE3) » Vegetation for production » Establish commercial forestry to manage recharge (VP7)
	» MA3 (Upper Slope – Colluvial) » Vegetation for ecosystem function » Maintain and improve existing native vegetation to protect current landscape hydrology (VE8)	» MA5 (Lower Slope – Colluvial) » Vegetation for ecosystem function » Maintain and improve existing native woody vegetation to reduce discharge (VE3) » Vegetation for production » Establish commercial forestry to manage recharge (VP7)
	» Bimberi Wetlands » Vegetation for ecosystem function » Maintain and improve existing native vegetation to protect current landscape hydrology (VE8) » Manage animal impact on sensitive areas for hydrology outcomes (VE10) » Exclude feral animals (pigs and horses) » Fire management » Appropriate location of infrastructure	» MA10 (Flow Lines) » Vegetation for ecosystem function » Maintain and improve existing native woody vegetation to reduce discharge (VE3) » Maintain and improve riparian native vegetation to reduce discharge to streams (VE4)
At Risk Management Areas		
	» MA 1, 2, 3 » Clearing and poor management of native vegetation (DLU4) » Reducing runoff from fresh surface water catchments (DLU6) » Hard hoofed animals in wetlands » Inappropriate burning regime	» MA 2, 3, 5 & 10 » Clearing and poor management of native vegetation (DLU4) » Establishment of commercial forestry (VP7) - trade-off with water yield » Deep ripping of soils to maximise water infiltration to subsoil (DLU11)

H8.5 Ginini Flats Wetland Complex: HGL Wetland Assessment Case Study

1. Wetland Type

There are many existing international, national, state, regional and local scale wetland classification systems. Each classification system is designed with a specific aim relating to the context of its use and will therefore group wetlands differently to other systems (Finlayson and van der Valk 1995; Finlayson et al. 1999). Wetland types assigned to the Ginini Flats Wetland Complex from relevant classification systems are shown in Table 1. Assigned type from these classification systems was based on the presence of waterlogged peat soils and associated *Sphagnum*, except for the Hydrogeomorphic classification of Semeniuk and Semeniuk (1995, 1997, 2011) which does not consider properties other than hydrology and geomorphic setting. Claus et al. (2011) assign an upland climate setting due to the elevation of the wetland complex being between 700-1800m, where an alpine climate setting is allocated if located above 1800m. In contrast, Hope et al. (2012) allocate montane (equivalent to upland) if elevation was less than 1200m, subalpine if elevation was between 1200-1600m and alpine if elevation was greater than 1600m (revised from the method in Hope et al. 2009). The elevation thresholds used by Hope et al. (2012) are more consistent with defining bioregions under the Interim Biogeographic Regionalisation for Australia (DSEWPC 2012) and the climate described within the Ginini Flats Wetland Complex Ecological Character Description (Wild et al. 2010).

H8 6 Wetland Hydrology and Hydrogeology

Hydrology

Both the Interim Australian National Aquatic Ecosystem and NSW lacustrine and palustrine wetland typologies outline 3 categories for wetland water sources: 1. precipitation and surface runoff, 2. river or stream flow and 3. groundwater discharge (Claus et al. 2011; Aquatic Ecosystems Task Group 2012). A water balance equation for all mapped wetlands within the ACT was conducted by Cowood et al. (in prep). All wetlands were designated with the default precipitation and surface runoff water sources and water loss through evapotranspiration. The default equation was maintained if no other water sources or losses were identified. Stream flow was added as a source or loss if the wetland polygon intersected the Australian Hydrological Geospatial Fabric (Geofabric) 'Geofabric AHGF Mapped stream' spatial layer (BOM 2012). The number of stream inflow and/or outflow intersections was noted as well as if the intersection was with a major or minor river or stream. The Geofabric stream spatial layer was sourced via the Bureau of Meteorology data portal (www.bom.gov.au/water/geofabric/index.shtml). Concentrated surface runoff was added as a source or loss if the wetland polygon intersected the Digital Topographic Database 'HydroLine' spatial layer (NSW LPI 2013), sourced from the NSW Office of Environment and Heritage corporate data set. Again noting the number of drainage line inflow and/or outflow intersections that were not already considered as stream flow.

Table 1: Wetland types assigned to Ginini Flats Wetland Complex, * denotes the wetland type was assigned during a site assessment as part of this research using the method referenced.

Classification System	Wetland Type	Reference
Ramsar Convention	Non-forested peatlands	Wild et al. 2010
DIWA	Peatlands - forest, shrub or open bogs	Environment Australia 2001
ANAE	Peat bogs and fen marshes	Brooks et al. 2014*
NSW MER	Upland bogs and fens	Claus et al. 2011*
ACT/NSW Peatland	Subalpine *Sphagnum* shrub bog	Hope et al. 2012
Hydrogeomorphic	Basinmire	Semeniuk and Semeniuk 2011*

Groundwater discharge and recharge was added as a source and loss if the wetland polygon intersected 1 or more of 4 separate groundwater interaction spatial layers. Given the level of uncertainty regarding the nature of the spatially derived groundwater interaction (Woodward et al. 2016), and that no comprehensive validation could be undertaken as part of this research, a confidence level was also assigned based on the number of spatial layers the wetland polygon intersected: 0 for no intersection through to 4 having intersected all groundwater spatial layers. The first 2 spatial layers were the 'Reliant on Surface Expression of Groundwater' and 'Reliant on Subsurface Expression of Groundwater' from the National Atlas of Groundwater Dependant Ecosystems (GDE Atlas) spatial layer (Sinclair Knight Merz 2012). It was noted if the intersection was with a high, moderate or low potential for groundwater interaction area as classified within the spatial layer. These spatial layers were sourced via the Bureau of Meteorology data portal (www.bom.gov.au/water/groundwater/gde).

The next 2 spatial layers were derived by running the FLAG model for the ACT (Roberts et al. 1997). In the model a DEM is used to derive the shape and curvature of a given landscape, expressed as fuzzy membership values and combined using fuzzy set theory with assumptions regarding the water cycle, to predict the likely location and extent of waterlogged areas resulting from groundwater discharge. Training sets are required to interpret the FLAG outputs and scale according to local conditions. The FLAG method has previously been used to delineate landforms (Summerell et al. 2005; Murphy et al. 2005; Cowood et al. 2016), identify waterlogged and seasonally wet soils (Dowling et al. 2003; Summerell et al. 2004) and wetland extent in a small area of New Zealand (McKergow et al. 2007).

Both 30m and 10m resolution FLAG outputs were generated for the ACT using FLAG software and ArcInfo, following the method of Roberts et al. (1997). Input DEMs used were the 1 second Shuttle Radar Topography Mission DEM (Gallant et al. 2011) and the 10m DEM developed by Cowood et al. (2016) following the method of Hutchinson and Dowling (1991). Given the different DEM resolutions, an 8x8 pixel smoothing window was used for the 30m DEM and a 13x13 pixel smoothing window for the 10m DEM. The mapped wetlands for the ACT were used to develop 3 training sets to interpret FLAG outputs: training set 1 was all mapped wetlands; training set 2 removed riverine wetlands; and training set 3 removed riverine and modified wetlands. Each training set was used to compare the individual 30m and 10m total predicted waterlogged area versus actual mapped wetland area, developing a series of quantitative measures to evaluate the FLAG outputs: accuracy, efficiency, discrimination and power. The maximum power measure for each training set was used to select an alpha-cut threshold value to scale the FLAG output to derive predicted wetlands for the study area.

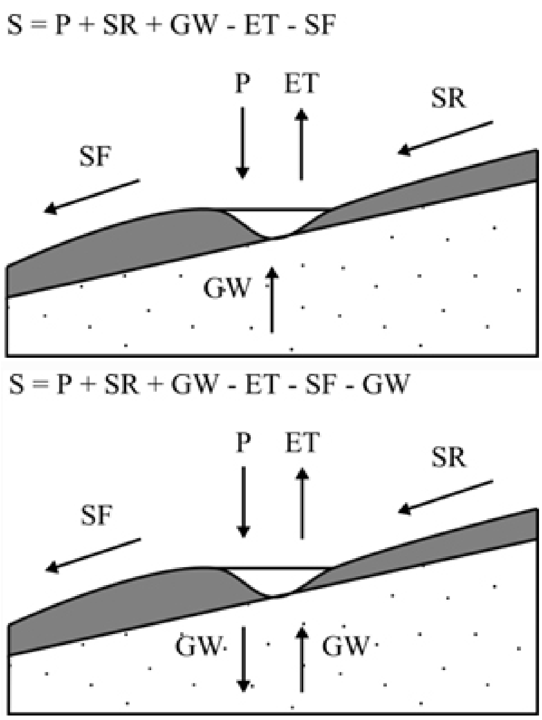
Determined hydrological parameters for the Ginini Flats Wetland Complex are:

» Water Sources: direct precipitation, localised surface flow (surface runoff and subsurface lateral flow) and recharge from the shallow perched groundwater system.
» Water Losses: evapotranspiration, non-perennial stream outflow (Ginini Creek, Stockyard Creek) and losses to the shallow perched groundwater system (West Ginini only).
» Water Regime: Permanently waterlogged
» Water Balance Equation:

S = P + SR + GW – ET – SF
(Cheyenne, East Ginini, Figure 1a)

S = P + SR + GW – ET – SF – GW
(West Ginini, Figure 1b)

Figure 14: Conceptual models of the water balance equation for Ginini Flats Wetland Complex.



Hydrogeology

Datasets used to determine the hydrogeological characteristics of HGL Units within the ACT HGL Project included tjose in Coram et al. (2000), Evans (1987), Skelt et al. (2004) and Van der Lely (2001), as outlined in Muller et al. (2016) and Cowood et al. (2016). Alpine to upland HGL Units typically have local groundwater flow systems, have short flow paths with moderate to steep hydraulic gradients, low to moderate hydraulic conductivity, low to moderate specific yields and fast to medium response times. Specific hydrogeology descriptions for the Ginini Flats Wetland Complex are shown in Tables 2 and 3.

Table 2: Summary of values for typical hydrogeological parameters of Bimberi HGL

Aquifer Type	Unconfined to semi-confined in fractured rock and saprolite Lateral flow through unconsolidated colluvial sediments on lower slopes and in flow lines
Hydraulic Conductivity	Moderate Range: 10-2–10 m/day
Aquifer Transmissivity	Low Range: <2 m2/day
Specific Yield	Low Range: <5%
Hydraulic Gradient	Moderate Range: 10–30%
Groundwater Salinity	Fresh Range: <800 µS/cm
Depth to Watertable	Locally shallow (bogs and fens). Otherwise intermediate Range: <2–8 m
Typical Sub-Catchment Size	Small (<100 ha)
Scale (Flow Length)	Local Flow length: <5 km (short)
Recharge Estimate	Moderate
Residence Time	Short (months)
Responsiveness to Change	Fast (months)

Table 3: Summary of values for typical hydrogeological parameters of Picadilly HGL.

Aquifer Type	Unconfined to semi-confined in fractured rock and saprolite Lateral flow through unconsolidated colluvial sediments on slopes
Hydraulic Conductivity	Moderate Range: 10-2–10 m/day
Aquifer Transmissivity	Low Range: <2 m2/day
Specific Yield	Low Range: <5%
Hydraulic Gradient	Steep Range: >30%
Groundwater Salinity	Fresh Range: <800 µS/cm
Depth to Watertable	Deep Range: >8 m
Typical Sub-Catchment Size	Small (<100 ha)
Scale (Flow Length)	Local Flow length: <5 km (short)
Recharge Estimate	Moderate
Residence Time	Medium (years)
Responsiveness to Change	Medium (years)

H8.8 Wetland Assessment

A detailed assessment of climate change impacts on wetlands in the ACT to determine their future climate change vulnerability has been undertaken by Cowood et al. (in prep). Mapping of Management Areas allows for detailed hazard assessments to understand the patterns in the chosen variables specifically for the areas to be managed within the HGL Framework NRM Modules, and consideration of landscape setting when identifying suitable locations to undertake Management Actions. The detailed assessment will only be using a single future time period, but will individually asses the consensus, wet-cool extreme and dry-hot extreme scenarios. Variables used in this assessment represented indicators of current anthropogenic pressure, future hydrological change in water sources and losses and future ecological change in vascular plant and amphibian communities. Statistical methods are used to group wetlands that are projected to experience similar levels of change in the future and determine the principle components of change from the suit of variables. The assessment considers the unique water balance equations of the wetlands to determine their climate change vulnerability.

It is recommended by the Commonwealth Scientific and Industrial Research Organisation Climate Adaptation Flagship that natural resource management planning must consider a range of likely futures and possible desired outcomes (Rissik et al. 2014; Timbal et al. 2015). This recommendation has been adopted by the ACT Government when developing their ACT Climate Change Adaption Strategy (ACT EPD 2016). For the detailed wetland assessment 3 NARCliM near future (2020-2039) scenarios were chosen using the climate change projections for the ACT (Olson et al. 2014; NSW OEH 2015): a consensus scenario representing the multi-model mean of the 12 climate models; a wet-cool extreme scenario representing the single climate model with the coolest mean annual temperature and highest mean annual precipitation for the near future; and a dry-hot extreme scenario representing the single climate model with the hottest mean annual temperature and lowest mean annual precipitation for the near future (Table 4). Selection of future extreme scenarios used the same principles as the Climate Futures Framework (Clark et al. 2011; Whetton et al. 2012), where two climate variables, e.g. precipitation and temperature, are used to identify the range of plausible futures scenarios such as the 'Maximum Consensus', 'Best Case' or 'Worst Case'.

Table 4: Determination of future extreme scenarios for the ACT through ranking of the 12 NARCliM project climate models by near future mean annual precipitation and temperature.

CLIMATE MODEL	PRECIPITATION		TEMPERATURE		
	mm	RANK	oC	RANK	
MIROC3.2 (medres) R2	1465.83	1	9.34	1	Wet-cool
MIROC3.2 (medres) R3	1437.34	2	10.35	5	
MIROC3.2 (medres) R1	1433.15	3	9.43	2	
CSIRO-Mk3.0 R1	1373.12	4	9.65	4	
CSIRO-Mk3.0 R2	1240.39	5	9.54	3	
CSIRO-Mk3.0 R3	1159.68	6	10.80	6	
ECHAM5/MPI R2	1079.65	7	10.83	7	
ECHAM5/MPI R1	1068.00	8	10.97	9	
ECHAM5/MPI R3	1008.18	9	12.06	11	
CCCMA3.1 R2	849.51	10	10.91	8	
CCCMA3.1 R1	837.61	11	11.13	10	
CCCMA3.1 R3	711.48	12	12.47	12	Dry-hot

Hydrological impact assessment data for the 3 future climate scenarios was acquired from the NSW Office of Environment and Heritage. While the preceding NSW hydrological impact assessment dataset of Littleboy et al. (2015) was produced at a 10km grid to match the scale of the NARCliM Project, the dataset used in the detailed assessment was downscaled using a 100m sampling grid. The downscaled hydrological impact assessment data was produced using the same method (Littleboy et al. 2015), but the 100m sampling grid allowed for refined attribution of the landform, land use and soils input data, although NARCliM climate variable input data was still only available at a 10km resolution. The downscaled hydrological impact assessment data is better suited for attributing the Management Areas and undertaking a detailed wetland assessment. Littleboy et al. (2015) integrates the NARCliM precipitation change projections into a water balance model based on the 'PERFECT' model of Littleboy et al. (1992) and 'HYDRUS 2D' model of Simunek et al. (1999) (see also Rassam and Littleboy 2003). Daily time-series precipitation and actual evapotranspiration, soil properties, land use and topography are entered into the model to determine surface flow (surface runoff and lateral flow) and groundwater recharge for each grid cell. Volumes of surface flow are governed by model parameters describing potential infiltration, antecedent soil water, surface and vegetative cover and slope. Volumes of groundwater recharge are controlled by parameters quantifying drainage rates through the soil profile, soil depth and slope. Comparison of the modelled near and far future precipitation, surface flow and groundwater recharge volumes relative to the current volumes, allows the absolute change (mm) in future annual and seasonal volumes to be determined.

The CSIRO have developed a set of measures to understand the implications and nature of change in biodiversity for 2050 as a result of climate change (Williams et al. 2014). The first measure, potential degree of ecological change, represents ecological similarity between current composition and potential future composition of vascular plants, mammals, amphibians and reptiles. For this measure the lower the similarity value the greater the potential change in future biodiversity. If change is seen to occur further measures are used to characterise the nature of change. The second measure, disappearing ecological environments, represents current environments that may become absent from the entire continent in the future. The third measure, novel ecological environments, represents new environments that may arise in the future but which don't exist anywhere on the continent currently. The measures have been developed for 2 different climate change scenarios representing mild and hot climate futures using a form of community level generalised dissimilarity modelling as described by Harwood et al. (2014). The mild future uses the Model for Interdisciplinary Research on Climate produced by the Japanese research community (MIROC5) and the hot future uses the Canadian Earth System Model (CanESM2). Although this ecological data utilises different climate change projection models to the hydrological impact assessment of Littleboy et al. (2015), it represents the best available data of ecological change to be used in current research. Here we have paired the mild climate future ecological change measures with the consensus and wet-cool scenario hydrological change data, and the hot climate future ecological change measures with the dry-hot scenario. It is recommended that when datasets on the potential impacts of climate change for biodiversity and habitat threats using the NARCliM climate projections becomes available that this analysis is repeated.

Anthropogenic pressures are considered through the GIS based landscape hazard assessment developed by the QLD Department of Science, Information Technology, Innovation and the Arts (2015). The landscape hazard assessment is part of the Queensland Wetland Programs framework for assessing and monitoring the ecological character and potential hazards of wetlands (QLD DEHP 2014). The assessment is based on the earlier Catchment Disturbance Index which was developed as part of the National Framework for the Assessment of River and Wetland Health (National Water Commission 2007; Norris et al. 2007; Turak et al. 2011) and also considered the Victorian Wetland Catchment Disturbance Index and Wetland Condition Index (Papas et al. 2008; Papas and Moloney 2012, VIC DEPI 2014). The approach aims to characterise the human induced pressures arising from land use at a regional scale and enable the attribution of a realistic level of overall pressure to individual subcatchments. A total of 22 individual pressures to wetlands were determined, consistent with or adapted from those presented in Dudgeon et al. (2006), Marshall et al. (2006), Negus et al. (2009) and Lynch (2011), under five broad categories applicable to aquatic ecosystems. These are: direct/indirect inputs, harvesting, changes to the water regime, biological introductions and perpetuation and habitat disturbance and alteration. The 45 land use classes within the Australian Land Use and Management Classification (ABARES 2011) were simplified to 15 land use groups, on the basis that each group represented a unique key driver of specific wetland pressures. For each land use group a pressure profile was developed based on the principles of Driver-Pressure-State-Impact-Response conceptual models (European Environment Agency 1999; Smeets and Weterings 1999), characterising and determining scores for the individual 22 pressures and assigning a final pressure weighting for each land use group. Overall land use pressure for a given subcatchment is determined through a summation of the percent area of each individual land use group multiplied by its associated final pressure weighting, to produce the final score (QLD DSITIA 2015).

Anthropogenic Pressure

Immediate anthropogenic pressure at or directly adjacent to the Ginini Flats Wetland Complex and overall subcatchment land use pressure are:

» Immediate pressure: 0.10 (ACT range 0.10 – 0.78)

» Subcatchment pressure: 10.22 (ACT range 10.22 – 63.27)

(Cowood et al. in prep). The immediate land use, and predominant land use in the Bendora subcatchment (98.38%), is nature conservation (ALUM class 1.1; ABARES 2011). This land use is considered to present the lowest pressure to wetlands as per the assessment approach developed by QLD DSITIA (2015).

Ecological Change

A summary of the ecological change values for each future climate scenario from Cowood et al. (in prep) are shown in Table 5. The lower the similarity value the greater the potential change in future biodiversity.

Hydrological Change

A summary of the ecological change values for each future climate scenario from Cowood et al. (in prep) are shown in Table 6. The lower the value (positive or negative) the lower the future changes in annual volume and seasonality of delivery. Downscaled 100m grid hydrological impact assessment data, for the consensus, wet-cool and dry-hot scenarios, were acquired from the NSW Office of Environment and Heritage. The absolute change (mm) between current and near future annual and seasonal volumes of precipitation, evapotranspiration, surface flow and groundwater recharge for each scenario was integrated with spatial mapping using the ArcGIS ‘intersect’ tool. Further analysis of the resulting database file was conducted within Microsoft Excel. The mean value for each annual hydrological change variable, for each future climate scenario, was calculated and attributed. The seasonal gridded values were used to determine the current and future seasonality of delivery for the hydrological variables as per the method of Williams et al. (2010a, 2010b). This developed 2 new attributes representing the seasonality ratio values for all grid cells: the balance between Summer (positive values) and Winter (negative values) dominance in delivery; and the balance between Spring (positive values) and Autumn (negative values) dominance in delivery. The greater the ratio value (positive or negative) the stronger the seasonal pattern. The mean current and future ratio value for the Summer/Winter and Spring/Autumn variables, for each climate scenario, was calculated and attributed. The absolute change in ratio values between current and near future seasonality, for each future climate scenario, was also determined for all grid cells. The mean value for each seasonality absolute change variable, for each future climate scenario, was calculated and attributed.

Table 5: Table 5. Summary of potential degree of ecological change values.

	Similarity of amphibians		Similarity of vascular plants	
Wetland	**Consensus/Wet-cool**	**Dry-hot**	**Consensus/Wet-cool**	**Dry-hot**
Cheyenne	0.772	0.705	0.664	0.570
East Ginini	0.772	0.705	0.664	0.570
West Ginini	0.744	0.675	0.648	0.543
ACT max	0.800	0.727	0.719	0.571
ACT min	0.713	0.690	0.632	0.398

Table 6: Summary of hydrological change values.

Variable		Consensus			Wet-cool			Dry-hot		
Cheyenne		**Ginini (E)**	**Ginini (W)**	**Cheyenne**	**Ginini (E)**	**Ginini (W)**	**Cheyenne**	**Ginini (E)**	**Ginini (W)**	
Annual	Precipitation	-46.807	-46.807	-45.392	-6.613	-6.613	-6.764	-25.284	-25.284	-23.362
(ac mm)	Evapotranspiration	12.603	12.603	11.882	28.639	28.639	29.764	-6.362	-6.362	-8.701
	Surface runoff	-18.320	-18.320	-23.066	-13.348	-13.348	-17.869	-5.473	-5.473	-5.328
	Groundwater recharge	-44.530	-44.530	-38.291	-23.881	-23.881	-21.988	-24.694	-24.694	-21.938
Summer/ Winter	Precipitation	-0.034	-0.034	-0.039	0.102	0.102	0.116	0.569*	0.569*	0.545*
(ac ratio)	Evapotranspiration	-0.012	-0.012	-0.012	0.106	0.106	0.112	-0.151	-0.151	-0.132
	Surface runoff	-0.435	-0.435	-0.342	0.165	0.165	0.095	0.918	0.918	2.983
	Groundwater recharge	-0.733	-0.733	-0.716	0.228	0.228	0.106	-19.523	-19.523	-6.182
Spring/ Autumn	Precipitation	0.155	0.155	0.152	0.057	0.057	0.048	0.237	0.237	0.230
(ac ratio)	Evapotranspiration	0.029	0.029	0.034	-0.003	-0.003	-0.002	0.100	0.100	0.106
	Surface runoff	0.335	0.335	0.279	0.197	0.197	0.238	1.585	1.585	0.700
	Groundwater recharge	0.260	0.260	0.145	0.275	0.275	0.340	3.006	3.006	0.339

* Dry-hot extreme scenario: no change in overall seasonality except Summer/Winter precipitation.

Climate Change Vulnerability

An agglomerative hierarchical cluster analysis was undertaken to group wetlands considered similar with regard to the 16 current anthropogenic pressure and future ecological and hydrological change variables for each future climate scenario. Analysis was undertaken in SPSS Statistics 23, using the Ward's minimum variance method (Ward 1963) and the squared Euclidean distance measure to determine dissimilarity between wetlands. For each future climate scenario the appropriate number of output clusters was determined by examining the cluster dendrogram and agglomeration coefficients (Manning and Munro 2007). This was assisted by a series of Kruskal-Wallis one-way analysis of variance tests (Kruskal and Wallis 1952), undertaken in SPSS Statistics 23, to further explore the similarity and dissimilarity between clusters for each variable within a future climate scenario dataset. The non-parametric test was chosen as the majority of the 16 variables were found to be not normally distributed. In each future climate scenario wetlands were found to best fit into 3 clusters.

To further explore the identified clusters and identify the common or unique indicator variables driving variability within a future climate scenario, a series of principle component analyses were also undertaken in SPSS Statistics 23. The orthogonal Varimax rotation was used, with Eigenvalues of greater than 1 and suppressing small coefficients below 0.3.

The Kruskal-Wallis one-way analysis of variance and principle component analysis results facilitated characterisation of each cluster, along with the calculated mean value for each cluster for the 16 variables. Characterisation and calculation of mean values for each cluster allowed for ranking of wetland clusters as experiencing low, moderate or high levels of current anthropogenic pressure and projected future ecological and hydrological change, for each of the variables in a future climate scenario. The distribution of ranks across the 3 categories for each variable provided the overall climate change vulnerability for the cluster for that future climate scenario.

It is at this stage of the wetland assessment that an assumption is made surrounding the consequences of water source and loss fluctuations which control the depth of water, wetted extent and seasonal timing of transition between wetter and drier periods for a wetland (Dollar et al. 2007; Poff et al. 2007). It is understood that the hydrological dynamics of a wetland will influence the habitat types available, composition and succession of the biotic assemblage and factors such as primary productivity, anaerobic conditions, light and nutrient availability (Westlake et al. 1998; Cronk and Fennessy 2001; Keddy 2010). The assumption is therefore made that an increase in water storage at a wetland can also have negative effects, just as a decrease in water storage could. Therefore any negative mean values for each cluster were considered positive values during ranking.

The wetland assessment found that projected ecological change and annual and seasonal hydrological change would occur across the ACT, although patterns of change differed between the 3 future climate scenarios (Cowood et al. in prep). The wetland assessment results found the Ginini Flats Wetland Complex to be in the ACT wetlands lowest climate change vulnerability category for the wet-cool scenario, due to greater levels of ecological and hydrological change projected to occur in other parts of the ACT. For the dry-hot extreme scenario the Ginini Flats Wetland Complex was within the ACT wetlands moderate climate change vulnerability category. However for the consensus scenario the Ginini Flats Wetland Complex is located in the area of the ACT with the highest levels of projected ecological and hydrological change, and is therefore situated in the highest climate change vulnerability category. Specifics for each future climate scenario are outlined below.

Consensus Scenario Outcomes

In the consensus future climate scenario the Ginini Flats Wetland Complex was located within Cluster 2 and considered to have the highest climate change vulnerability category within the ACT. This is despite having the lowest immediate and subcatchment anthropogenic pressures and lowest levels of potential degree of ecological change. For the 12 hydrological change variables, this cluster ranked the highest change for 9 variables and ranked moderate for 2 of the remaining 3 variables. The highest levels of change were found for all 4 annual change variables, experiencing reductions in annual precipitation, surface runoff and groundwater recharge associated with an increase in annual evapotranspiration. Precipitation and evapotranspiration are projected to experience weakening Summer and Autumn seasonality, resulting in surface runoff and groundwater recharge increasing in Summer dominance but also weakening in Autumn dominance. Principle component analysis found that 11 of the 16 variables were present in PC1 and PC2 across all 3 clusters, with only 3 variables unique to PC1 and PC2 for this cluster: annual and Summer/Winter groundwater recharge and potential degree of ecological change in vascular plants.

Wet-cool Extreme Scenario Outcomes

In the wet-cool extreme future climate scenario the Ginini Flats Wetland Complex was located within Cluster 2 and considered to have the lowest climate change vulnerability category within the ACT. Again this cluster had the lowest immediate and subcatchment anthropogenic pressures and lowest levels of potential degree of ecological change. For the 12 hydrological change variables, this cluster ranked the highest change for 5 variables, ranked moderate for 2 variables and ranked low for the remaining 5 variables. The highest levels of change were found for 2 annual change variables, experiencing the highest reductions surface runoff and groundwater recharge. Annual precipitation increase ranked moderate, with the increase in annual evapotranspiration ranked the lowest of the 3 clusters. Precipitation and evapotranspiration are projected to experience increasing Summer seasonality, with precipitation weakening in Autumn seasonality while evapotranspiration increases. Surface runoff and groundwater recharge both show weakening in Winter and Autumn dominance. Principle component analysis found that 7 of the 16 variables were present in PC1 and PC2 across all 3 clusters, with only 4 variables unique to PC1 and PC2 for this cluster: immediate anthropogenic pressure, potential degree of ecological change in amphibians and Summer/Winter and Spring/Autumn groundwater recharge.

Dry-hot Extreme Scenario Outcomes

In the dry-hot extreme future climate scenario the Ginini Flats Wetland Complex was located within Cluster 2 and considered to have moderate climate change vulnerability category within the ACT. Again this cluster had the lowest immediate and subcatchment anthropogenic pressures, lowest level of potential degree of ecological change in amphibians, but a moderate level of potential degree of ecological change in vascular plants. For the 12 hydrological change variables, this cluster ranked the highest change for 7 variables and ranked low for the remaining 5 variables. The highest level of change was found for the reduction in annual groundwater recharge, experiencing the lowest reductions in annual precipitation, evapotranspiration and surface runoff. Precipitation is changing to Winter dominance and weakening in Autumn seasonal dominance. Evapotranspiration is projected to experience increasing Summer seasonality and weakening in Autumn seasonality. Surface runoff shows a weakening in Winter and Autumn dominance, while groundwater recharge has a strengthening Winter dominance but weakening in Autumn dominance. Principle component analysis found that 10 of the 16 variables were present in PC1 and PC2 across all 3 clusters, with only 3 variables unique to PC1 and PC2 for this cluster: annual surface runoff and Summer/Winter and Spring/Autumn groundwater recharge.

4. Implications For Management

Anthropogenic Pressure

The Ginini Flats Wetland Complex is already located in a low anthropogenic pressure area. It is recommended that the nature conservation land use continues and low levels of anthropogenic pressure are maintained into the future. Management Actions outlined in Section 2 of the main report relating to anthropogenic pressure fall under the following 4 Management Strategies: WCF Cultural function, WFM Fire management, WSM Sediment management, TA Track and access.

Ecological Change

The potential degree of ecological change measure of Williams et al. (2014), projects that the Ginini Flats Wetland Complex will experience change in the future composition of vascular plants and amphibians across all 3 future climate scenarios. Management actions should therefore try to favour the species that are wanted to persist into the future or to undergo succession towards their establishment. Management should also be undertaken to control unwanted invasive flora and fauna. Management Actions outlined in Section 2 of the main report relating to ecological change fall under the following 4 Management Strategies: WHM Habitat management, WPH pH management, WPM Pest management, AM Animal management.

Hydrological change

The annual and seasonal hydrological variables used in the wetland assessment project that the Ginini Flats Wetland Complex will experience future hydrological change across all 3 future climate scenarios. As additional water sourcing to the wetland to maintain the volume and timing of the current water balance is unfeasible, Management Actions should be focused on reducing evaporation, slowing surface runoff and maintaining soil moisture. Management should also be undertaken to maintain the peat and *Sphagnum* ***relationship and avoiding erosion within the wetland, the catchment, the plug and the outflow channel. Management Actions outlined in Section 2 of the main report relating to ecological change fall under the following 3 Management Strategies: WHR Hydrology management, WPH pH management, WSM Sediment management.***

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Table 7: (Footnotes)

1 Keystone species are those which control the structure and functioning of the peatland or bog community, are always present and influence some aspect of the critical processes (Hope et al. 2000)

2 Given the sensitivity of the Ginini Flats, monitoring methods that have minimal impact are recommended. Monitoring the pools and streams could employ more traditional methods such as sweep netting edge water and pool habitats.

3 Refer to Wild et al. 2010 pp 52 – 55.