Identifying Fleurieu Peninsula swamps with eco-hydrological restoration potential in the Tookayerta catchment

A targeted assessment of landscape change within the SA Murray Darling Basin NRM Region

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Executive summary

Nature Glenelg Trust was engaged by Natural Resources – SA Murray Darling Basin to undertake a multi-faceted study of the Tookayerta catchment; to improve general understanding of the history of the catchment, and to determine and prioritise swamps with high eco-hydrological restoration feasibility.

This assessment report establishes the platform necessary for future, detailed, site-specific investigations to guide eco-hydrological restoration projects in the Tookayerta Catchment. It complements the restoration planning process concurrently undertaken within this catchment at Hesperilla Conservation Park (refer to Bachmann and Farrington, 2017).

Key findings from the review of the historic and background information presented in this report are:

- The catchment was largely undeveloped until the 1890s.
- After the 1890s, the peatlands of the valleys were heavily targeted for drainage and clearance.
- The pattern of that early development and subdivision of the peatlands is still evident in both the cadastral pattern today and in the extensive network of over 100 km of artificial drains across the catchment.
- While most of the catchment was subjected to *ad hoc* drainage works, completed within the boundaries of each property, a notable exception was the Nangkita settlement where a more comprehensive (larger, multi-parcel, intensive) and sophisticated drainage network was established.
- The wider catchment (uplands and swamps) experienced a second-wave of development with heightened intensity from the 1920s, with the advent of new pasture establishment technology and mechanised clearance. This wave of clearance and drainage was largely complete by the 1970s.
- Additional changes impacting on catchment hydrology include:
    - construction of dams throughout the catchment – with a dramatic period of increase between 1950 and 1995 that has since plateaued.
    - sinking of groundwater wells, which dramatically increased in number since the mid-1990s; an increase that corresponds with the decline in new dam construction.
- The predominant land use is livestock grazing although this has shown a declining trend, being replaced by irrigated horticulture (through the expansion of wineries and olives) and a large increase in rural-residential properties.
- The development of the uplands, and reduced focus on maintaining all the existing drains through the subsiding peatland, has led to persistence, and in some cases, recovery of wetland biodiversity values over the past 50 years.

- The catchment is home to a large number of threatened flora and fauna species across a number of taxonomic groups, and recent restorations in similar wetland systems suggest many species are likely to respond favourably to restoration works.
- The catchment has seen significant, proactive conservation works (especially stock exclusion and weed control) implemented since the 1990s.
- *Phragmites australis* poses a particular management challenge, where it forms expanding and dominant stands, due to traits (morphology, physiology, reproductive and potentially genetics) that enable it to be a strong competitor; especially in wetland areas where stock have been removed within the past 20 years. Blackberry and pasture grasses are also of major concern.
- Despite these changes impacting water resources, the catchment still produces reliable groundwater-driven base flows that indicate it has strong potential for successful hydrological restoration of important wetland sites.

As a result of a subsequent multi-faceted landscape assessment and prioritisation process, a number of areas within the catchment have been identified for future site-specific hydrological restoration planning, preliminary field surveys and/or landholder liaison.

While each of these is worthy of further consideration and should be pursued subject to funding and landholder interest, two sites are specifically highlighted here:

1. ***Square Waterhole Swamp at Hesperilla CP***

Restoration feasibility planning has already been completed for this 11 hectare site (see Bachmann and Farrington 2017), with a focus on future works to improve sustainability of water management within and around this public land reserve.

2. ***Swampy Crescent and Tooperang (private land)***

Of the remaining sites, all situated across multiple private land parcels, Swampy Crescent is an obvious candidate for more detailed follow-up assessment. This is on the basis of existing landholder interest, past project works and technical feasibility. The area also links with areas of wetland habitat under conservation management along the lower Tookayerta Creek at Tooperang, creating an opportunity to pursue the restoration of a large, hydrologically intact and connected reach of wetlands.

The proposed project at Swampy Crescent-Tooperang would be based on a process of genuine consultation and sharing technical information with the landholders in the wetland system: working collaboratively through the steps involved in hydrological restoration feasibility planning. The aim would then be to reach agreement on potential on-ground hydrological restoration solutions for future implementation, across property boundaries to benefit the swamp ecosystem.

Reconnaissance field surveys to ground-truth site conditions (drainage and/or swamp vegetation) at high value sites without obvious hydrological modifiers are also a high priority. Such sites include Black Swamp, two sites in the headwaters of the Tookayerta catchment and the Mt Compass School Swamp. This work could help determine the best course of action, including if a more comprehensive eco-hydrological investigation is required.

Additional discussions are also recommended with landholders that are managing wetlands for stock exclusion and weed control at a number of sites, but may have reservations about hydrological works. At many of these locations, the technical aspects, scope and feasibility of hydrological restoration is not yet clear.

Should any of these actions lead to the implementation of on-ground hydrological restoration projects (across multiple private properties) at Swampy Crescent or one of the other identified priority areas, it would provide an excellent opportunity to demonstrate both (a) the merits of working to restore hydrological processes across multiple property boundaries and (b) the major role private land has to play in the effective recovery of the critically endangered (*EPBC Act 1999*) Swamps of the Fleurieu Peninsula ecological community.

Contents

1 Introduction

The Swamps of the Fleurieu Peninsula (Fleurieu Swamps) are a critically endangered ecological community listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. In the Mt Compass district, remnant swamps typically exist as narrow bands of vegetation in areas of groundwater expression and along natural and artificial drainage lines.

Scientists and environmental managers have been trying to understand the reasons for the apparent decline in condition of the swamps, particularly as habitat for the endangered Mt Lofty Ranges Southern Emu-wren. Pilot studies have been undertaken by the Fleurieu Swamps Recovery Team to examine the impact of disturbance (e.g. fire). However, it is also generally accepted that changes to the local hydrology of the swamps and surrounding areas are likely to be a key factor driving the change in their condition.

A targeted study of the Tookayerta catchment in the SA Murray Darling Basin NRM Region, is required to provide critical information in how local swamp systems have been impacted by landscape change and land-use intensification, both through time and across the geographic extent of this area. There are a large number of artificial channels in the catchment, and regular applications to clear vegetation from these channels are processed due to associated problems with stock and vehicle access.

A catchment-scale eco-hydrological investigation will improve our understanding of the way ground and surface water interacts in this system, its relationship to past / present land use and land form, and how this influences condition at wetland sites. In combination with information already being disseminated under the Fleurieu Swamps recovery project, it is anticipated that this study will provide a platform for future communication with landholders in the area; namely, the starting point for more detailed, site-specific discussions about the hydrological restoration potential of Fleurieu Swamps. If successful, this has the potential to deliver longer-term, self-sustaining outcomes to underpin long-term persistence of this nationally threatened ecological community.

1.1 Project objective

To undertake a multifaceted study of the Tookayerta catchment for:

1. Improving general understanding of the process of change that has led to the current condition and distribution of Fleurieu Swamps in the catchment; and,
2. Determining swamps in the catchment with high eco-hydrological restoration feasibility* (for future detailed investigation).

*(*Note: in this context, feasibility includes considerations such as landholder willingness, cost, technical requirements and other practicalities, as well as likely eco-hydrological response and predicted benefit to environmental values)*

1.2 Requirements

- Land tenure assessment
- History of changes in drainage, diversions and land use
- Evaluation of background / existing information on native vegetation, landscape context, habitat for threatened species
- LiDAR data capture
- Compilation and assessment of eco-hydrological features and data
- Assessment of climatic trends
- Consultation with key stakeholders
- Field visit to confirm desktop findings
- Evaluate the suitability and desirability of hydrological restoration

1.3 Project deliverables

- Provide advice on strategic areas for future engagement with landholders, based on land use, impacts of hydrological restoration and downstream implications
- Electronic copies of the final report
- Electronic copies of any literature cited (papers, fact sheets, etc.)
- Presentation of the restoration options to Natural Resources, SA MDB.

1.4 Project context

This report outlines the findings of a series of desk-top and field-based investigations aimed at providing a comprehensive overview of historical patterns of change in the Tookayerta Catchment, an overview of wetland based ecological values throughout the catchment and how threats to catchment and localised hydrology can be mitigated to restore wetland condition and promote resilience of these systems against future threats.

The following sections provide:

- A general overview of the catchment (**Section 2**);
- A historical context for understanding the current condition of the catchment, land use and property configuration (**Section 3**).
- A detailed description and analysis of more recent changes to native vegetation and hydrological properties of the catchment (**Section 4**).

1.5 Consultation

Two publicly advertised community presentations were held in Mt Compass, in December 2016 and April 2017, providing an opportunity to discuss the project with a wide range of people and take on board their ideas. The December session was particularly well attended by a representative cross-section of the local community (Figure 1.1).

Figure 1.1: The gathering audience at the community event in December 2016 at Mount Compass.

Communication has also been maintained with government agency staff, NGO's, research organisations, volunteer interest groups and other individuals who have a stake in ongoing surveys, research and conservation management throughout the catchment. This culminated in a workshop held at Mt Barker in April 2017 (Figure 1.2).

Figure 1.2: A workshop with experts in April 2017 at the Natural Resources Centre in Mt Barker.

This has been an iterative process, coupled with NGT's investigation as it has unfolded. In this way, participants in these discussions have learned about the emerging background information and as new insights have emerged. This has then helped us to build and share a growing collective understanding of the catchment and its history, while talking over potential options for future management throughout the process.

We are extremely grateful for the following individuals and groups for sharing their knowledge of the site and wider catchment, contributing to the report and/or meeting with us to discuss future management options:

- Nicola Barnes, ecology (DEWNR)
- Marcus Pickett, avian ecology (CCSA)
- John Gitsham, ecology and private land management (GWLAP)
- Stuart Hicks, public land management (DEWNR)
- Rebecca Duffield, ecology (CCSA)
- Jasmin Packer, ecology (Adelaide Uni)
- Julie Schofield, ecology (CCSA)
- Tim Vale, ecology (CCSA)
- Lisa Kirwan, public land management (Alexandrina Council)
- Clive & Claire Chesson, flora (Friends of Parks)
- Leo Davis (Native Orchid Society of SA)
- Tim Jury, flora (NCSSA)
- Mardi Van Der Wielen, water planning (DEWNR)
- Kylie Moritz, ecology (DEWNR)
- Doug Bickerton, ecology (DEWNR)
- Jason Higham, ecology (DEWNR)
- The MLRSEW/FPS Recovery Team
- The late Brian Brawley (landholder – Swampy Crescent)
- Peter Matejcic - (President, Field Naturalists Society SA Inc.)
- Merrilyn Saunders – (landholder, Nangkita)
- John Brame (landholder, Nangkita)
- Marie and John Hogg (landholders, Nangkita)
- All other participants at the community information sessions

2 Site description

The Tookayerta Creek catchment is located in the south-eastern Mount Lofty Ranges, around 60 kilometres south of Adelaide. The local climate is temperate with annual rainfall from 450mm in the eastern lowlands to 900mm in the upper catchment (Spencer, 2011) and the catchment is hydrologically classified as a high rainfall catchment with permanently flowing streams (Savadamuthu, 2004). Extensive Permian sand aquifers underpin the catchment with very good quality groundwater resources, which are a major component of stream baseflow during summer months (Harrington, 2004). The catchment topography ranges from around 60m in the eastern end of the catchment to around 400m in the western ridges of the catchment and encompasses two glacially eroded valleys (where the watercourses are situated today), carved out of surrounding basement rocks, which have been infilled by various glaciene sediments (Barnett and Zulfic 1999).

The two major streams, Nangkita Creek and Tookayerta Creek, originate from swampy headwaters in the western portion of the catchment and flow in an easterly direction before joining as the Lower Tookayerta Creek and flowing via Black Swamp into Lake Alexandrina. A third major tributary, Swampy Creek, joins the lower Tookayerta Creek downstream of the junction between upper Tookayerta Creek and Nangkita Creek. The major watercourses in the catchment are shown in Figure 2.1.

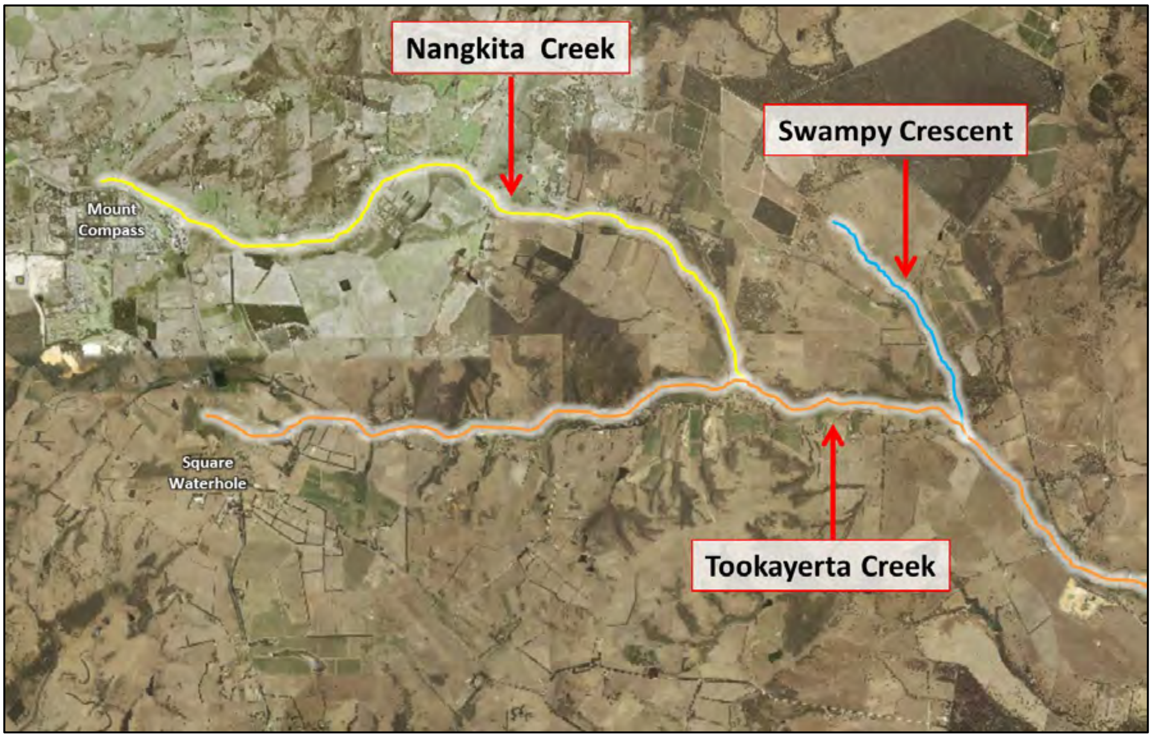

Figure 2.1: The major watercourses in the Tookayerta Catchment. Prior to development, swamps throughout this entire catchment were generically referred to as forming part of "Black Swamp".

Stream habitats are generally heavily associated with swampy littoral areas or disappear into swamp vegetation (e.g. tea tree) or large beds of *Phragmites* along stream sections. The Swampy Creek area is one of the better remaining examples of how most of the upper catchment would have functioned prior to clearance, grazing, excavation and drainage; i.e. as a continuous swamp (Hammer, 2009). The swamps that now remain, as shown in Figure 2.2, are fragmented throughout the catchment and are mostly interconnected by artificial drainage channels or dams.

Creek lines are modified (deepened or straightened) or entirely artificial (drainage channels) in many areas but there are also true lotic habitats, providing critical refuge for freshwater specialist species, particularly in upper Tookayerta Creek (Hammer, 2009).

Despite the scale of habitat loss, the catchment is still considered one of the most ecologically diverse for aquatic biota in the Eastern Mount Lofty Ranges, with the remnant swamps and wetlands providing diverse habitats inhabited by rare and endangered species (RMCWMB, 2003). Lloyd (1986) stated that the Tookayerta catchment retained the best examples of wetland associated native vegetation in the Mount Lofty Ranges and has the most significant wetlands of their type in the Murray Darling Basin. While the catchment contains only eight percent of the total number of mapped Fleurieu swamps (15% of total mapped area), 44% of those classified as "high value" (65% of total area) occur in this catchment. This includes the largest mapped Fleurieu swamp (Black Swamp - 182 Ha) (SAWID).

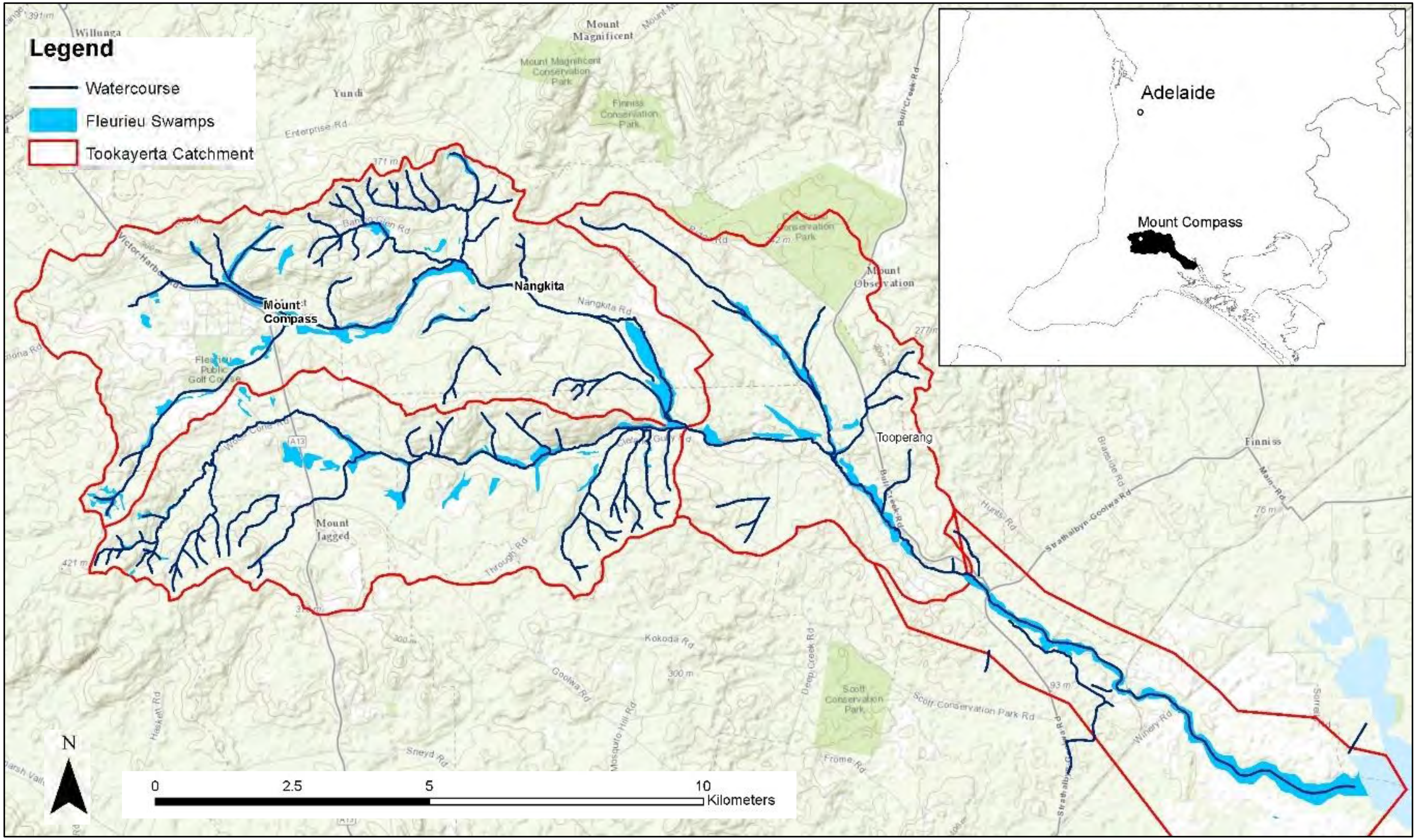

Figure 2.2 Overview of Tookayerta catchment showing sub-catchments, major watercourses and Fleurieu Peninsula Swamps

2.1 Climatic context

In a Mediterranean climate, summer rainfall is generally lost to evaporation meaning that winter rainfall (April–October) is a more reliable indicator of the water balance in a catchment than average annual rainfall (Barnett and Rix, 2006). Figure 2.3 provides an overview of rainfall trends, at the closest BOM weather station (Mount Compass) across these months and suggests that the catchment had been experiencing a deficit from average rainfall since 2004, with eight of the past twelve years yielding below average rainfall. However, the recent 2016 season represents the fourth wettest period on record and, despite following on from two low rainfall years in a row (2014 and 2015) has lifted longer term trends back closer to average conditions.

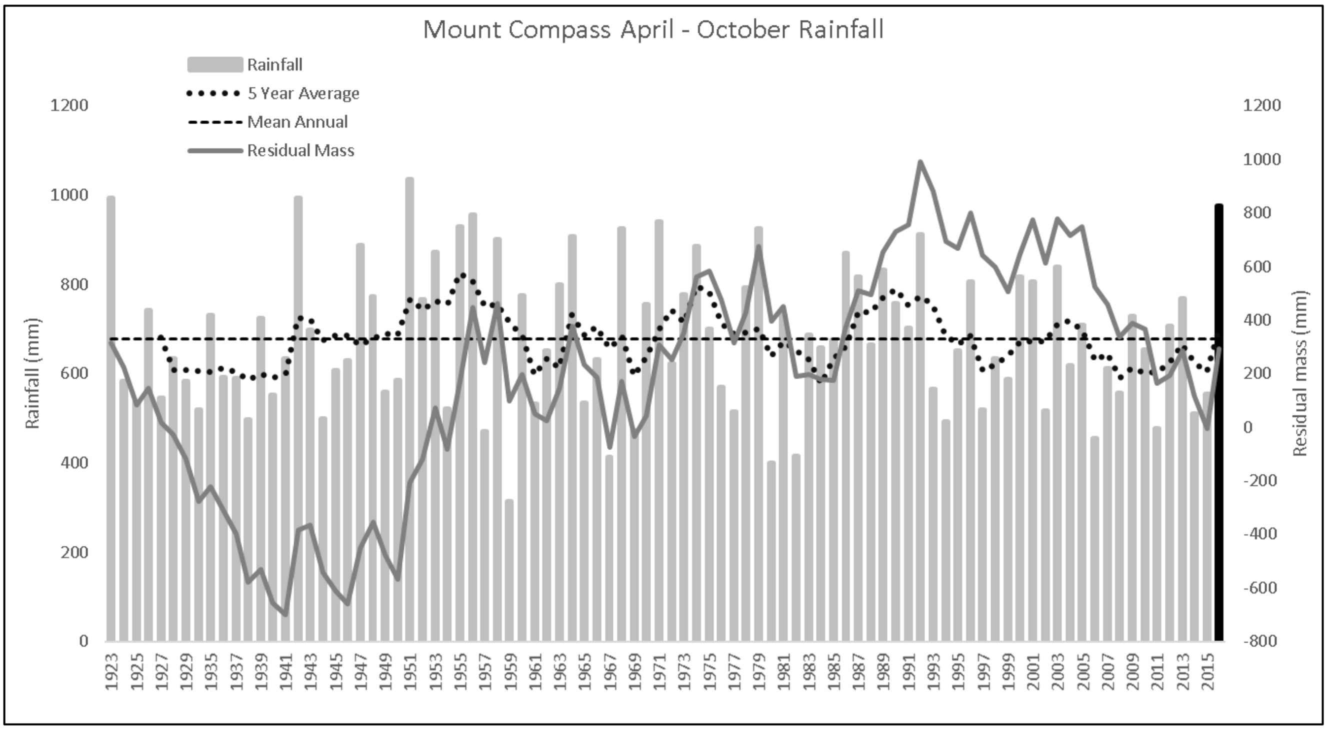

Figure 2.3: Effective (April – October) rainfall and deviation from average (residual mass) for Mount Compass BOM station (23735), 1923 – 2016.

Of note, future climate projections suggest winter-spring rainfall could decline by 15 to 30 percent by 2070 (Siebentritt *et al*. 2014), meaning an ongoing trend of decline should be factored into future management decisions in the catchment.

3 Early catchment history and development

Defining past environmental conditions is critical for understanding both the trajectory of (and reasons for) change and the potential for contemporary environmental management to achieve positive outcomes. This requires an ability to derive and interpret information from a diverse range of historic information sources; vital context for the purposes of this landscape assessment and forming the basis of the following section.

3.1 Catchment history prior to the 1890s

The Tookayerta catchment (as defined in this report) is contained entirely within the Hundred of Nangkita (originally spelt Nkangkita), which was defined and proclaimed by South Australian Colonial Secretary, A. M. Mundy, in 1846 (Adelaide Observer, 1846):

> 6. *Hundred of Nkangkita.*
>
> Bounded on the west by the range between Wood Cone and Mount Compass, which separates the Myponga from Longmarsh; thence from Mount Compass by a continuous range to Mount Observation; thence along the most direct spur to the north-west corner of section No 2363; thence down the River Finniss, keeping midchannel to the Goolwa; thence along the midchannel of the Goolwa to the north east of Hindmarsh Island, to the channel which finds its way to the sea mouth of the Murray, to the east of Hindmarsh and Mundoo Islands; thence to follow that channel to the sea mouth of the Murray; thence to follow the sea coast to a point south of a trigonometrical station south east of section No 2209, and by that station to the midchannel of the Goolwa; thence up the Goolwa to Currency Creek; thence up Currency Creek to a road which crosses it at the south-west corner of section No 2011; thence following that road through sections Nos 2011, 2015, 2005, between sections Nos 2017, 2018, 2031, and 2032, through 2018, 2036, 2034, and 2096, and from the north-west corner of the latter section (2096) passing up a spur which separates the waters of the Long Swamp and the Finniss from Currency Creek, and continuing along this spur to Mounts Jagged and Wood Cone,

Despite its early proclamation and proximity to both Adelaide and busy early trading locations at Goolwa and Victor Harbor, much of the Hundred escaped closer settlement over the subsequent 40 years, due to its perceived lack of suitability for agricultural development: consisting of large tracts of what was considered inferior stringybark scrub over sandy soils on the hills, and impenetrable tea-tree swamps in valleys lacking natural drainage.

For decades, the Hundred of Nangkita was considered a 'scrub desert', as described in this account from the South Australian Weekly Chronicle in 1865:

> In the farmers' hundreds, as I have before stated, and still affirm, there is comparatively but little unsold land of any immediate value. In some hundreds there is none at all; in others, though it may appear extensive on the map, it is nearly all dense scrub, or (as in the case of the Hundreds of Waitpinga, Nkangkita, &c.) absolute desert.

This early pattern of a lack of development is reflected in the earliest map of the surveyed parcels of land in the area from 1854, see Figure 3.1, which shows the northern portion of the Hundred of Nangkita (where the bulk of the Tookayerta catchment is situated) at that time almost entirely lacking parcels of land surveyed for closer settlement.

Figure 3.1: The Hundred of N(k)angkita in 1854, showing the remote location of the inn at Square Waterhole and the lack of closer settlement in what was then called "Square Waterhole Country".

This general area of undeveloped scrubland became widely known in this pre-development era as 'Square Waterhole Country', after the name of the location of the early inn was situated on the main overland transport route from Adelaide to the south coast. At that time the road was little more than an extremely rough sandy bush track. A detailed description of a journey through the area published in the Adelaide Observer in 1887, paints a picture of a remote wilderness, with very few inhabitants:

NO. II.—FROM WILLUNGA TO PORT VICTOR.

After a night's rest at the clean and comfortable hostelry known as the "Bush Inn," we started early, with a bright cool morning, for Port Victor, for the purpose of inspecting and forming an opinion of the capabilities of the intervening country for cultural occupation. The famous Square Waterhole, the infamous Black Swamp, the wrongly named Hungry Swamp, and many historical places exist upon this route. Once there was an accommodation house at the Square Waterhole, where the accommodation was next to nothing and the civility usually expected at such places was altogether absent. Afterwards there was an inn, which was a little better, but the inducements to travellers that way were insufficient and the place is now deserted. There are only two inhabited cottages visible from the road upon the whole route, and one of these, occupied by a stationman under the Road Board is likely to be empty soon. The first house is near Mount Compass, a mile or two west of Square Waterhole. The other is several miles further on, at Hungry Swamp, where George Gaultier occupies a selection of nearly 1,000 acres at an annual rental of £3 10s.

The following article from the Evening Journal (1889) two years later details describes how the bulk of Square Waterhole Country was still in the hands of government:

In the Hundred of Goolwa, running from the Hindmarsh River to Currency Creek and up to Mount Jagged, there are no blocks, and the same may be said of the next four hundreds to be mentioned. Goolwa includes 55,040 acres, of which 16,590 are under lease. Some of the land chiefly comprised is what is known as the Square Waterhole country, amounting to 3,340 acres, is still in the hands of the Government. But the bulk of this unsold country is included in the Hundred of Nangkita, which is bounded by the River Finniss on the east, and runs away up towards Willunga. It embraces no less than 23,080 acres of Crown lands, and 24,295 acres which are held on lease; so that in this hundred, out of 74,880 acres, the Crown is still the owner of nearly two-thirds of the land. But after leaving the Finniss and proceeding as far as Strathalbyn and Bull's Creek, we find that the case is very different in the hundred known as Kondoparinga. There are no vacant Crown lands, and only 12,916 acres are held upon lease.

By this time, the former Square Waterhole Inn was deserted, and the only dwelling situated near present day Mt Compass was the residence of the Road Board's 'Stationman'. By the late 1880s, this was local pioneer George Waye (see right, Figure 3.2), who had been living there in remote conditions with his family since June 1874, after replacing the first 'roadman' in the district, Thomas J. O'Callaghan. Their lonely and demanding job was to maintain and repair 11 miles of the Willunga road/track along its new route, after its 1860s realignment (see Figure 3.3).

Figure 3.2: Mr and Mrs Waye

As roadman, O'Callaghan had been based at present-day Mt Compass (also then referred to as 'Square Waterhole', given its proximity to that location) since the early 1860s, around the time the newly aligned road was built through what later become the town. He was removed from his posting and sent to another station by the Road Board after an allegation of an unapproved absence from his duties (in Yankalilla) on the 13th and 14th of March 1874, despite testimony from a number of people that he had been attending to his duties on those dates (Adelaide Observer, 1874). Only a few years earlier (in 1871), O'Callaghan arrived home from work to witness the first roadman's cottage (his residence) being consumed by fire, after an ember from the chimney fell on the dry thatch roof while his wife was stoking the fire (Adelaide Observer, 1871; Southern Argus, 1871).

FIRE.—On Tuesday, the 4th instant, a cottage situated near the Square Waterhole, occupied by a roadman named Callaghan, was totally destroyed by fire. It appears to have originated from a spark from the fire, and being built of wood the house was quickly consumed, the whole of the household furniture being destroyed as well.

A replacement roadman's cottage was built for use by O'Callaghan and later, George Waye. As an elderly man in 1925, when recalling the first 15 years of working there under the Road Board (before transfer to the District Council), Waye said, "at that time, Mount Compass was all scrub, hundreds and thousands of acres of it. The road was simply a bush track." He also said that he "used to patrol the roads for days on end and never see a single soul" (Victor Harbor Times, 1925). However, with the land surveyed into smaller blocks for closer settlement in 1880/81, as shown in Figure 3.3, the state government was responding to community pressure to see this last vast area of wilderness so close to Adelaide developed, making the land available for more intensive agriculture.

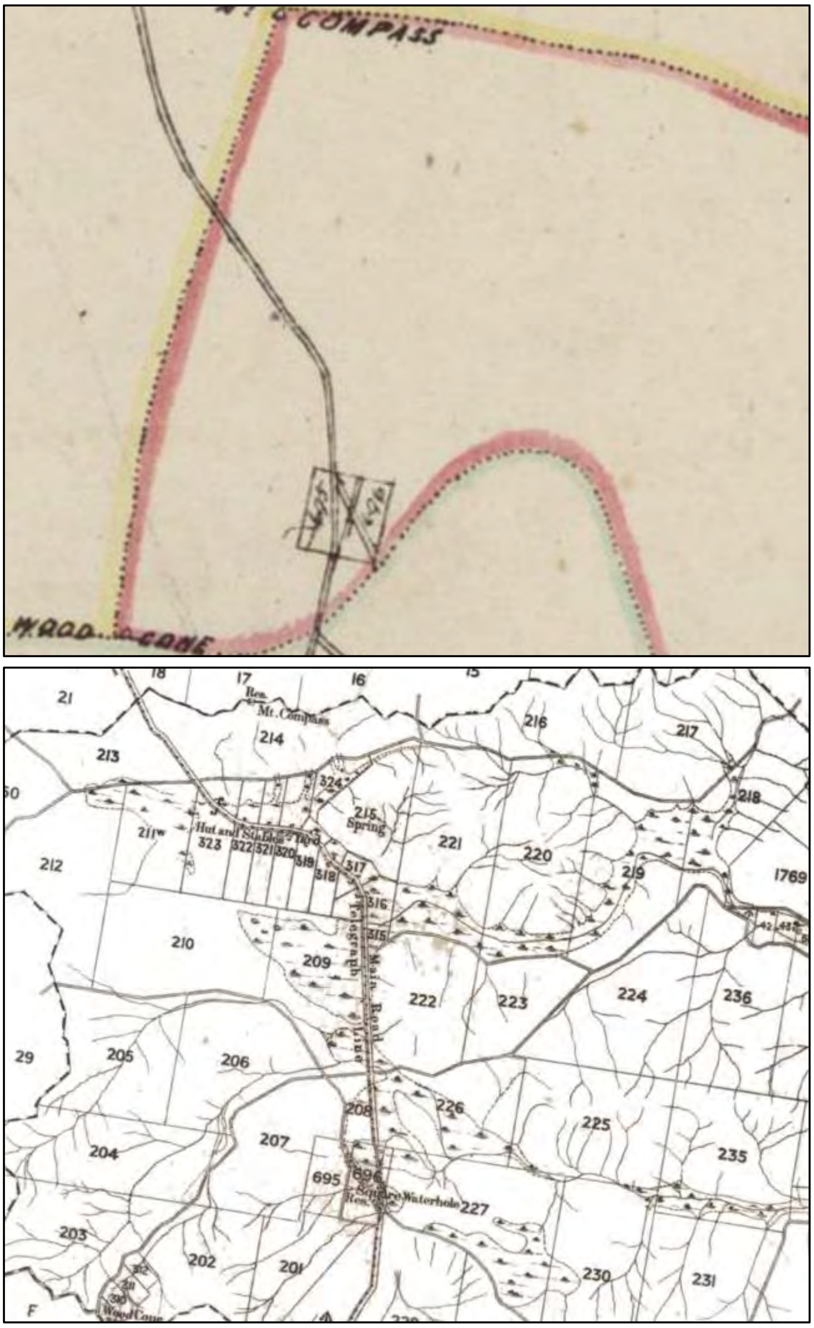

Figure 3.3: Paving the way for closer settlement: An identical view of surveyed parcels in the "Square Waterhole Country", between 1854 (left) and 1894 (right). Note the road realignment.

Indeed as early as 1881, the government held an auction of many of the recently surveyed parcels in the Hundred of Nangkita, initially made available for sale under miscellaneous lease (Adelaide Observer, 1881):

SALE OF MISCELLANEOUS LEASES

The following are the particulars of the sale of miscellaneous leases which took place at the Land Office on Thursday, August 18, and was very well attended, and the bidding was brisk:—

Hundred Nangkita.

Section 168, and reserve north-west of, 193 acres, J. Nosworthy, £10 15s. 3d

Sections 199, 231, 234, and 235, 1,506 acres, L. Giles, £36 10s. 6d.

Sections 201, 202, 207, and reserve east of Section 201, 1,189 acres, G. Goulter, £22 19s. 1d.

Sections 203, 204, 205, and 206, 1,614 acres, Miller & Smythe, £18 14s. 6d.

Section 208, 54 acres, M. Stuckey, £2 9s. 6d.

Sections 209, 210, 211, and 212, 1,813 acres, A. France, £20 16s. 1d.

Section 213, 208 acres, A. France, £3 2s. 4d.

Section 214, 403 acres, D. Gouge, £5 18s. 7d.

Section 214, 403 acres, D. Gouge, £5 18s. 7d.

Sections 215 and 221, 971 acres, Gardner Bros., £8 0s. 11d.

Sections 216 and 217, 777 acres, Gardner Bros., £4 4s. 9d.

Sections 219 and 220, 1,258 acres, Gardner Bros., £45 19s. 10d.

Sections 222 and 223, 587 acres, A. France, £5 18s. 11d.

Sections 224, 236, 237, and 238, 1,953 acres, G. Goulter, £23 2s 9d.

Sections 225, 226, 227, and 230, 1,789 acres, L. Giles, £43 4s. 1d.

Sections 228 and 229, 673 acres, L. Giles, £9 1s. 1d.

Sections 232, 233, 251, 252, and 253, 2,006 acres, L. Giles, £29 12s. 1d.

Sections 239 and 241, 555 acres, W. R. Mortlock, £4 11s 3d.

Sections 240 and 242, 829 acres, A. France, £7 19s. 1d.

Section 243, 122 acres, A. France, £1 10s. 2d.

Sections 244, 245, 247, and reserve east of Sections 245 and 247, 1,062 acres, G. D. Nosworthy, £12 18s 6d.

Section 246, 35 acres, G. D. Nosworthy, 7s. 11d.

Sections 248, 249, and 255, 1,333 acres, A. France, £20 11s. 1d.

Section 250, 316 acres, H. D. Gouge, £3 18s.

Section 254, 506 acres, A. France, £5 17s. 2d.

Section 256, 67 acres, G. D. Nosworthy, £1 5s. 7d.

Sections 257 and 259, 681 acres, W. Binny, £20 17s. 7d.

Section 258, 70 acres, D. Gouge, 16s 4d.

Section 260, 331 acres, J. Byrnes, £3 7s. 7d.

Section 261, 59 acres, J. Byrnes, 14s. 7d.

Sections 262 and 263, 583 acres, A. France, £10 3s. 7d.

Sections 264 and 267, 593 acres, J. Byrnes, £8 15s. 5d.

Section 265, 19 acres, A. France, 6s. 7d.

Section 266, 38 acres, A. France, 8s. 2d.

Section 2087, 35 acres, A. Byrnes, 17s. 11d.

This led to some of the early pioneer families formally establishing pastoral runs in the district, but despite the number of leasees who took up land, this initial subdivision process wasn't immediately effective in facilitating closer settlement and development – as highlighted in descriptions over the past couple of pages.

A pioneer family already active in the wider district (since their arrival in the 1850s), that did answer that early call to take up land at that time was the Gardner Brothers, who purchased the leases over much of the land (several thousand acres) surrounding present-day Mount Compass. After erecting ninety miles of six-wire fencing, they used the land mainly for summer grazing and usually sold their sheep at Mt Barker or Strathalbyn each year before the wet season (RMCD, 1946).

One of those brothers, George Byron Gardner (1851-1949) recalled giving the roadman George Waye "permission to use part of the swamp for vegetable growing" at present-day Mt Compass (see Figure 3.4).

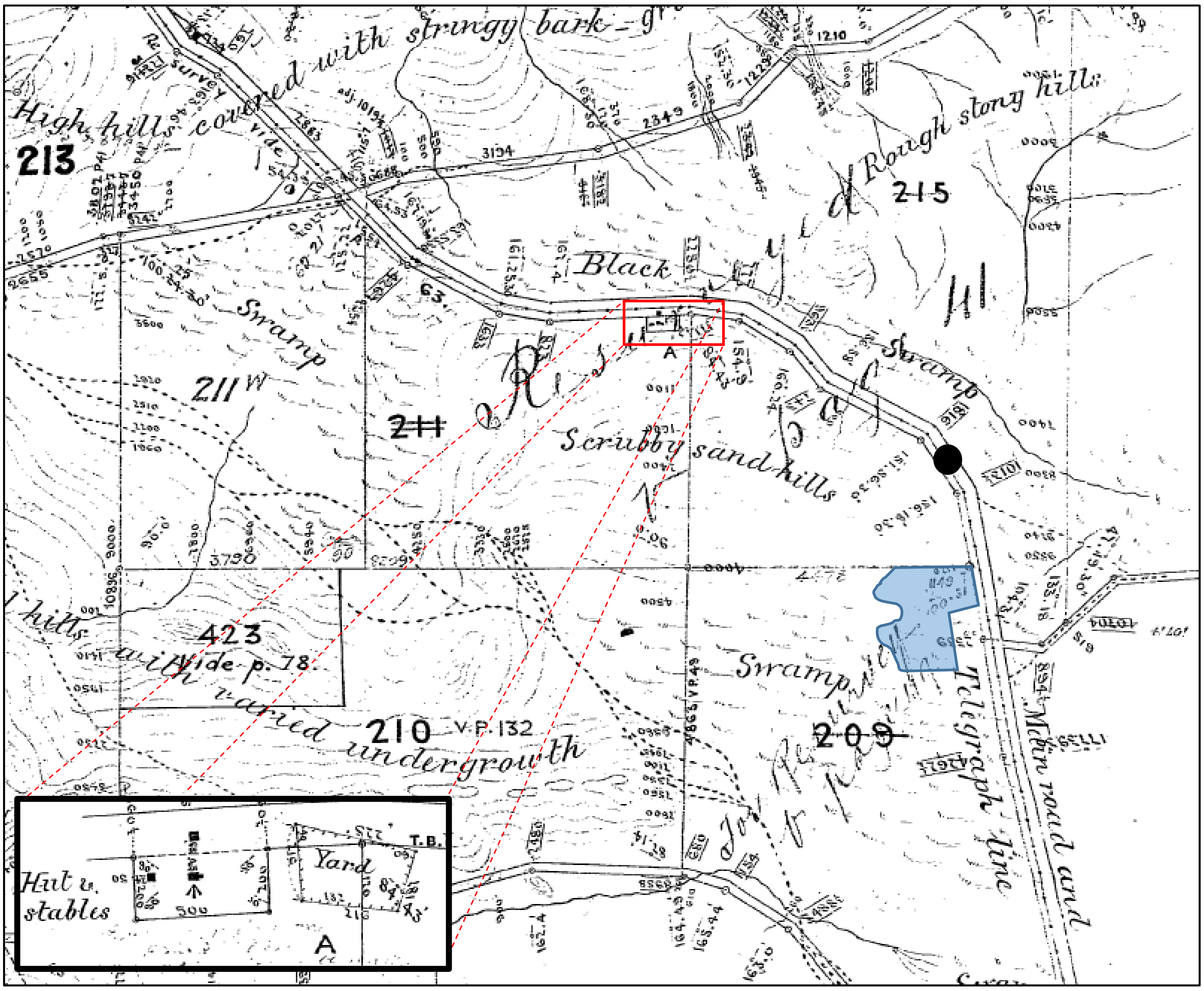

Figure 3.4: The centre of present day Mount Compass (black dot) in 1880, before the town existed, showing the Roadman's Reserve (inset). *Roadman George Waye and his family were the only local residents at this time. The present day remnant School Swamp is highlighted blue – a fraction of the former swamp extent. Also note that the term "Black Swamp" was applied to all of the continuous swampy land through the Square Waterhole Country.*

He noted that Mr Waye "grew some wonderful crops, and his success probably had much to do with the idea of making this a closer settlement area" (RMCD, 1946). By the late 1880s, there was a growing push from within the community for the government to invest in the systematic drainage of land throughout the Square Waterhole Country prior to proceeding with intended plans to offer more blocks of land for sale, as noted in these resolutions from a meeting at Port Elliot in 1888 (Evening Journal, 1888):

Meeting at Port Elliot.—At a well attended meeting held at the Royal Family Hotel, Port Elliot, on Saturday evening, March 31, Mr. J. D. Sutherland in the chair, the following resolutions were carried unanimously:—1. That it is very desirable that the Black Swamp and Square Waterhole country should be systematically drained, as recommended by the Conservator of Forests, and the surplus water conserved as far as possible; and, further, that each block offered for sale or lease should compromise portions of the scrub and swamp lands in suitable proportions. 2. That it would be exceedingly injudicious to part with certain choice blocks of the Black Swamp and Square Waterhole country while the question of draining these lands is under consideration of the Government. 3. That the members for the district be requested to urge these considerations on the Commissioner of Crown Lands at an early date. 4. That the hearty thanks of this meeting and of the Southern districts generally are due to Mr. Hussey, M.P., for the great interest he has taken in this matter, and that the electors in the South generally should support him in such action.

While it would appear that the state government itself never co-ordinated overall drainage works for the district as originally requested, it did eventually resume some key sections of land over subsequent years and reconfigure parcel boundaries to facilitate the development of the swamps on the basis of their particular agricultural productivity potential. One such area resumed by the government was the miscellaneous lease first held by the Gardner Brothers (and later a Mr McConville) in the vicinity of Mount Compass. This enabled the subdivision and resale of land at this location and soon led to the formation of the town.

After divesting himself of his local interests, George Gardner left the district and purchased land at Koppio on the Eyre Peninsula, where he established himself and was later remembered as one of Eyre Peninsula's early pioneers. After contributing his early recollections, recorded in the *History and Development of Mount Compass* (RMCD, 1946), George Gardner died a few years later in 1949, at 98 years of age (Port Lincoln Times, 1949).

3.2 Catchment history from 1890 to 1945

The dramatic change in land-use that had already swept across many neighbouring districts was now about to unfold in the "Square Waterhole Country". Unlike other parts of the state however, due to the nature of the land and vastly different soil types, the early pattern of development in the Mount Compass district was destined to be different. Thanks to the early experiences of George Waye and, later, the Wright Brothers who leased land off Mr McConville at Mount Compass in 1890 and established the first commercial scale market garden on drained swamps in the district, the fertile peatlands were to be the initial primary focus of development. The experience of the Wright Brothers was captured in the article from the Evening Journal in 1892:

> **OUR INHERITANCE IN THE SOUTH.**—Messrs. Blacker and McDonald, the members for Noarlunga, had on view at Parliament House on Tuesday afternoon some fine samples of vegetables grown in their district. The land is situated six miles out of Willunga, on the Port Victor-road, at a place known as the Square Waterhole. It is held under a miscellaneous lease by Mr. McConville. The growers of the vegetables are the Brothers Wright, who have sublet twenty acres. The land is swampy, but the soil is described as a black, rich, and peaty variety. Amongst the specimens of vegetables were a very fine mangold, some cabbages, potatoes, and parsnips, all of which were of excellent quality. Two years ago people said this land would not have grown anything, but in less than that period the Wright Brothers have reclaimed five acres of the swamp. Last year they grew 12 tons of potatoes, 2 tons of onions, 1½ tons of turnips, over 3,000 cabbages and cauliflowers, and 5 cwt. of French beans. Green peas were grown in large quantities and were sold from Christmas to Easter. They have also planted over 100 fruit-trees, including apples, pears, and plums. This, it is thought, clearly proves that the land is really good, and there is a large area near by. A petition was sent in to the Commissioner of Crown Lands from some of the residents recently, asking for the land to be cut up into blocks, and it is thought that if the land were cut up into about 10 acres, with about 100 acres of higher land, a large number of people would be able to get a living on it.

The efforts of the local MPs were clearly effective, because only a year later, in 1893, the land in the vicinity of present-day Mount Compass had been resumed from miscellaneous lease and subdivided, to be made available for closer settlement. This followed similar subdivisions in 1890 at Nangkita and Swampy Crescent, as shown in Figure 3.5.

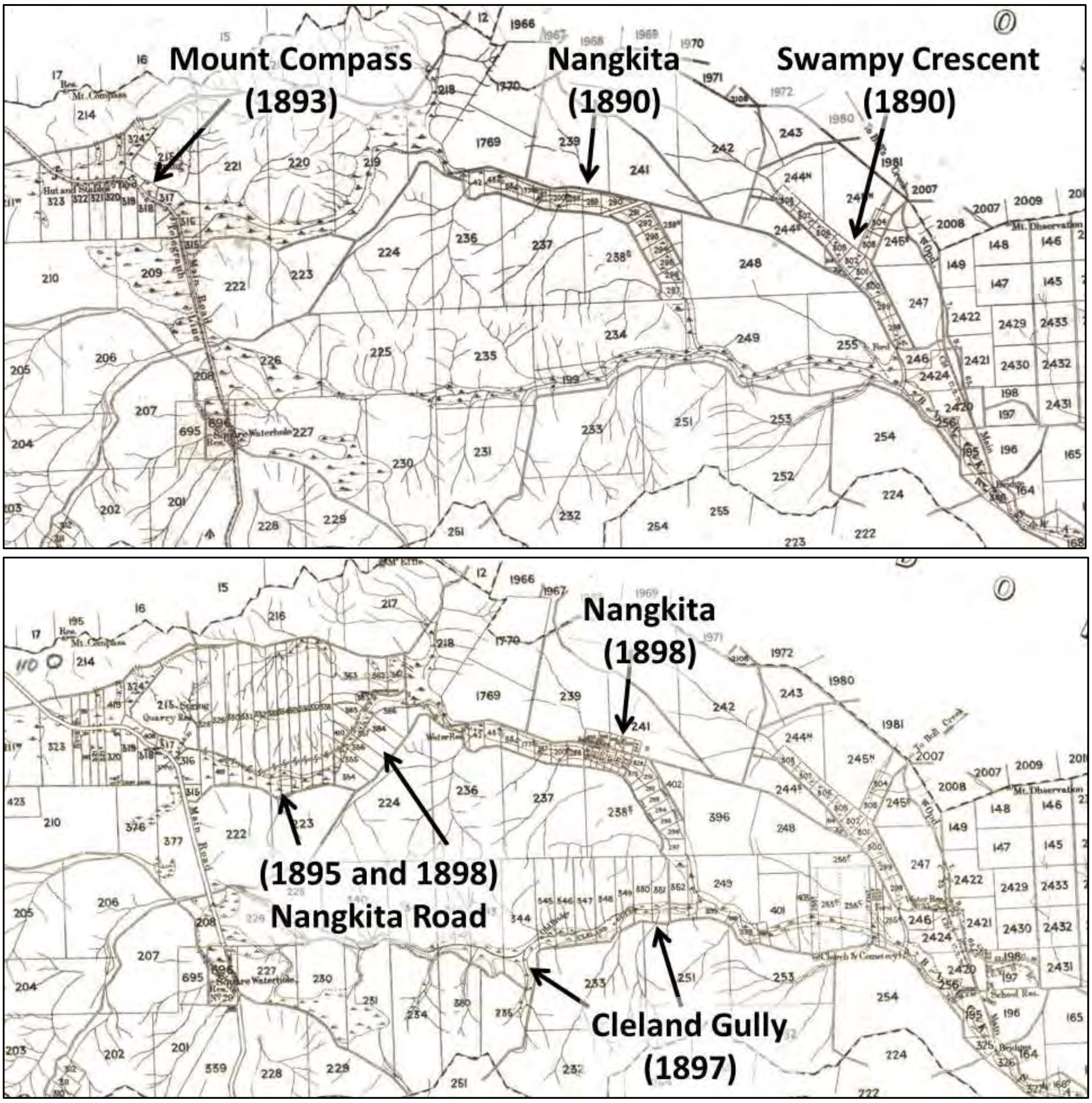

Figure 3.5: Changing parcel boundaries in the Hundred of Nangkita in the 1890s, showing the date and location of key subdivisions designed to promote closer settlement reliant on the peat flats.

By the end of that decade, additional land had been resumed by the government and subdivided for more intensive agricultural development along Nangkita Rd and (what later became known as) Cleland Gully, as well as some additional lots at the Nangkita settlement. As can be seen from the maps in Figure 3.5, the philosophy of these subdivisions changed slightly over time. The first land divisions at Nangkita and Swampy Crescent created small lots primarily consisting of peatland for drainage as market garden development blocks, whereas the later subdivisions on the Nangkita Road and at Cleland Gully aimed to create slightly larger allotments, but with each lot having access to a small (but deemed equitable) amount of more valuable fertile peatland in the valley, with the balance made up of higher ground.

The drainage works that followed on these properties were largely undertaken by the landowners in an ad hoc fashion as they developed their parcels for production (especially market gardening and orchards). In some cases, trial plantings of osiers (willows) for basket making, hops for brewing and tobacco were also attempted.

A more co-ordinated, considered and systematic approach to drainage however was established at Nangkita in the early 1890s, as shown in Figure 3.6.

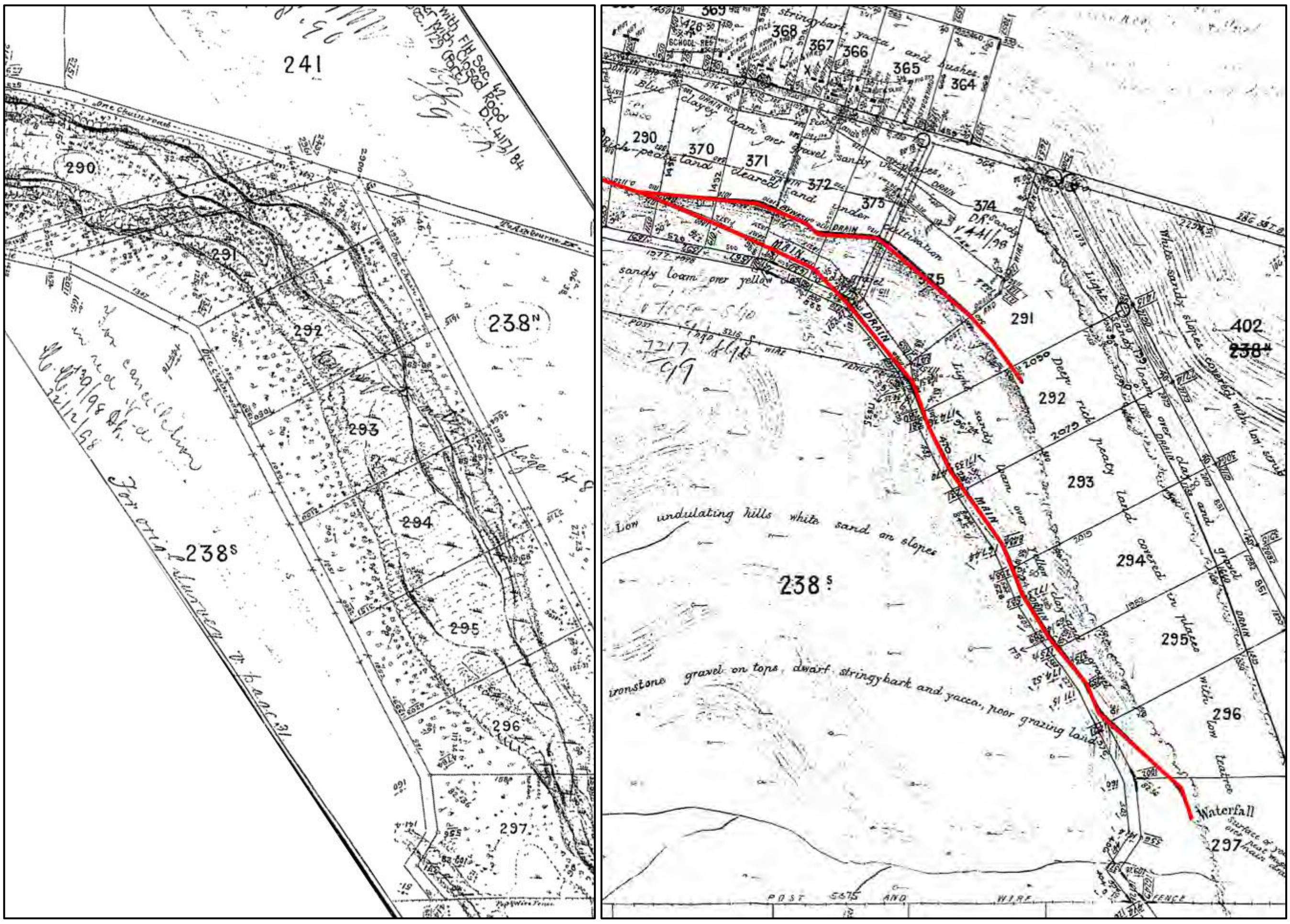

Figure 3.6: The 1890 subdivision (left) and 1898 resurvey (right) of Nangkita. *Also showing the location of (1) the main bypass drain along the contour of the slope before discharging over an artificial waterfall back into the valley downstream; and (2) the location of the drain on the valley floor to enable the first peatland area at Nangkita to be cleared and cultivated. Both drains flow to the south east.*

Despite initially being subdivided in 1890, the area wasn't intensively settled until established as a South Australian government-endorsed village commune under the under Part VII of the *Crown Lands Amendment Act 1893*, a scheme intended to mitigate the effects of the depression then affecting the young colony by giving the unemployed meaningful work on the land. The Nangkita Association (made up of unemployed families from Port Adelaide) was one of a number of settlements (as many as 14) surveyed across the state, but the only one situated south of Adelaide (one was at Mt Remarkable and the rest were along the Murray River).

Many of the village settlements faced difficulties (practical, social and economic), and Nangkita was no different – as the new settlers to the commune confronted great hardships in draining, clearing and farming the land upon their arrival in March 1894. The first task of drainage appears to have been partially underway before their arrival, by an existing resident of the area, Mr. Porter and his sons, who had already constructed the main bypass drain (as shown in Figure 3.6) by 1894 (Southern Argus, 1894):

> Operations commenced with the excavation of a canal, which has its beginning at the upper end of the estate, and the water is thus made to flow along the side of the slope, between which and the bed of the stream the irrigated plots are situated. It is Mr. Porter's aim by diverting the course of the main stream and circumscribing its flow to one side, to reclaim a large portion of the bog, which when drained—and there appear to be no insurmountable difficulties in the way of its being accomplished—will be splendid potato land. With the object of irrigating a far larger area a drain of ample dimensions has been started some considerable distance up the valley, which, when completed, will command a hillside that seems eminently suited for vine culture. Mr Porter, whose cultivation is peculiarly his own, hopes to be able at no very distant date to place grapes in a perfect state of preservation in the London market at a season when the European supplies have run out, and when the prices will be consequently at their highest.
>
> Cucumbers, tomatoes, and sweet melons are growing luxuriantly and promise an abundant yield.
>
> The work of reclamation and channel making has been done entirely by Mr. Porter and his sturdy sons, who, from the eldest downwards seem imbued with much of the independent and resolute spirit that characterises their father. It is the belief of many that the time will come—possibly not for 20 or 30 years it may be—when the Black Swamp from one end to the other will be the scene of a numerous and busy population.

This ingenious solution ensured that each block downstream of the flow diversion point had access to a permanent supply of gravity-fed water on demand for domestic and irrigation purposes, while concurrently reducing the amount of water entering the peatland on the valley floor through the Nangkita blocks, which were also being drained. This bypass drain ultimately re-joined the level of the main valley floor and watercourse downstream, after tumbling over an artificial waterfall (that resulted from the erosion associated with this steep upslope terminus for diverted flows). This noteworthy feature, which has continued to erode, is still present today (see Figure 3.7). An article from the Adelaide Observer in 1901, describes the appearance of this system of drainage within 10 years of its construction:

> Perhaps, however, the chief value of Nangkita will be to show how the work of draining may be done on a large scale. When the settlement was founded a large drain, over a mile in length, was cut along the hillside to carry off the surplus water. As showing the natural fall in the swamp it may be mentioned that the outlet of this drain at its terminus is some 60 ft. above the swamp level. Here the released water tumbles over a steep hillside with a sheer fall of some 40 ft. before finding its way again into its natural course. From any part of this drain channels may be opened to supply the gardens during the dry weather, thus giving natural facilities for intense culture of the most profitable kind. This is the lesson which Nangkita teaches—that systematic draining is better than any haphazard method by the individual settler. If the remaining swamps could be drained and cleared systematically by the Government as they are required for settlement the work of the settler would be simplified and accelerated,

Figure 3.7: The present appearance of the artificial waterfall created at the terminus for the upslope bypass drain constructed at Nangkita in the early 1890s. Note the substantial effects of 125 years of erosion.

The calls for more systematic drainage at a larger scale across the catchment prior to settlement however were mostly not heeded, and this has been a significant factor in both (a) the way these typically smaller bocks of land were subsequently developed and (b) has also directly contributed to their current condition (and in some instances partial recovery).

The living conditions and actual physical work required by the settlers to make the main peatland on the valley floor available for planting, in an era that pre-dates mechanised clearance, were extremely challenging (South Australian Chronicle, 1894):

> **In the meantime the settlers for the most part are living in tents and wattle and daub-buildings. The settlement comprises 1,800 acres, 800 of which are swamp. This is composed of a strong peaty soil, very similar to that to be found in the neighborhood of Millicent and Rendlesham. The settlers have devoted most of their attention to clearing this swamp, which will be their main strength, as excellent results have been secured from similar country in the neighborhood. A drain has been cut down the centre which carries off the water, and some 35 to 40 acres have been cleared. With a view of ascertaining how long it took to clear the land two men were put on to clear a certain portion and it was found that on an average it would take one man, working nine hours a day, 40 days to clear an acre. It is really hard work,**

Despite the lofty and idealistic ambitions of those who pushed for the scheme in SA, challenging times were not far ahead. As early as 1896, after a number of controversies at settlements around the state and the difficulties of communal living under such harsh conditions, Nangkita and a number of other settlement associations were officially disbanded. By that time a number of people had left the settlements and the many detractors of the scheme at a political level successfully pushed to limit the perceived risk (both socially and financially) to the state government.

Despite its closure however, there is evidence that a small number of settlers stayed on at Nangkita after that date, as shown in this article extract from a short time later, in 1901:

> *"Further along the swamp widens again, and the village settlement of Nangkita is reached. The village still remains, but the association is no more. The few settlers who remain hold the land in separate blocks, and pay a rental based upon the capital outlay. Nangkita boasts a school and a post-office, which makes it a centre for those who live in the locality, and its annual demonstration to celebrate the foundation of the village is an event of some note." (Adelaide Observer, 1901)*

Along with the limited number of local resident families that preceded them, the remaining settlers formed the nucleus of the small community that remained at Nangkita. Just how small that community was can be gleaned from the fact that by 1900, only 25 registered electors remained in close proximity to the village at Nangkita. For comparison, there were 46 registered electors who lived either in, or closer to, Mount Compass (Advertiser, 1900). The land used for the settlement was itself resumed and resurveyed by the state in 1898 into smaller allotments (as shown in Figure 3.5 and Figure 3.6) and made available under the more typical (i.e. individual, not communal) terms described in the extract above.

More broadly across the Mount Compass district, the pattern of development associated with the reclamation of the peat swamps, was leading to significant changes in the character of the catchment and the formation of a township at Mount Compass:

> *About five years ago there was only one solitary house at Mount Compass, and a small patch of about five rods* (i.e. imperial units) *of the swamp cultivated. Now, through the example of the Messrs. Wright Bros., there is a large area of swamp reclaimed and under cultivation; substantial houses have sprang up in all directions; it has a black smith's shop and only wants a post office and public school to make the township complete.* *(Advertiser, 1896)*

For the next few decades, early development in the district focussed mainly on making the swamps of the district productive for market garden style developments, with the higher slopes (of less fertile soils) only mainly used as rough pastoral country for grazing livestock. This headline of an article in the Register in 1915 perfectly summarises local attitudes and the style of development that was generally being promoted at the time:


THE BLACK SOIL COUNTRY.
MT. COMPASS AND THE PEAT FLATS.
THE PROFITABLE 10-ACRE BLOCK — FORTUNES IN MARKET GARDENING.

However, with time, rapid advances in agricultural technology in the 1920s and 1930s – including mechanisation and new equipment, fertilisers, trace elements, new pasture varieties and changes in farming practices – made it possible for more of the land to be opened up, more quickly. Crucially, active development was now pushing beyond the margins of the "peat flats" and into scrub country previously considered unproductive. The results, as shared in the following excerpt from an article by a travelling party inspecting development in the district around Mt Compass in 1935, were enough to encourage others to expand their activities or take up land and follow suit:

> *We made an Inspection of three of the paddocks and, at a point where one of these joined the land that had not been cleared, were able to witness a remarkable comparison between the country in its natural state and that developed. On one side of the fence there was nothing but a dense mass of scrub, heath, black grass and use less bush, with insufficient feed to fatten a rabbit, and, on the other, we were standing in clover and rye grass above our boot tops, although four sheep to the acre were being grazed thereon….*
>
> *Proceeding along the Nangkita valley we saw hundreds of acres of rich flats and thousands of acres of high land still in a virgin state,*

> *with small areas here and there in pastures typical of what practically the whole should resemble.* (Chronicle, 1935)

In short, the “Square Waterhole Country” was about to witness an explosion in rates of land clearance of the high country and slopes that would transform the land and set in train the sequence of events that explain the present-day condition and pattern of development across the Hundred of Nangkita and the Tookayerta Catchment.

While development of the peatlands would also continue, the focus was shifting to the untapped potential of the vast acreages of higher ground as a result of the sheer area of this country that remained undeveloped across the catchment. This excerpt from an article in 1936 demonstrates the shift in attitude that was under way from the perspective of local farmers:

> *“There is no greater worker for the district than the never-tiring veteran, Malcolm Jacobs, who has spent many years working the fertile organic flats, but even he had not recognised the potential value of high land lying just behind his house until recent years, when no time was lost in bringing that very much despised land into economic production as pasture land. “* (Chronicle, 1936)

Experimentation quickly led to faster results, and the economics of land ownership in the district was changed forever, with scrubland no longer considered useless as had previously been the case:

> *“The secret of this development has been the sowing of ample supplies of subterranean clover seed with heavy applications of superphosphate, in the early stages of development it was rare for more than 2 lb. or 3 lb. of seed to be sown with a dressing of 1 cwt. of super, and it was necessary to wait three years for a return.*
>
> *With present methods, which include the sowing of from 15 lb. to 20 lb. of seed, dressed with 3 cwt. of superphosphate, new land within six months reaches a stage of productivity high enough to carry one sheep to the acre. The cost of clearing the scrub and giving the land its first ploughing is approximately £2 an acre. Mr. Kidman, in one clover paddock on Ravenswood, where he has established a Ryeland stud, has carried from four to five sheep to the acre for the past 12 months. Before this property was taken in hand, it would not have grazed one sheep to 20 acres.*
>
> *Councillor Jacobs this year has a crop of seven acres of potatoes, which he expects will yield 50 tons. At the present price, the total return will be approximately £950, or about £135 an acre. This land was under scrub last year.”* (Chronicle, 1939)

3.3 The impact of past development patterns on present land use

Before assessing more recent trends in land use change, it is worth reviewing just how critical the net effect of the historic process of land development (described so far up until the 1940s) has been in influencing the way the Tookayerta catchment is still managed today. The cadastral boundaries, which govern the pattern of land ownership, development and use today, are still predominantly a reflection of the original pattern of development determined by the surveys of the 1880s and 1890, as shown in Figure 3.8.

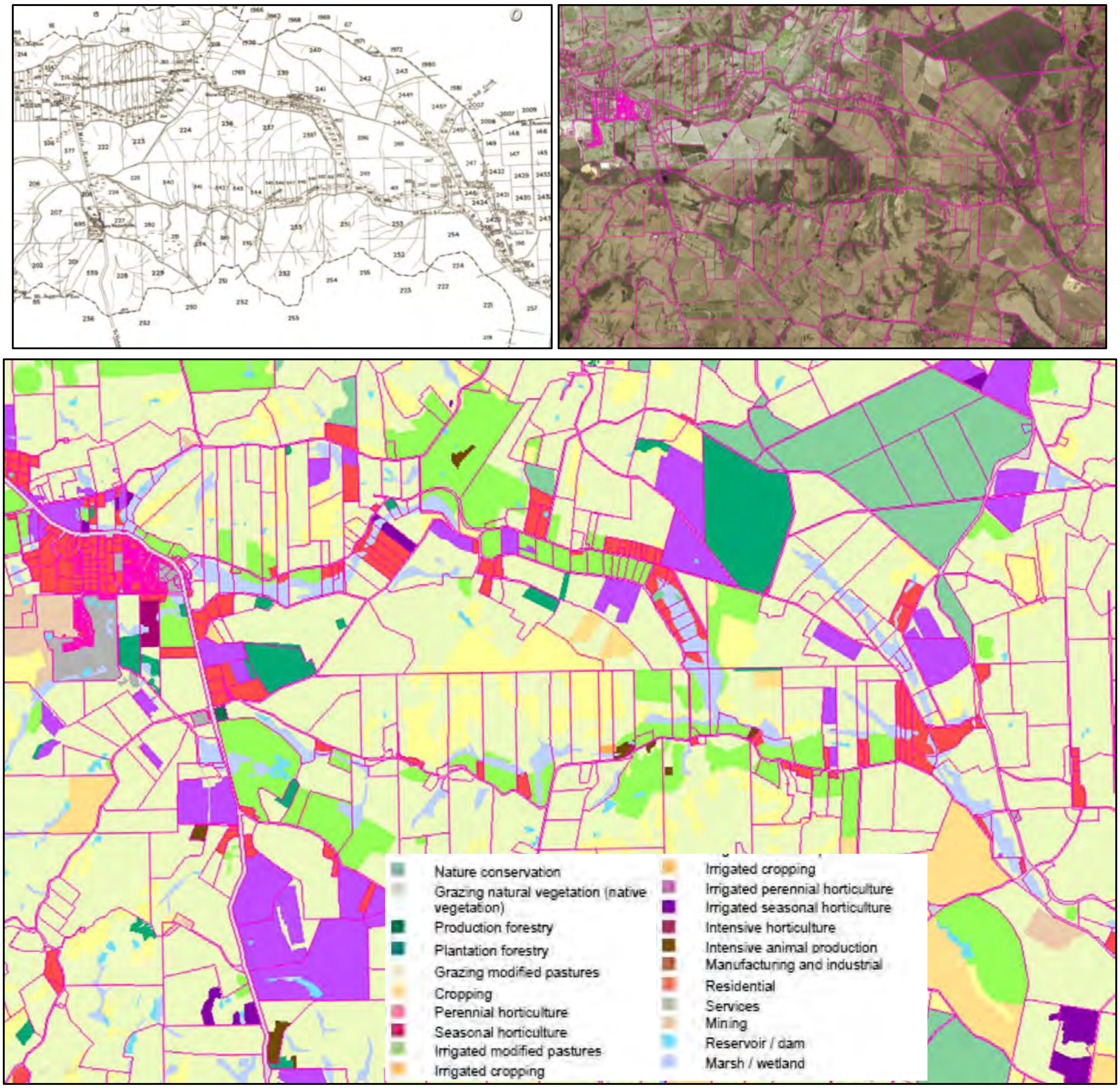

Figure 3.8: The clear and direct relationship between early parcel configuration as a result of the development process outlined in the 1880s and 90s (top left), and (a) current parcel configuration (top right), (b) current land use delineation (bottom). Source: 2008 layer from Naturemaps

Clearly understanding the relationship between remnant swamp distribution (shown in blue in Figure 3.8) and the pattern of land tenure is a critical consideration in the analysis of restoration feasibility on private land.

4 Contemporary catchment changes and trends

4.1 Modern (post-1945) changes in regional and catchment vegetation cover

While large parts of the Fleurieu Peninsula had already been cleared by 1945, the rate of development further accelerated through upscaling of mechanised land clearance after World War II, also facilitated by the knowledge that most soil types in higher rainfall districts could now be actively improved for agriculture. The result for the remnant biodiversity of the Mt Lofty Ranges was dramatic, leading to the loss of over 60% of the native vegetation that still remained in 1945, by just 35 years later in 1980.

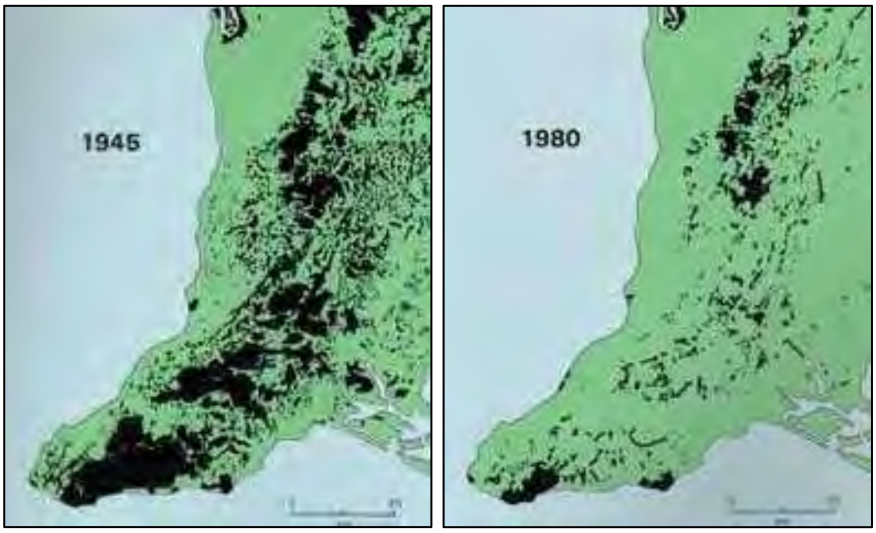

Figure 4.1: Of 240,000 hectares of native vegetation present in the Mt Lofty Ranges in 1945, only 90,000 hectares remained in 1980, a decline of 62.5%.

Imagery from 1950 reveals that vegetation clearance had already occurred through much of the catchment prior to 1950. However, a comparative view using 1949 and 2014 aerial imagery (Figure 4.2 and Figure 4.3) shows significant vegetation clearance in the vicinity of Mt Jagged in the southwest, from the centre of the catchment and also in the north-west, occurring between 1949 and 1960.

An analysis of decadal vegetation change undertaken as part of this project using historic aerial imagery reveals that clearance between 1949 and 1960 resulted in the loss of more than half of the remaining vegetation at the time (Figure 4.4).

Smaller losses occurred up until the introduction of the *Native Vegetation Act 1991* but since this period, small increases in native vegetation have occurred as a result of natural regeneration. Additional vegetation cover has also been gained in the form of forestry plantations and some assisted revegetation (Figure 4.4).

Figure 4.2: A 1950 aerial view of the Tookayerta catchment, showing areas of vegetation clearance up to 1950

Figure 4.3: A current aerial view of the Tookayerta catchment, showing present vegetation cover.

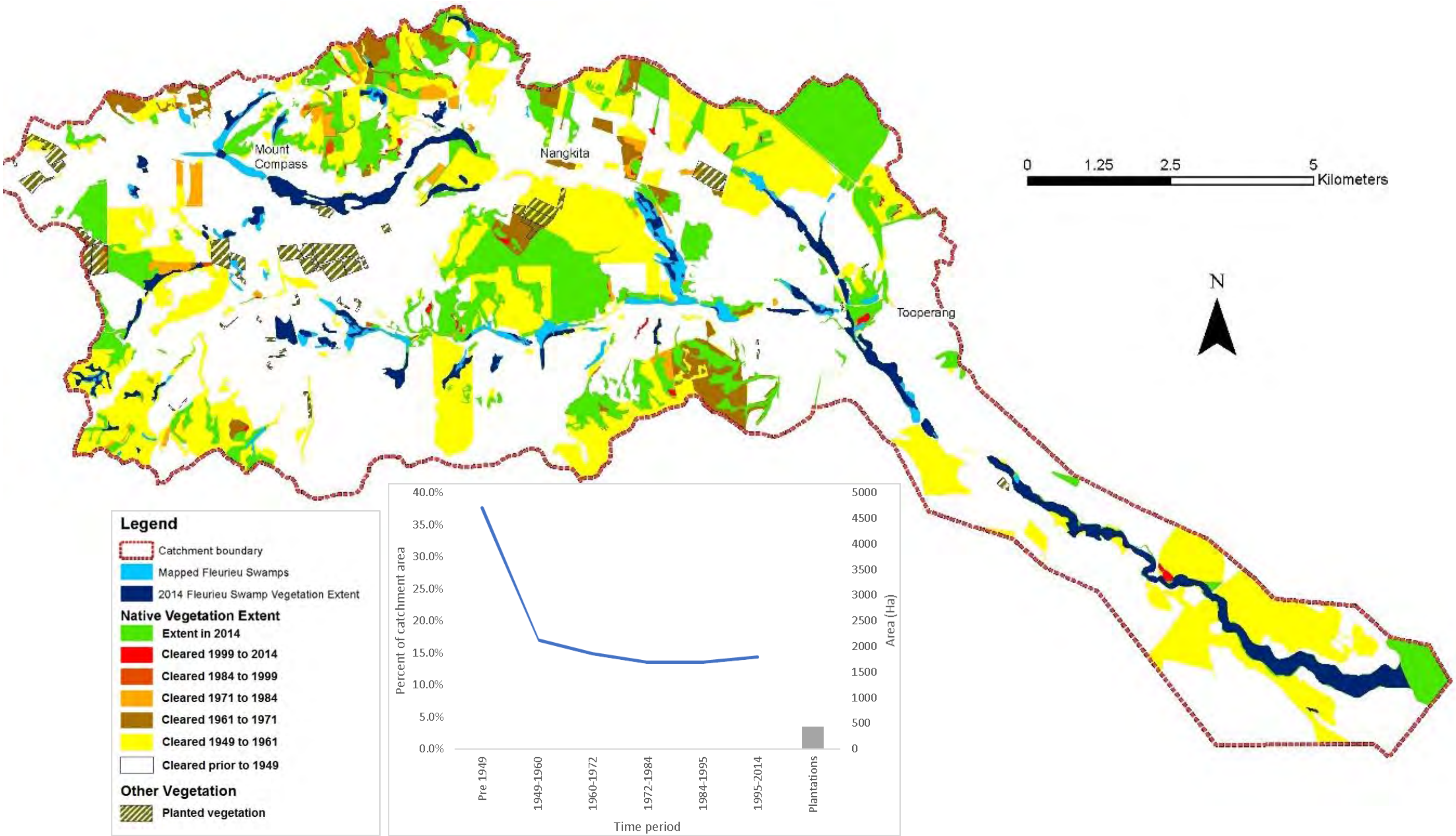

Figure 4.4: A timeline of modifications to vegetation extent in the Tookayerta catchment.

4.2 Changes in catchment hydrology

Aside from changes to vegetation cover, which influence runoff and aquifer recharge, the physical movement of water through the catchment has also been modified by the construction of artificial drains and water storage dams, along with the establishment of wells for groundwater extraction. Because the streams are a source of permanent fresh water, initial settlement in the catchment was close to the streams, and most of the settler selections were divided into narrow blocks to give each settler access to the water (Casanova, 2016). Early settlement was largely dependent on rainfall and uninterrupted streamflow (i.e. minimal storage and extraction). However, stock grazing and drainage on flats and wetlands resulted in the collapse of peat beds and significant instream erosion (Compass Creek Care, 1997) which, combined with the clearance of uplands and wider catchment erosion, acted to modify the geomorphology of the catchment's watercourses and wetlands. Increasing reliance on catchment water, in combination with droughts, saw manual and fuel powered extraction of water from aquifers and streams. From 1950 onwards, with the introduction of machinery, there was development of artificial water storages, combined with increased pumping of water resources by electric pumps. The following section provides an overview of the main water affecting activities in terms of timelines of development.

4.2.1 Drainage

As described in Section 3, the first agricultural activities in the Tookayerta catchment were focussed in and around the peatlands on the flats. Initially these were considered far more productive than the sandier slopes and as a result, attempts to develop them via drainage were commonplace.

An investigation of aerial imagery from 1949 through to the present day has allowed us to compile a history of drainage, both in terms of drains constructed over time, and also to assess where active drains occur today. An overview of drainage history is provided in Figure 4.5 to Figure 4.7 (see Appendix 1 for year specific maps) and shows that a bulk of drainage works had been undertaken prior to 1949 with close to 100 kilometres of drains established (Figure 4.8). Additional drainage works continued to add an additional 20 kilometres of drains up until 1995, after which new drainage works have been negligible.

This analysis reveals that every mapped wetland on a major watercourse has been drained (or impacted by drainage works) at some point and that approximately 80% of drains remain active today, based on those drains still visible from 2014 aerial imagery (Figure 4.9). These drains have significantly changed flow dynamics; with the system behaving more responsively under flow, reducing the capacity for peat hydration, wetland storage capacity and water filtration.

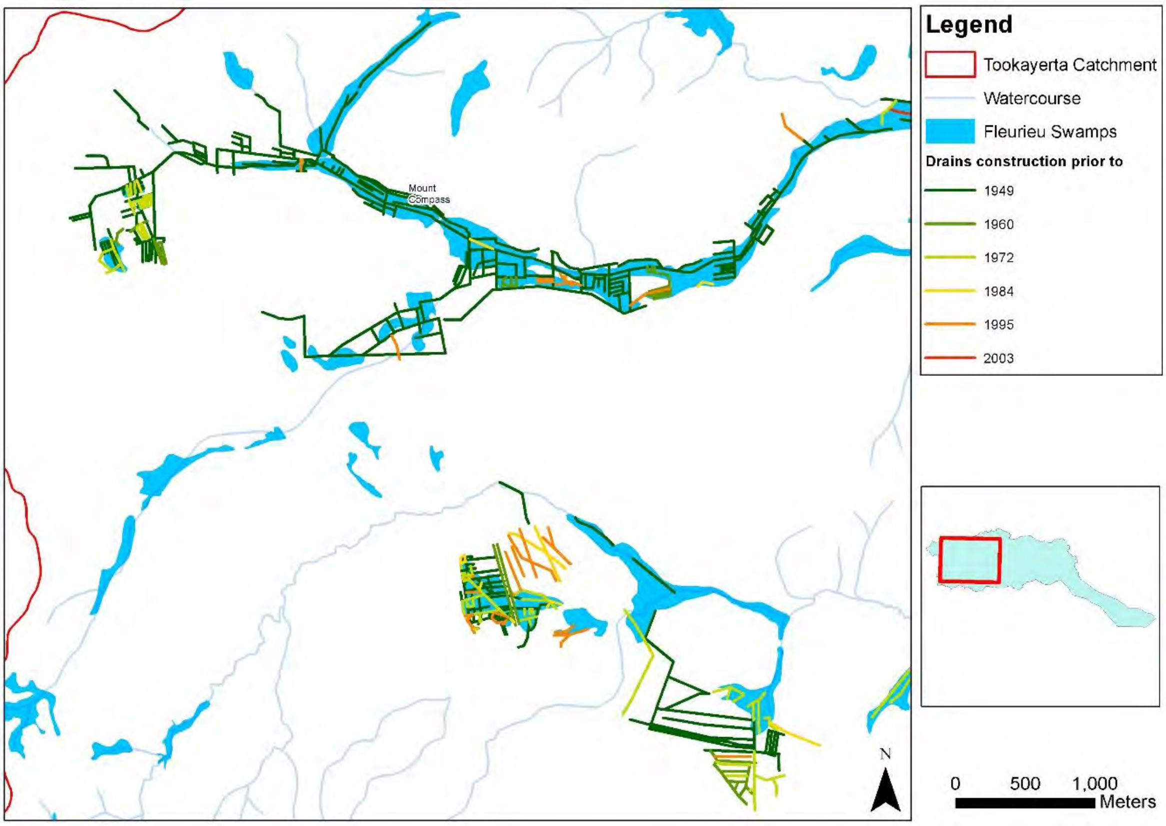

Figure 4.5 Overview of artificial drains and periods of construction through Fleurieu Swamps of the Tookayerta catchment (western).

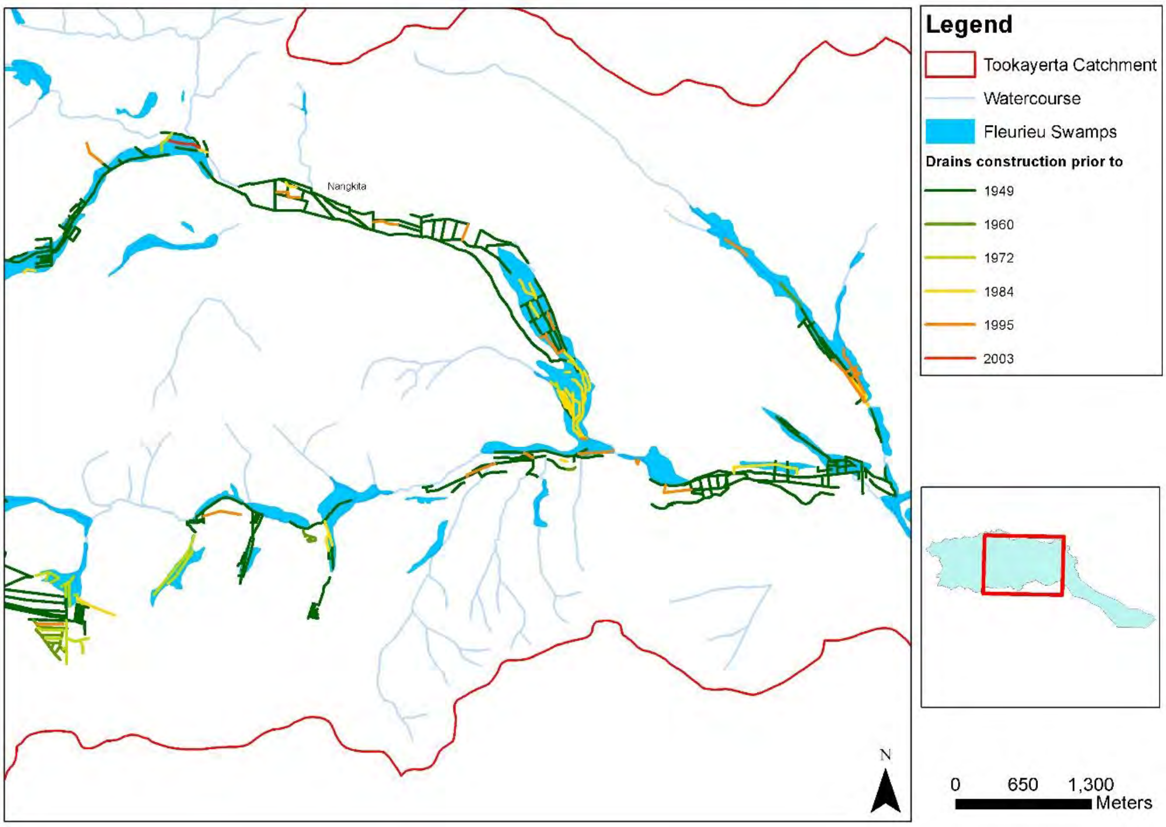

Figure 4.6 Overview of artificial drains and periods of construction through Fleurieu Swamps of the Tookayerta catchment (central).

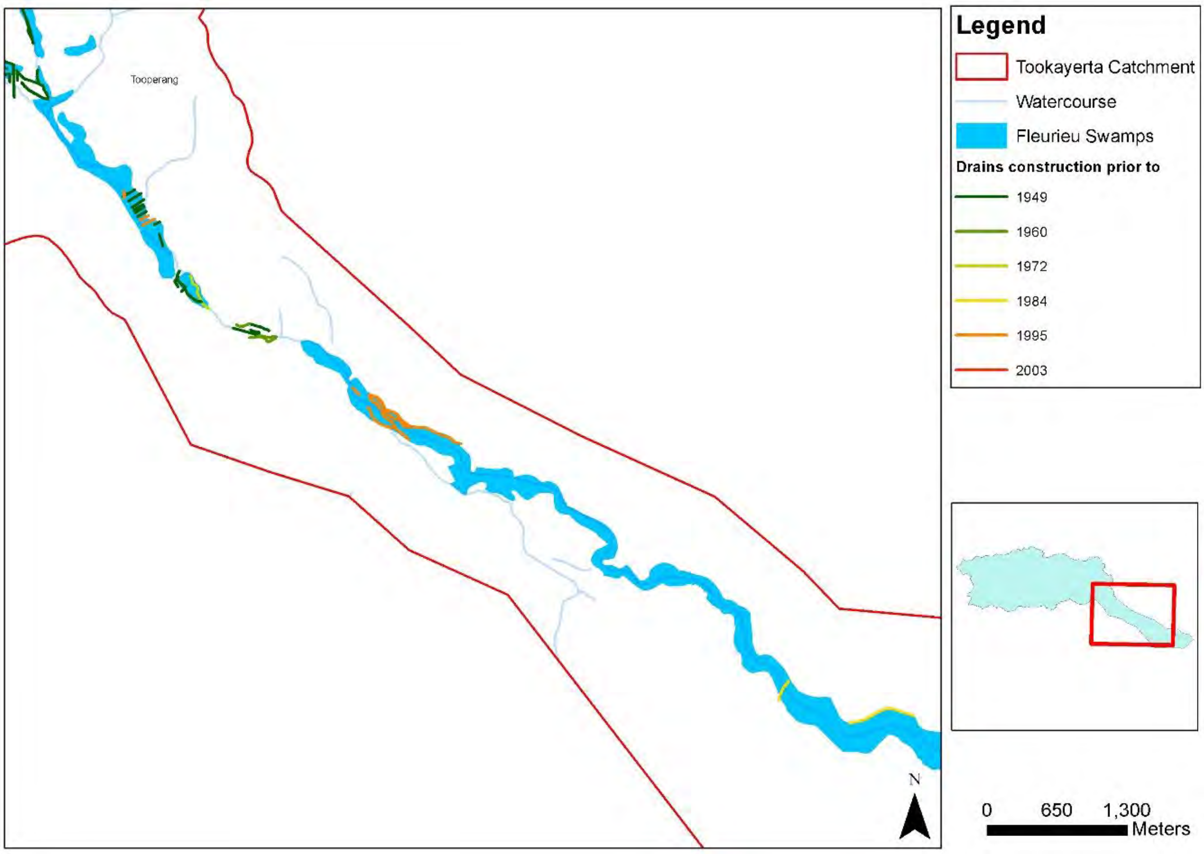

Figure 4.7 Overview of artificial drains and periods of construction through Fleurieu Swamps of the Tookayerta catchment (eastern).

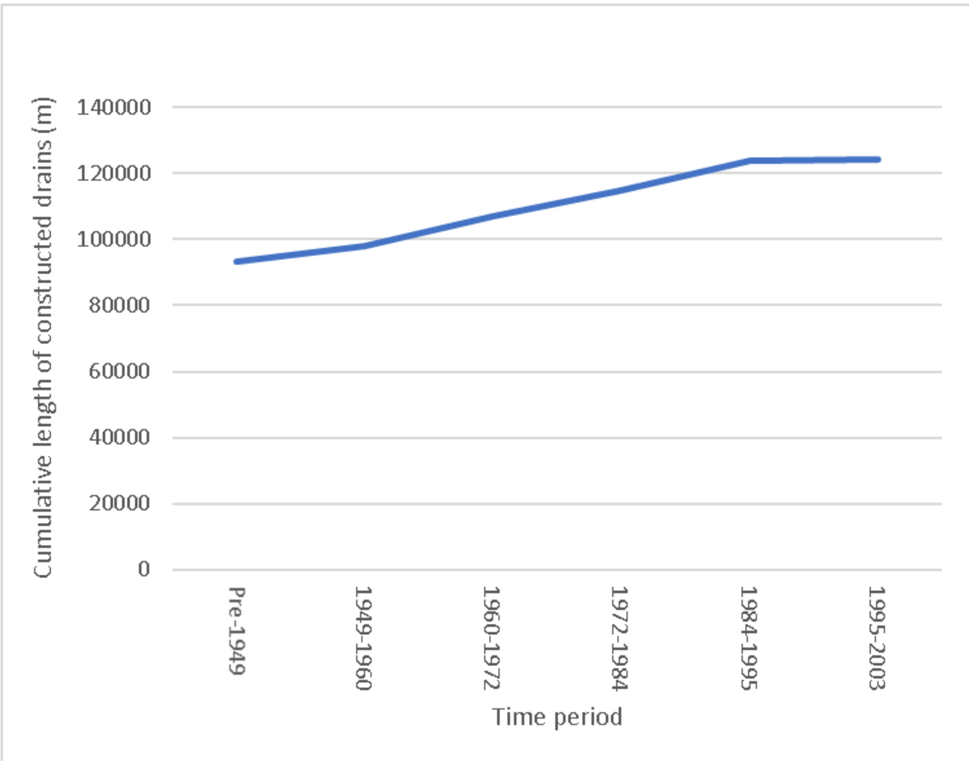

Figure 4.8 Timeline of drain construction in the Tookayerta catchment, based on aerial imagery.

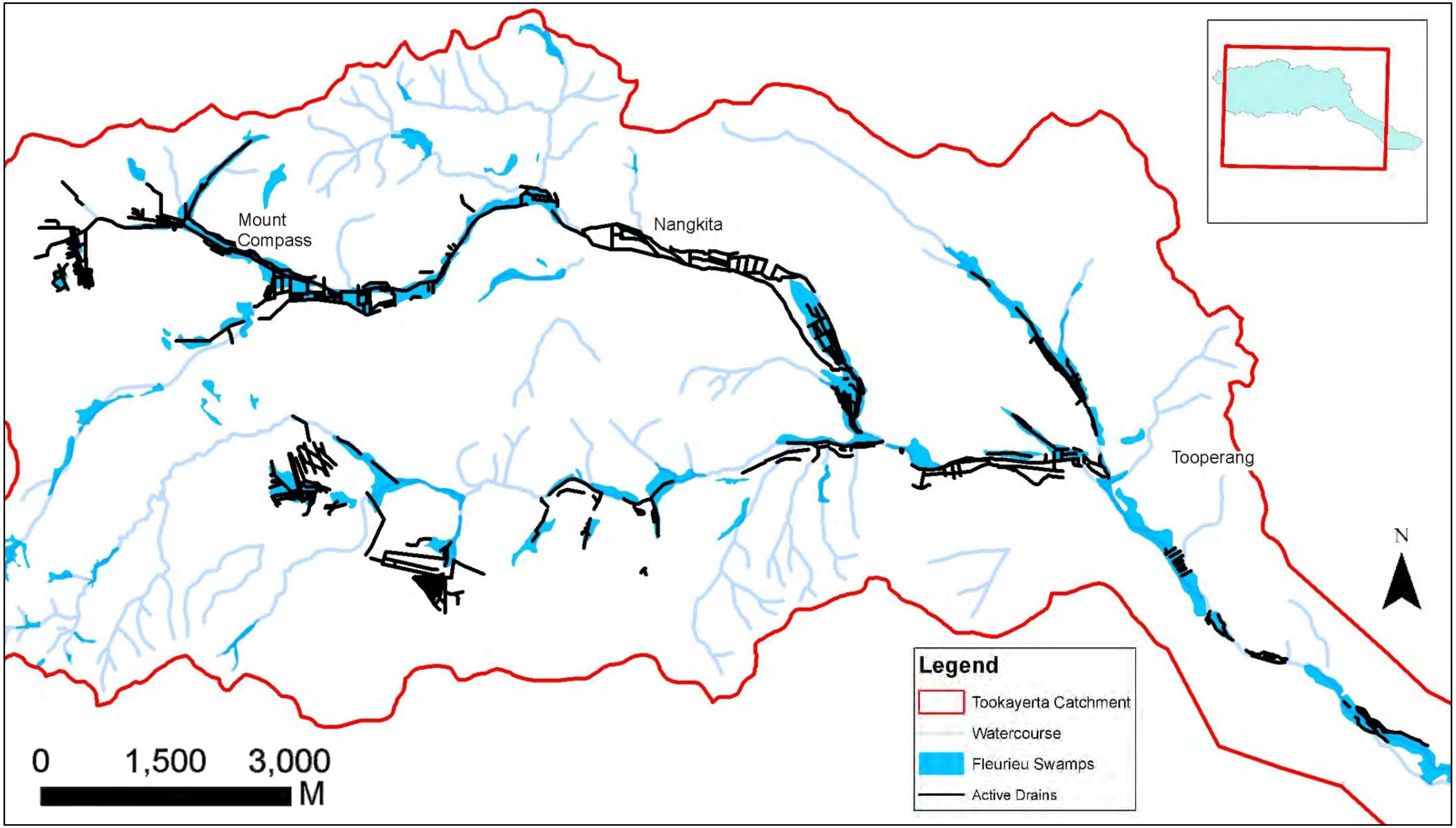

Figure 4.9 Overview of active drains through Fleurieu Swamps of the Tookayerta catchment

4.2.2 Dams and direct stream extraction

Modelled stock and domestic surface water demand in the catchment is 175 ML per year (SAMDB NRMB, 2009). The maintenance of largely permanent flow in the Tookayerta catchment, as a result of groundwater interactions, means that the water-taking infrastructure in the Tookayerta catchment is different to other catchments. Most of the water taken from the surface for consumptive use is directly extracted and used from drains or watercourses as needed throughout the year, rather than being caught in dams during winter to spring to be used over summer and autumn (SAMDB NRMB, 2013). There are several gated weirs, in-stream storages and an aqueduct, all of which are managed informally. This high reliance on direct use means that the maintenance of threshold flows is critical for ensuring users have access to sufficient water at the right times and there are anecdotal reports of upstream users compromising downstream availability during low rainfall and low flow periods.

As a result of the history of direct extractive use from the permanently flowing open drainage channels, dam density is lower than other similar rainfall catchments and the impact of dams throughout the Tookayerta catchment on the water balance is not considered to be as significant as elsewhere. However, dams that are present still act as barriers for the runoff generated from the catchment area upstream of the dam, reducing the total volume of flow (or indeed recharge) available, and also delaying flow events by holding back flows until dams fill and spill. These impacts are proportionally larger when dams are not at capacity such as during the irrigation period of October to March (VanLaarhoven and van der Wielen, 2009) and modelled impacts indicate that mean monthly summer flows are reduced by approximately 17% (Savadamuthu 2004). These impacts should also be considered for their local effects i.e. in relation to aquatic environments in downstream proximity to a dam. Aside from diverting surface flow away, dam footprints can also alter the bathymetry of aquatic systems, creating a depressed bed level and point of accumulation which draws water out of surrounding sediments and/or increases flow away from fringing areas. This is a particularly important consideration in wetlands where saturated sediments are a key determinant of vegetation type.

A timeline of dam construction from 1949 to 2014 has been generated using an analysis of aerial imagery, in conjunction with spatial information generated in a similar investigation undertaken in 2001 (Savadamathu, 2001) (Figure 4.10).

Our analysis reveals that dam numbers have increased (from 537 to 556) between 2001 and 2014. Some large water storage areas in the sand mining footprint at Mount Compass have been dug out and, along with the decommissioning of another large dam in the headwaters of Cleland Gully, the estimated volume of current dam retention in the catchment (using the formula of McMurray (2004)) is 920 ML, down from the estimate of 1104 ML from 2001 (Savadamathu, 2004) but similar to 930 ML from 2005 (cited in SAMDB NRMB, 2009).

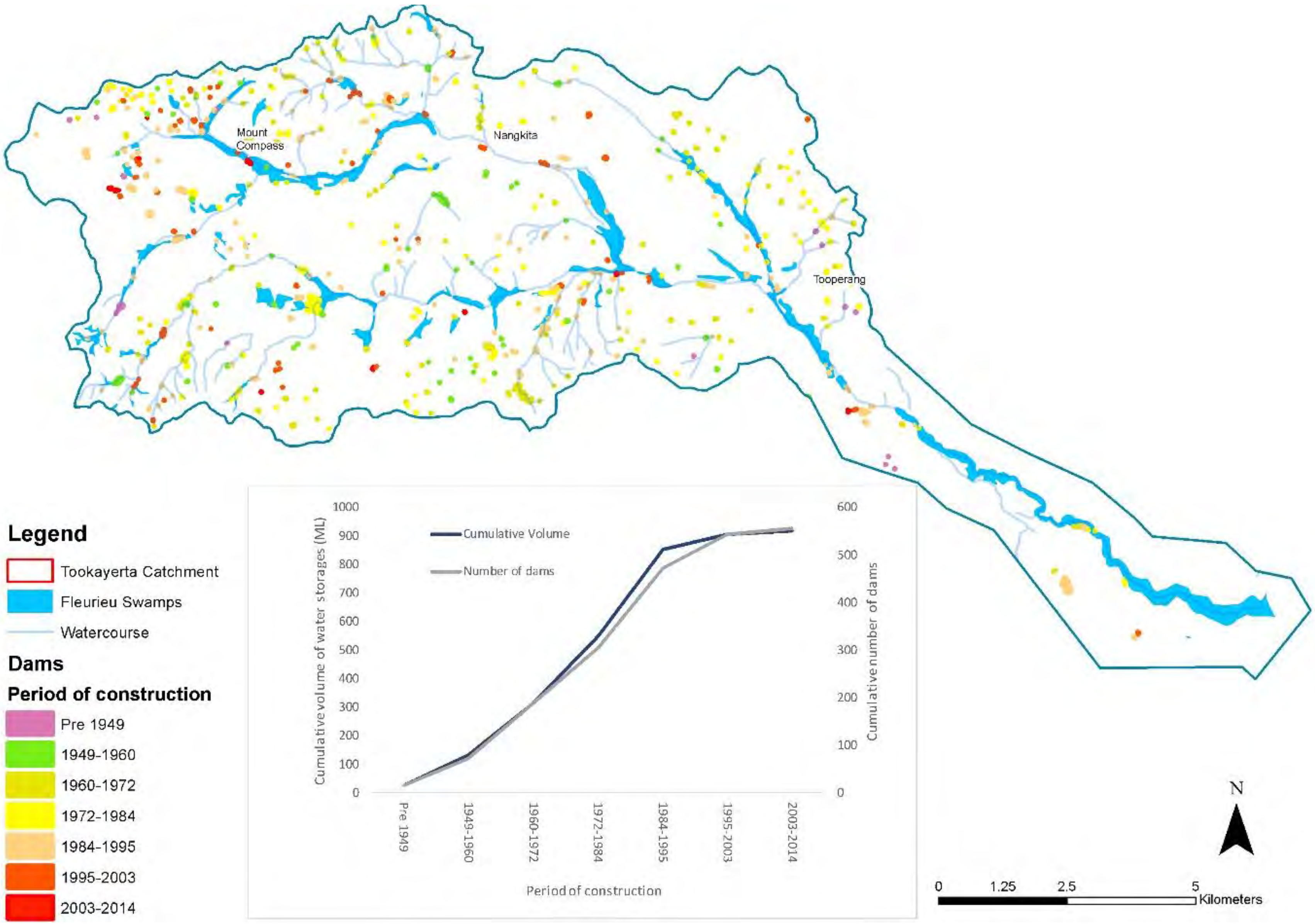

Figure 4.10 Overview of dam construction timeline and surface area footprints in the Tookayerta catchment.

The pattern of dam sizes is similar to previous estimates with 86% of the dams constituting only 26.7% of the total retention volume i.e 73.4% of volume is held in 14% of the catchments dams (Table 4-1). The greatest rate of construction and increase in volumes stored occurred between 1984 and 1995. Approximately 13 dams, holding an additional 14 ML or 1.6% of total catchment dam storage have been constructed since 2003.

Table 4-1 Farm Dams in the Tookayerta Catchment - Size Classification

Dam size	Number	Proportion of dams	Combined Volume (ML)	Proportion of catchment stored volume
<0.5 ML	300	54%	73	8.0%
0.5 - 2 ML	178	32%	172	18.7%
2 - 5 ML	48	9%	149	16.3%
5 - 10 ML	13	2%	91	9.9%
10 - 20 ML	10	2%	141	15.3%
20 - 50 ML	5	1%	145	15.8%
> 50 ML	2	<1%	147	16.0%
Total	**556**		**920**	

4.2.3 Groundwater wells

In combination with the alteration of surface water flows, groundwater use has also increased across the catchment in the past 70 years. The Permian Sands aquifer is widely developed for irrigation and town water supply use in the Mt Compass area (Barnett and Zulfic, 1999) where the aquifer is more permeable. Within the Tookayerta catchment the main component of groundwater use is irrigation.

Installation of meters has occurred incrementally over the last few years, so a complete record of metered use from licensed bores does not yet exist; however, most of the licensed (irrigation) bores that require a meter have one (M. Van Der Wielen, pers. comm.). Modelled stock and domestic groundwater demand in the catchment is 97 ML per year (SAMDB NRMB, 2013), 55 ML of which contributes to Mount Compass water supply (SAMDB NRMB, 2009).

Estimated licensed extractions from all aquifers across the Eastern Mount Lofty Prescribed Water Resources Area (which takes in the Tookayerta catchment) is estimated at 32 100 ML/y and is below the estimated sustainable yield of 38 757 ML/y (DEWNR, 2016). However, it is possible that demand may exceed the sustainable yield at the local scale (e.g. the Permian Sand aquifer within the Tookayerta Permian Management Zone). An analysis of available drill-log data (accessed through WaterConnect) allows us to visualise a timeline of well construction (see Figure 4.11 to Figure 4.14). This reveals that between 1984 and 2004, the number of drill holes for water use across the catchment increased by nearly five times, with a pronounced rate of increase from 1994 to 2003 (Figure 4.15).

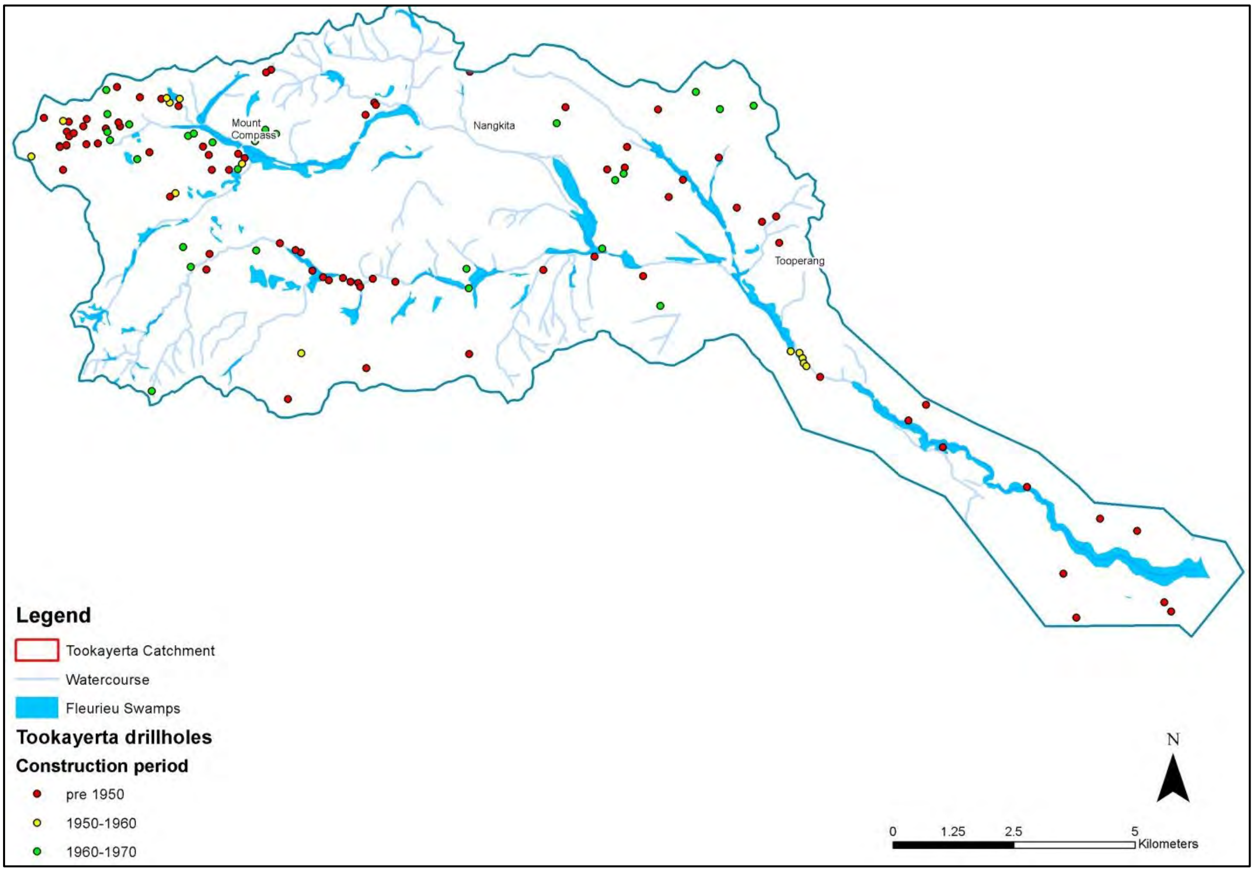

Figure 4.11 Groundwater well establishment across the Tookayerta catchment until 1970

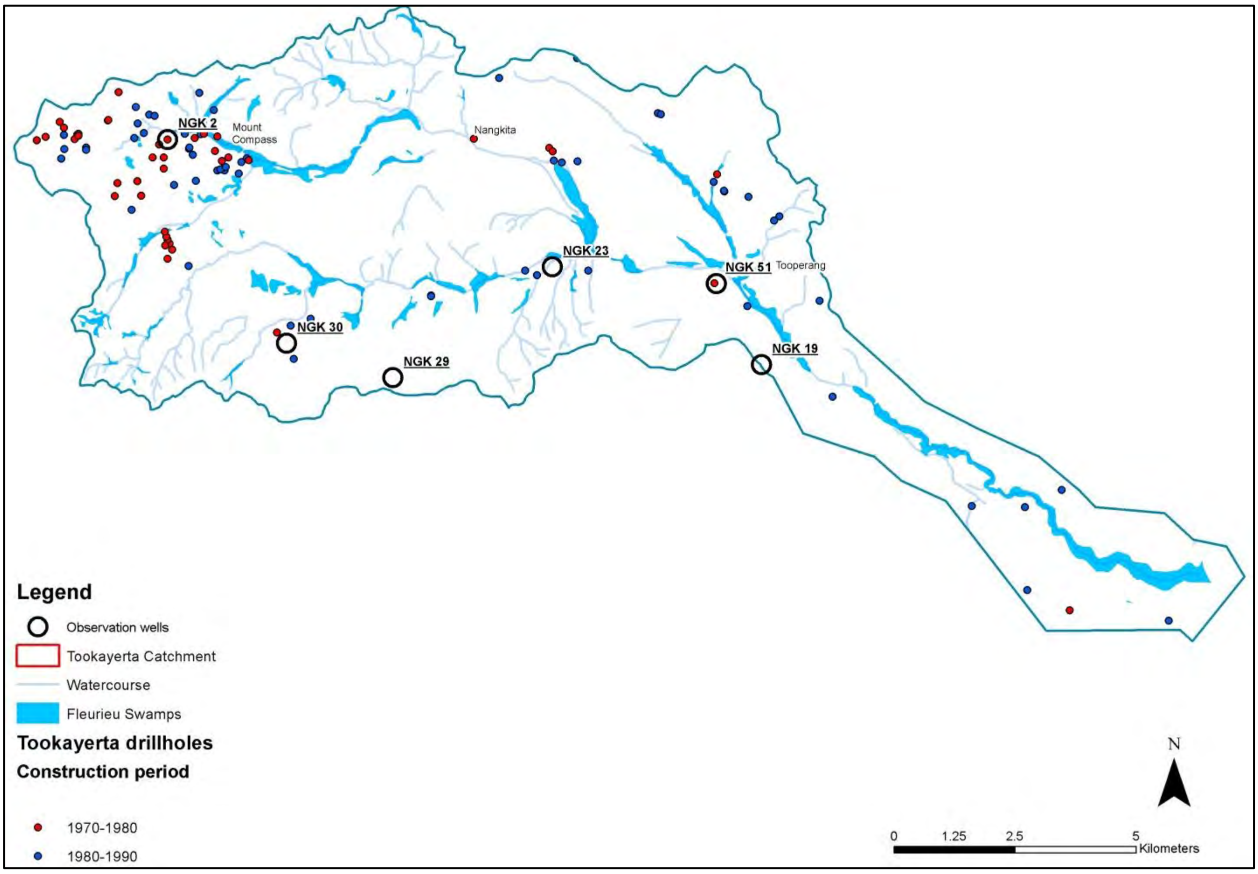

Figure 4.12 Groundwater well establishment across the Tookayerta catchment: 1970-1990

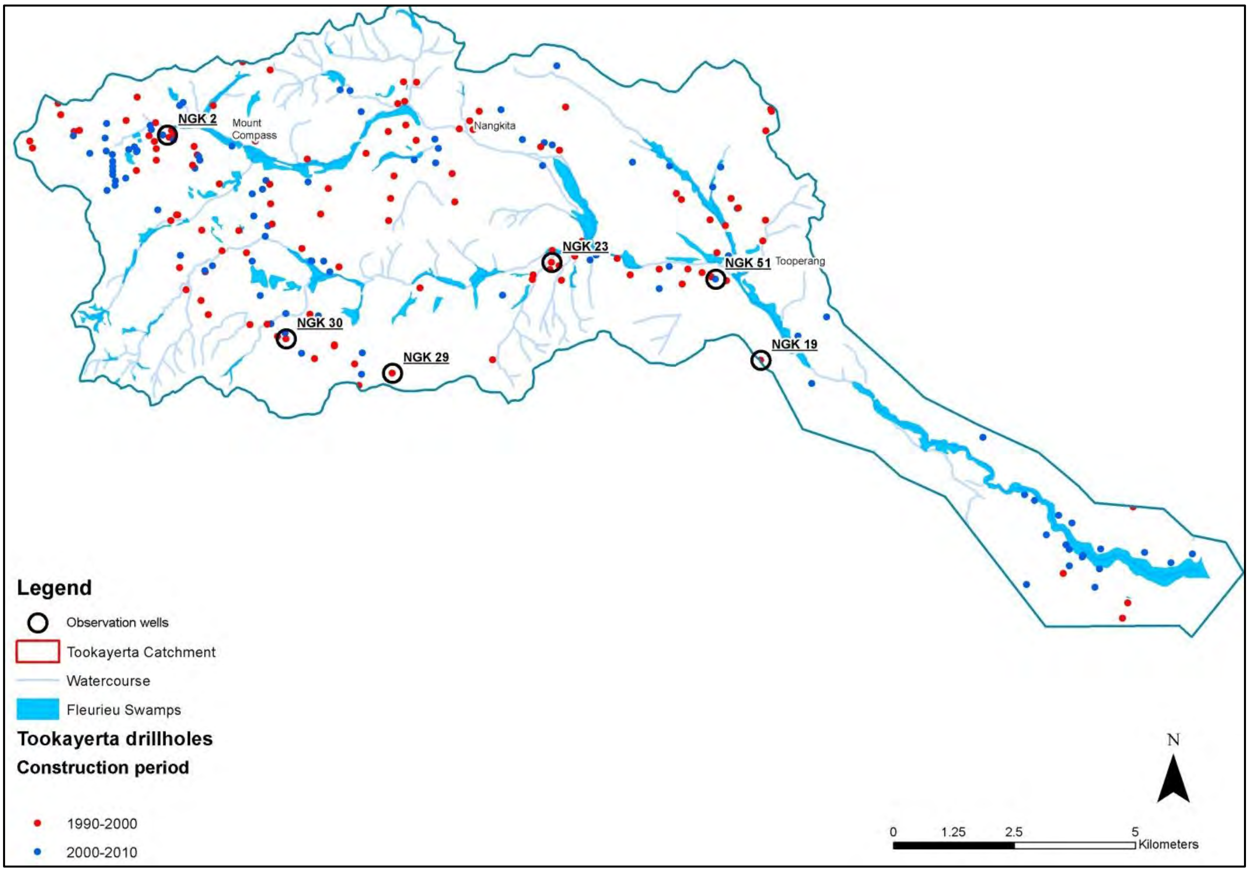

Figure 4.13 Groundwater well establishment across the Tookayerta catchment: 1990-2010

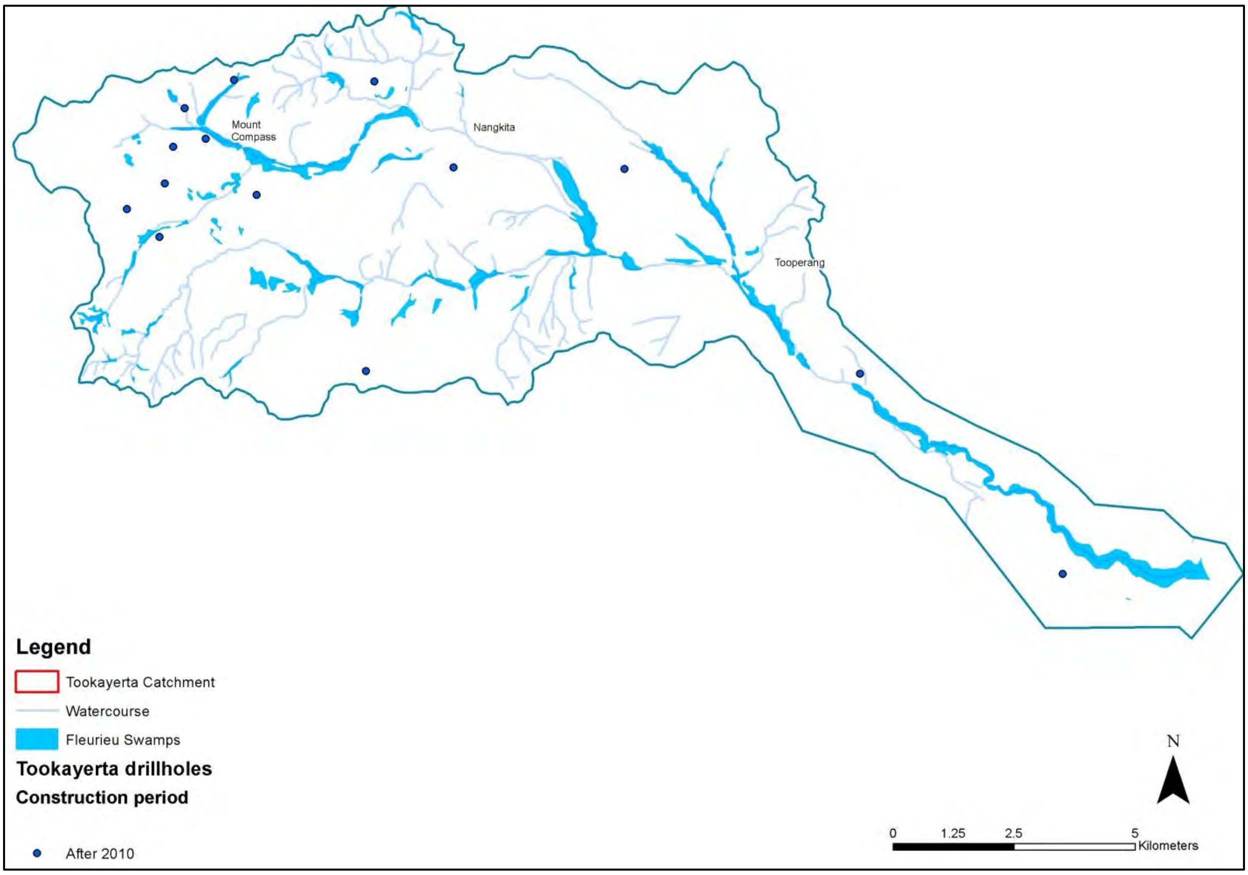

Figure 4.14 Groundwater well establishment across the Tookayerta catchment after 2010

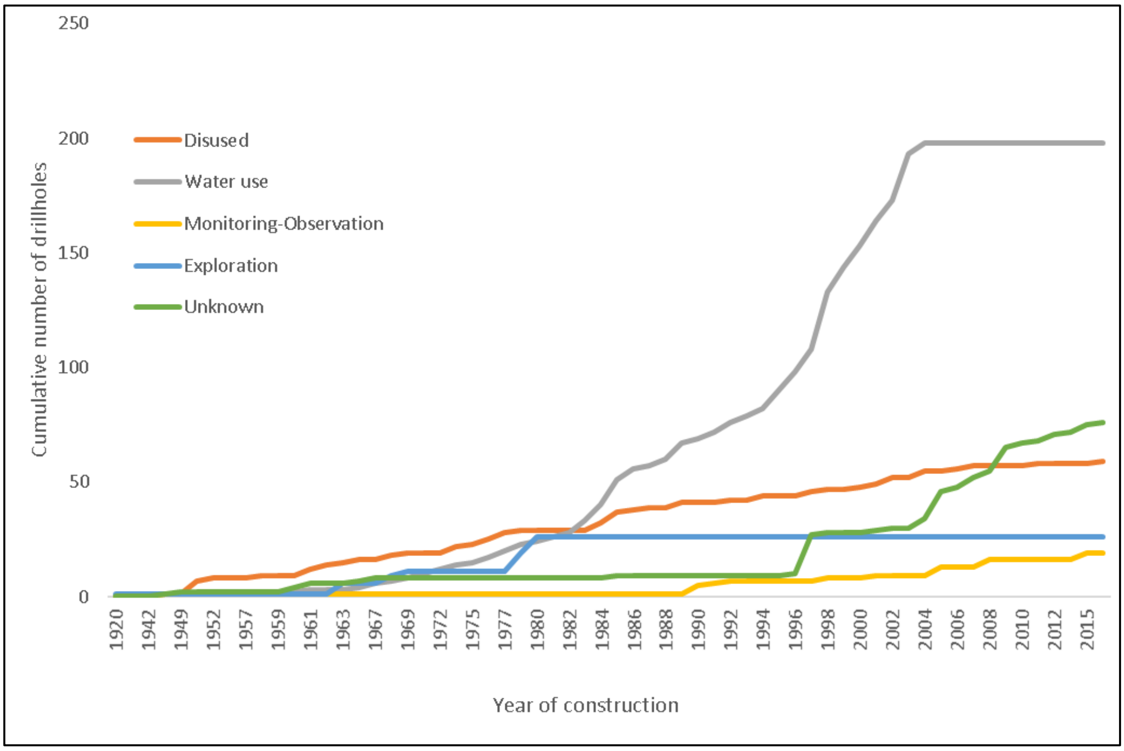

Figure 4.15 Timeline for groundwater well construction and purpose across the Tookayerta catchment

Despite this development, the limited number of monitoring of wells located close to drainage lines and swamps so far suggest no recent reductions in depth to groudwater (and hence possibly also baseflow) (Barnett, 2016), in proximity to these monitoring areas (NGK23 and NGK 51 - Figure 4.16).

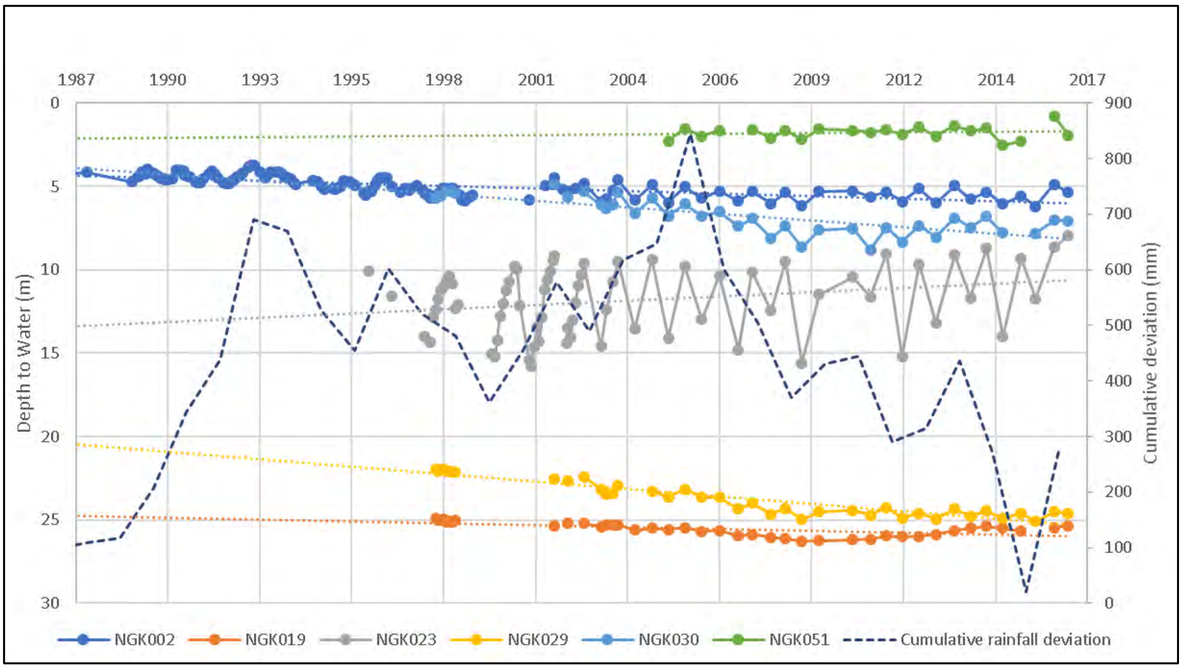

Figure 4.16 Groundwater trends across the Tookayerta catchment (see Figure 4.12 or Figure 4.13 for well locations) Data accessed through WaterConnect, Groundwater data.

A trend of gradual decline in depth to watertable apparent throughout upper catchment areas, from the mid 1990s to mid 2000s appears to have stabilised more recently. Increases in 2016 and early 2017 (Figure 4.16) due to well above average rainfall in winter and spring 2016 are aso evident in the most recent data.

The strong interaction between ground and surface water in the catchment means that any overuse of the groundwater resource is likely to adversely affect both surface water users and the environment (SAMDB NRMB, 2013).

4.3 Changes in catchment land use

The catchment supports a diverse mix of land uses including viticulture, horticulture, livestock grazing and biodiversity conservation, as well as a growing number of lifestyle properties.

Predominant land use is livestock grazing although this has shown a declining trend, instead being replaced by irrigated horticulture, specifically through the expansion of wineries and olives, as well as rural-residential properties.

A summary of land use trends in the Tookayerta Catchment is presented in Table 4-2.

Table 4-2 Landuse trends (% of area) across the Tookayerta catchment

Year	Native Forest	Wetland vegetation	Agriculture and pasture	Irrigated land	Mining	Plantations	Other
1893	69.2	15.5	14.9	0.4	0	0	0
1949	27.8	7.8	62	2.3	0	0	0.1
1979	9.7	3.1	74.7	10.3	0.2	1.8	0.2
1984	9.6	2.8	79.9	4.6	0.4	2.4	0.3
1989	9.4	2.8	76.3	7.4	0.7	3.0	0.4
1992	10.9	3.1	73.8	7.3	0.8	3.6	0.5
2008	13.5	3.7	56.6	15.6	1.4	3.1	6.0
2016	14.6	3.9	54.8	11.6	1.8	1.9	11.4

Data sourced from Generalised Landuse (DPTI, 2016), landuse (DEWNR, 2008) and Compass Creek Care (1997). Estimates of native forest and wetland vegetation from 2008 and 2016 derived from this study.

4.4 Conservation values

4.4.1 Swamp recovery

Spontaneous recovery

Despite the early and repeated attempts to convert the swamps in the Tookayerta Catchment to agricultural use, a small proportion of sites have persisted, and in a small number of cases have even recovered some of their previous ecological values.

The process by which this has occurred is linked to the physical properties of peat itself. Drained peatlands are prone to rapid post-drainage subsidence, meaning the lowest lying areas of peatland are likely to be subject to partial re-hydration, after contacting the new maximum level of the lowered groundwater table within a few short years. This means that, in the absence of aggressive drain maintenance, drained peatlands are often at risk of slow reversion back to swamp (albeit still hydrologically compromised).

Hence, while the area and quality of swamp habitat in the catchment has been dramatically reduced – with flows disturbed, floristics simplified, micro-habitats reduced and peat forming processes interrupted – many sites across the catchment have still managed to retain a suite of biodiversity values that may appear incongruous with a long and intensive history of development. But this is the beauty of how swamp recovery can still occur spontaneously in peat environments.

The earliest transitions from areas under agriculture to regenerating wetlands in the Tookayerta Catchment occurred in areas where attempts to convert the land either failed or were only temporarily successful (as a result of the processes described above). These sites are identifiable by the sheer number of drainage attempts evident in the analysis of historical aerial photography.

A detailed example of this type of management history (including intensive drainage and swamp recovery) at one such wetland in the catchment, Square Waterhole Swamp in Hesperilla Conservation Park, can be reviewed in Bachmann and Farrington (2017).

Assisted recovery

Aside from the process of unintended spontaneous recovery just described, often following site abandonment or land use change, dedicated assisted recovery (on-ground actions aimed at conserving and rehabilitating wetlands) works in the catchment didn't begin until the early 1990s. In 1992, several local landholders formed Compass Creek Care, a group aimed at protecting and rehabilitating the Tookayerta and Nangkita Creek system. The result was a program of raising awareness through education, monitoring and practical demonstrations. In 1997, a report on the catchment was produced (Compass Creek Care, 1997), outlining priorities and strategies for management. Major issues identified throughout the catchment included:

- erosion;
- wetland loss;
- water use efficiency;
- property neglect;
- weed outbreaks;
- nutrient leaching; and,
- other point source pollution such as effluent and pesticides.

In March 2003, the Swamps of the Fleurieu Peninsula were listed as a critically endangered ecological community under the *EPBC Act 1999*, due to the small patch size of remaining swamps and their vulnerability to ongoing threats. The purpose of the listing was to recognise that the long-term survival of this ecological community is under threat, to prevent its further decline, and to assist community efforts toward the recovery of the ecological community.

The Mount Lofty Ranges Southern Emu-wren and Fleurieu Peninsula Swamp Recovery Project (MLRSEWFPSRP) has been working extensively with landholders over the past 20 years to highlight the importance of the swamps for conserving biodiversity on the Fleurieu Peninsula. To assist landholders wanting to actively conserve swamps on their land, the Program has developed guidelines for different management practices currently used by landholders.

Within the wider project, several sub-projects have targeted local landholders throughout the catchment. The Nangkita Swamp Pilot Project focussed on a four kilometre section of continuous wetland, extending down Nangkita Creek from Mount Compass. Six of the 18 properties (37% of the wetland) along this area participated in swamp protection activities. Additional investment throughout the wider catchment, through the Fleurieu Swamps Recovery Project, and delivered by Goolwa Wellington LAP, has achieved 5,797 m of stock exclusion fencing, 84.4 hectares of revegetation, and over 200 hectares of weed control (J. Gitsham, pers. comm.).

In addition, a series of information pamphlets, along with information signage at local, publicly accessible wetlands, have created a greater regional recognition and appreciation for the values of wetlands in the catchment. One of those sites, which was subjected to historic drainage and now occupies only a fraction of its former extent, is the Mt Compass School Swamp (see Figure 3.4). This site is open to the public, has a boardwalk and displays a number of interpretative signs. The site is a highly valued and easily accessed local educational asset that also contains regionally significant plant and animal species.

4.4.2 Significant fauna

Thirteen state threatened species have been recorded in the catchment, four of which are nationally listed under the *EPBC Act 1999* (Appendix 2). Only two of the EPBC listed species

(Southern Brown Bandicoot and Mount Lofty Ranges Southern Emu-wren) are still reliably found within the catchment. Two species that previously occurred in the catchment, the Regent Honeyeater and Eastern Ground Parrot, are both considered extinct in South Australia (Gillam and Urban, 2014). The latter species is a wetland specialist that was observed in 1870 near present-day Mount Compass (Historical Bird Atlas, 2017), situated at the very western edge of its range and now represented by only a handful of historic records in the vicinity of Adelaide and the Fleurieu Peninsula. Despite its apparent early extinction in this area, the species continued to persist in near-coastal wetlands in the South East of the state until at several decades ago.

The record for Southern Bell Frog is thought to represent an unintentionally introduced population which has since died out (Department of the Environment, 2017). The Southern Brown Bandicoot and Chestnut Rumped Heathwren occur in Cox Scrub Conservation Park, to the north of the catchment. The Mount Lofty Ranges Southern Emu-wren is found throughout the catchment, despite only occurring in small and isolated populations. An overview of other threatened species, and their listing at state and federal level is provided in Table 4-3.

Table 4-3 Threatened fauna species found in and around Fleurieu Peninsula Swamps

Species	EPBC	NPWSA
Mount Lofty Ranges Southern Emu-wren (*Stipiturus malachurus intermedius*)	EN	E
King Quail (*Excalfactoria chinensis)*		E
Yellow-bellied Water-skink (*Eulamprus heatwolei*)		V
Lewin Water Rail (*Lewinia pectoralis*)		V
Flame Robin (*Petroica phoenicea*)		V
Freckled duck (*Stictonetta naevosa*)		V

Mount Lofty Ranges Southern Emu-wrens inhabit various Fleurieu Swamp vegetation assemblages including heathlands, reedlands and sedgelands. This includes the dense vegetation surrounding swamps and watercourses, with dispersal between isolated patches assumed to be exceedingly rare (Nicol and Possingham, 2010). Hence their location in the Tookayerta catchment, while representing key populations for the species, is somewhat fragmented (Figure 4.17) and vulnerable to localised impacts such as fire and anthropogenic-driven changes such as habitat deterioration (R. Duffield, pers. comm.).

Given this limited dispersal ability, they are heavily dependent on isolated remnant patches. They typically reside in dense, low vegetation such as *Leptospermum* spp., where there is a dominant sedge understorey, rather than shrub or coral fern dominated habitat (Tim Fearon, pers. comm.). Optimal management (including desirable interventions) of currently occupied patches is of primary importance for the conservation management of the species (Nicol and Possingham, 2010). Further, eco-hydrological restoration activities that increase the quality and connectivity of currently isolated habitat fragments have the capacity to support local persistence, and potentially assist in the longer-term recovery of the species.

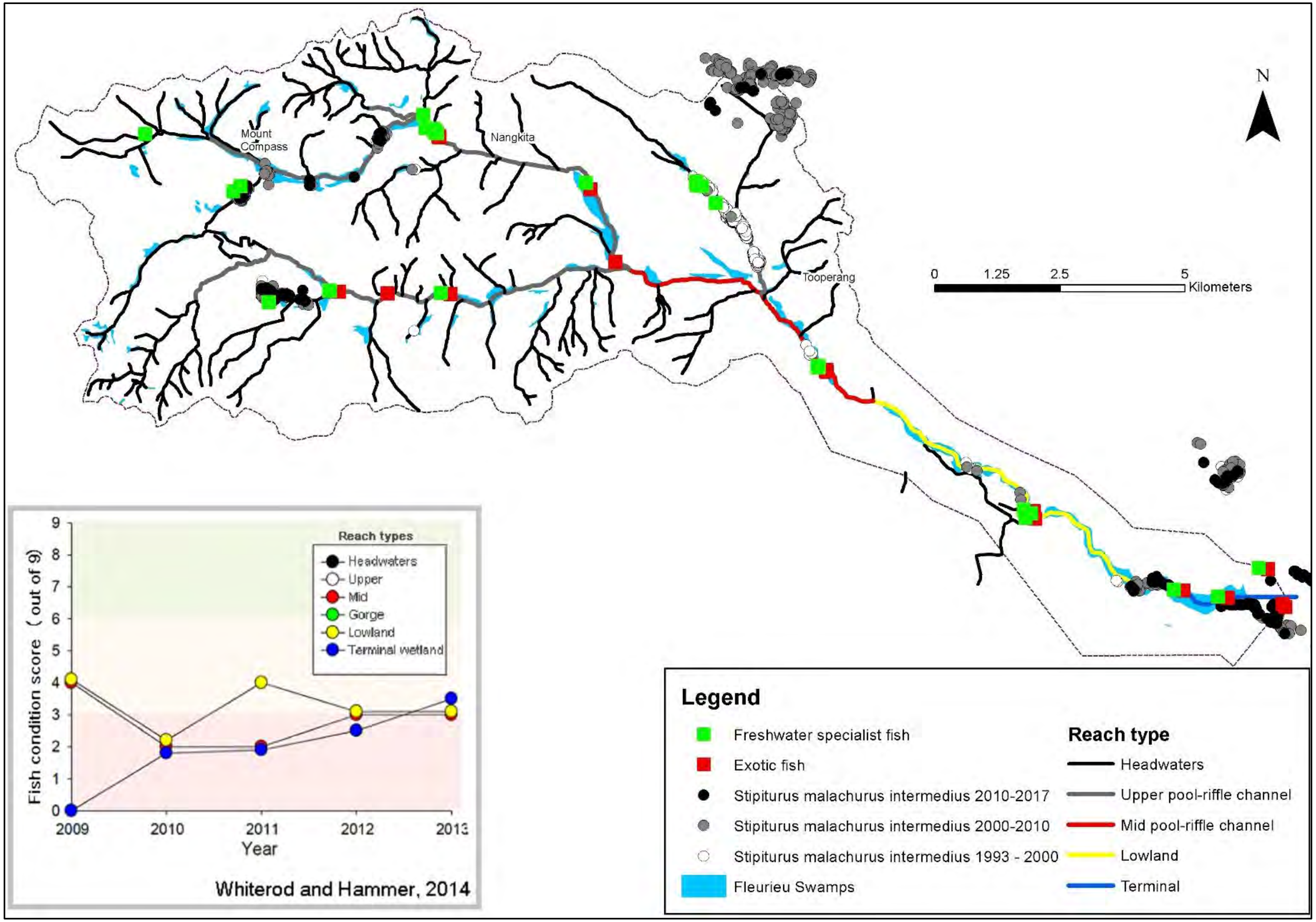

Figure 4.17 Significant fauna associated with aquatic ecosystems and swamp vegetation in the Tookayerta catchment. S. malachurus intermedius records are based on MLRSEWFPSRP data. Fish records from Aquasave – NGT fish inventory database (up to 2017).

4.4.3 Aquatic fauna

The Tookayerta and Nangkita creeks, along with Swampy Creek, are considered among the most reliable flowing streams (in terms of year-round flows) in the Mount Lofty Ranges. They provide a significant habitat for several sensitive and rare species of macroinvertebrates, and a range of flow-dependent species, many of which are particularly sensitive to disturbance and have highly restricted distributions in the region and State. (EPA, 2010).

A survey of the macroinvertebrates of the catchment in December 2003 indicated good stream health, with sites generally showing macroinvertebrate diversity greater than or equal to AUSRIVAS reference models (Hicks and McEvoy 2005). The Tookayerta and Nangkita Creeks support the only populations of the stonefly *Leptoperla tasmanica* in South Australia, along with a number of other rare species. The authors concluded that “the unique permanent flowing cool water and sandy substrates provide an exceptional habitat for South Australian stream biota”.

The South Australian EPA undertakes regular field assessment of streams throughout the state and prepares aquatic ecosystem condition reports (AECRs). Condition is assessed using the AUSRIVAS approach, which includes aquatic macroinvertebrate survey and measurement of water quality, vegetation and stream substrate (EPA 2016). The most recent assessments within the Tookayerta catchment took place in 2010, with site condition rated from fair to very good (EPA 2017).

Baseline fish surveys recorded the presence of at least four threatened freshwater specialist fish species (Mountain Galaxias, River Blackfish and Southern Pygmy Perch, Yarra Pygmy Perch) in the catchment (Hammer 2004). More specifically, fish-related assets identified by Hammer (2004) include:

- a patchy but secure population of River Blackfish in unique swampy habitat;
- two genetically distinct populations of Southern Pygmy Perch (a Tookayerta sub-population in the upper catchment and a Lake Alexandrina sub-population in the terminal wetland (Hammer 2001);
- Mountain Galaxias populations which (along with the Finniss Catchment) represent a different species to other EMLR catchments (which are *Galaxias oliros*); and,
- diverse native fish communities in the terminal wetland (at Tookayerta and Finniss junction), which include populations of Yarra Pygmy Perch.

A long-term fish monitoring program (since 2007) has allowed for regular assessment of the condition of identified fish-related assets across the catchment using presence, recruitment and survivorship indicators (for single species) as well as indicators relating to fish diversity.

This condition assessment shows an overall improvement in poorly performing reaches since the atypically dry 2009, although ecological assets performing well in 2009 have declined slightly (Whiterod and Hammer, 2014). More recent assessments have highlighted declines across some upper pool-riffle sites as well as the lowland reach and improvement in the terminal wetlands with the mid pool-riffle reaches remaining in consistent (Whiterod 2015; 2016, 2017).

Based on the scoring criteria used (as of 2017), the overall condition of the catchment was classified poor although mid pool-riffle and terminal wetland reaches were considered in moderate condition. In terms of fish-related assets, these conditions reflect that in mid pool-riffle reaches, populations of Mountain Galaxias, River Blackfish and Southern Pygmy Perch continue to persist strongly and the terminal wetland continues to recover (due to presence of Southern Pygmy Perch, although Yarra Pygmy Perch remain absent).

4.4.4 Significant flora

Two hundred and twenty-six threatened plant species have been recorded in the catchment, of which 66 are nationally listed (BDBSA, 2017; see Appendix 3). An investigation of species records within 100 metres of mapped wetland polygons revealed that four nationally endangered species have been recorded in and around wetlands (see Table 4-4).

Table 4-4 Threatened flora species found in and around Fleurieu Peninsula Swamps of the Tookayerta Catchment

Species	EPBC	NPWSA
Fleurieu Peninsula Guinea-flower (*Hibbertia tenuis*)	CR	E
Maroon Leek Orchid (*Prasophyllum murfetii*)	CR	E
Mount Compass Oak-bush (*Allocasuarina robusta*)	EN	E
Mount Compass Swamp Gum (*Eucalyptus paludicola*)	EN	E
Osborn's Eyebright (*Euphrasia collina* ssp. *osbornii*)	EN	E
Branching Rush (*Juncus prismatocarpus*)		E

The overstorey species for swamp habitats commonly includes *Leptospermum continentale* (Prickly Tea-tree), *Leptospermum lanigerum* (Silky Tea-tree), *Melaleuca squamea* (Swamp Honey-myrtle), *Melaleuca decussata* (Totem-poles), *Acacia retinodes* var. *retinodes* (Swamp Wattle) and *Viminaria juncea* (Native Broom) (Harding, 2005). *Viminaria juncea* and *Acacia retinodes* var. *retinodes* can also be present as an emergent species rather than dominant overstorey.

Dominant understorey species are typically sedge and rush genera such as *Baumea* spp., *Juncus* spp., *Eleocharis* spp., *Lepidosperma* spp., *Empodisma* spp., *Carex* spp. and *Gahnia* spp. Ferns commonly found in the medium stratum of many swamps include *Blechnum minus* (Soft Water-fern) and *Gleichenia microphylla* (Coral Fern), while *Pteridium esculentum* (Bracken Fern) is predominantly found around swamp margins (or sometimes within swamps where peat has been dehydrated through drainage). In a survey of Fleurieu Peninsula Swamps, *Baumea rubiginosa* was the most commonly encountered species (Littley, 1998).

It is also worth recognising that a swamp can be comprised of one vegetation assemblage or several assemblages, and that the plant species listed can occur as mono-stands (e.g. *Baumea* sedgelands or *Gleichenia* fernland) or as diverse complexes (R. Duffield, pers. comm.).

4.5 Biological threats and disturbances

4.5.1 Stock grazing and trampling

Harding (2005) identified that over 80% of Fleurieu Peninsula swamps surveyed were threatened to some extent by inappropriate grazing regimes and that intensive grazing by dairy cattle, including associated pugging and nutrient enrichment caused the most amount of disturbance to wetlands, followed by beef cattle grazing.

Aside from physical damage, grazing by cattle, sheep and horses also results in a removal of palatable plants and introduction of weed seeds and manure, into the riparian zone (Casanova, 2016). Swamp Recovery programs throughout the catchment have focussed on restricting stock access, to allow optimal grazing densities and timing in line with achieving a desirable disturbance regime.

Conversely, the removal of all forms of disturbance can result in homogenous swamp vegetation communities and/or proliferation of undesirable plant species, particularly around the edges of swamps. Determining appropriate disturbance (the what, how, when) is complex and the tipping point for either (too much or not enough) could dramatically change the swamp and impede recovery; hence this area of swamp recovery is currently the subject of further deliberation (R. Duffield, pers. comm.).

4.5.2 Weeds of significance

Weed infestations were regarded by Harding (2005) as the most commonly recorded threatening process within wetlands on the Fleurieu Peninsula, and also the most severe threat to wetland biodiversity. During wetland surveys, Harding (2005) recorded 153 introduced species, with thirteen of these currently deemed as high or severe threat across the Fleurieu. Of these, 11 species are considered to be having a more significant impact in the Tookayerta Catchment (Table 4-5), noting that of these, Blackberry is one of the most serious, invasive and widespread woody weeds found in the area.

Table 4-5 Weeds considered as high threat to wetland biodiversity

High threat weed
Yorkshire Fog (*Holcus lanatus*)
Blackberry (*Rubus* sp.)
Jointed Rush (*Juncus articulatus*)
Greater Bird's-foot Trefoil (*Lotus uliginosus*)
Cocksfoot (*Dactylis glomerata*)
Gorse (*Ulex europaeus*)
Clover (*Trifolium* sp.)
Watercress (*Rorippa nasturtium-aquaticum*)
Phalaris (*Phalaris aquatica*)
Water Couch (*Paspalum distichum*)
Montpellier Broom (*Genista monspessulana*)

Additionally, Drain flat-sedge (*Cyperus eragrostis*) is an emerging problem in the catchment, particularly in the middle reaches, and Sweet Vernal Grass (*Anthoxanthum odoratum*) is also noted as being more problematic in this area (R. Duffield, pers. comm.).

4.6 Cumulative impact of changes on wetlands

An inventory and mapping exercise of *Swamps of the Fleurieu Peninsula* revealed an estimated 42% loss of wetland area on the Fleurieu Peninsula since European settlement primarily in response to the development of the region for agricultural purposes, where swamp habitat was cleared, burnt, and drained (Harding, 2005).

The preceding sections outline the timeline of additional stress on water resources within the region, which have and are combining to decrease the water availability to many wetlands. As many of the threatening processes identified for Fleurieu Peninsula Swamps and wetlands relate directly to alteration of their hydrology (Duffield and Milne 2000, Harding 2005), it is to be expected that their overall resilience has been compromised.

Concurrent with our investigation of vegetation clearance, dam and well construction and wetland drainage, we have also undertaken an assessment of vegetation footprints within mapped polygons for Fleurieu Peninsula wetlands within the Tookayerta catchment (see Figure 4.18 for example). However, as a word of caution, it is worth noting that apparent vegetation footprints can sometimes be inaccurate, with annual or seasonal changes driven by factors such as rainfall, season and drainage maintenance having impacts on the aerial 'signature' of what may appear as swamp from the distance.

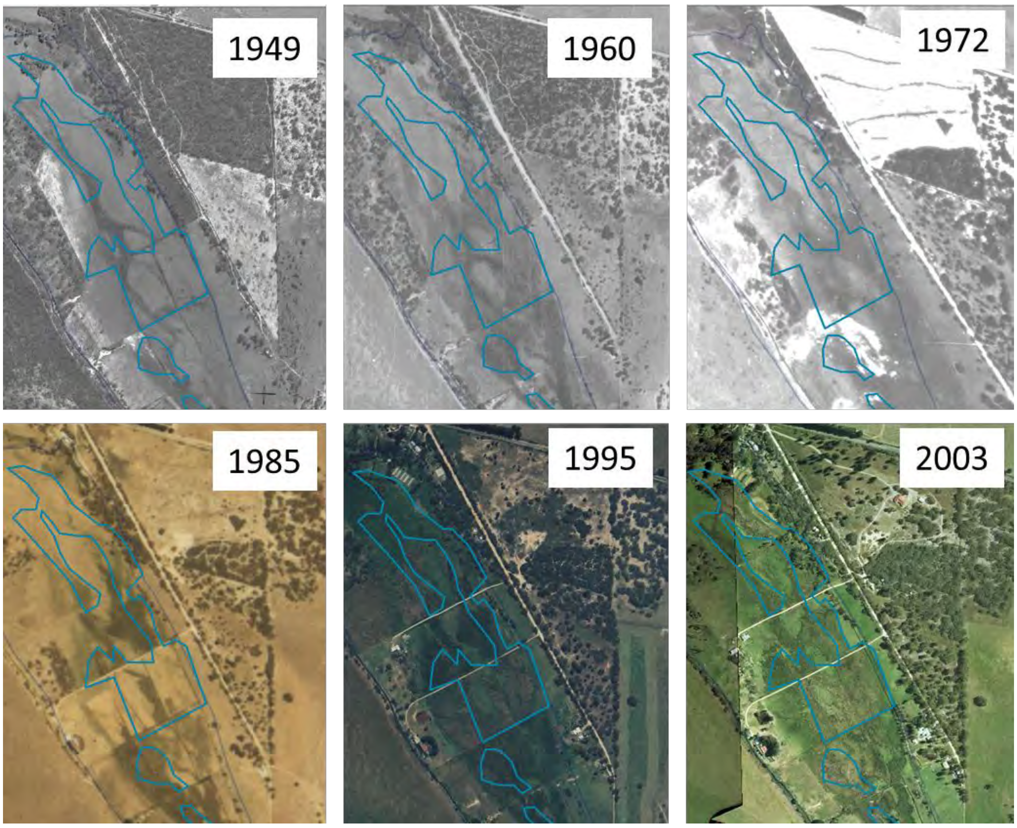

Figure 4.18 Example of wetland vegetation recovery, in this case from 1995 onwards with 2014 area shown in blue outline

The analysis revealed that of the 788 hectares of mapped wetlands within the catchment, 59 % (468 hectares) of the area contains native vegetation, assumed consistent with a functioning wetland ecosystem (trees, shrubs, sedges, ferns, rushes and reeds). Of these, 43% (200 hectares – including the 182 hectares Black Swamp) have remained relatively intact in terms of exhibiting an identifiable vegetation signature across all time periods analysed. The other 57% of wetland area has shown recovery following clearance, which mostly occurred prior to 1949 (Figure 4.19).

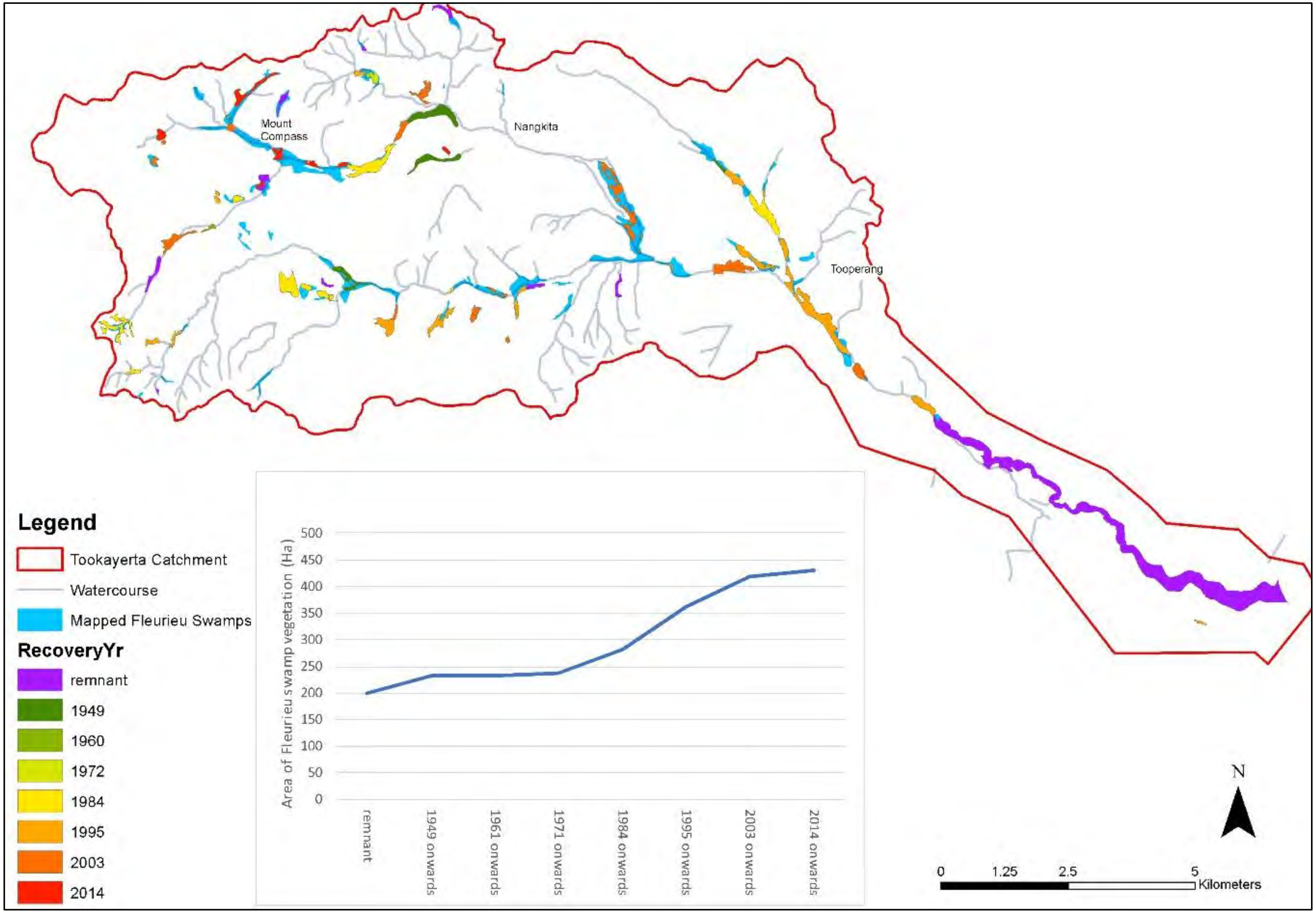

Figure 4.19 Areas of Fleurieu Peninsula Swamps with wetland vegetation communities

5 Considerations in determining a restoration approach

A healthy wetland generally has a range of plant species growing at different heights (Figure 5.1). The nature of regeneration across wetland footprints within the catchment varies, with many consisting of reduced structural diversity and in some cases, single species monocultures e.g. extensive *Phragmites australis* reed-lands, thick blankets of coral-fern and tea tree thickets.

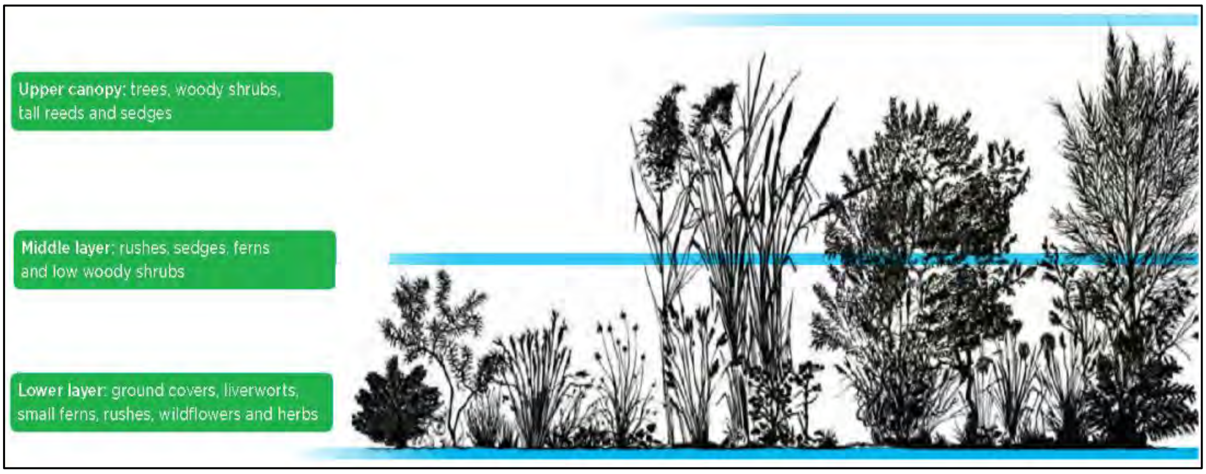

Figure 5.1 An example of multi-layered vegetation consistent with swamp health (adapted from Duffield and Hill (2002))

Ecological disturbance experiments (burning) by the MLRSEWFPSRP team have indicated that plant species richness increases in response to disturbance, with a subsequent decline in floristic richness from six years post-treatment (Rebecca Duffield, pers. comm. 2017). Additional observations suggest that light grazing by domestic stock may also promote the persistence of some species e.g. *Sprengelia incarnata*. An overwhelming trend which has been picked up during the life of the Swamp Recovery Project is an expansion of fringing vegetation communities (e.g. tea-tree, exotic grasses and *Lepidosperma* sedges) into the more central areas of wetlands, and replacing more aquatic sedge species (e.g. *Baumea, Restio* and *Schoenus* species) along with wet substrate dependent ferns (e.g. *Blechnum minus*) (pers. comm. Rebecca Duffield – Ecological Research, Conservation Council of SA). This is thought to be a response to overall site drying, correlating with declining rainfall (Figure 2.3) and is likely to have been exacerbated by reduced hydraulic resilience within sites where water supply is compromised or losses are enhanced by drainage.

In understanding the recovery of wetland vegetation, and the role that natural processes play in determining habitat quality, the role of autogenic (biotic) processes should also be taken into account. A recent study by Morris *et al.* (2015) investigated the role of autogenic processes in determining hydrological behaviour within wetlands, and, more specifically, the way in which climate signatures may not be reflected in some wetlands, by virtue of overriding internal processes, such as vegetation switches. These switches result in a positive feedback loop whereby the vegetation modifies its environment to produce more favourable conditions for itself (Wilson and Agnew, 1992) and may underpin the single species monocultures encountered across the Fleurieu Peninsula Swamps. Bundy and Benscoter (2016) found that shrubs encroaching on graminoid-dominated wetlands had lower water use efficiency and promoted greater loss of water through transpiration, thereby acting to dry out the substrate and provide greater opportunity for self-regeneration.

Phragmites australis appears to alter vegetation communities and create areas for expansion by high evapotranspiration (site drying) and litter accumulation (suppression of other species) (Roberts, 2016; Packer *et al*. 2017). In these circumstances, desirable disturbance is regarded as a process which eliminates the competitive advantage of the monopolising species, providing a circuit breaker to a positive feedback loop. Physical control of *P. australis* (e.g. slashing, fire) may to be the most appropriate and effective method in the Tookayerta catchment, where chemical approaches may have undesirable non-target effects and the scope of potential hydrological manipulation may be insufficient to disadvantage the species, given its broad tolerance (Packer *et al*. 2017. Any efforts to control *P. australis* should be informed by up to date information on the biology and ecology of the species (see Packer *et al*. 2017).

Fire is particularly effective at reducing *Gleichenia* extent but its long-term role for helping to maintain plant species richness remains equivocal against a backdrop of observations which indicate a drying trend across sites. A significant issue in the catchment, for which management interventions are not clear, is the presence of *P. australis* monocultures across areas of mapped wetlands. These are particularly pronounced in the upper and middle reaches of Nangkita Creek and also through Black Swamp, in the lower Tookayerta Creek (over the page Figure 5.2).

This is regarded as a significant issue in the middle reaches of Nangkita Creek where landholders are experiencing inundation of points of access to their properties and attribute this to the expansion of *P. australis* and its tendency to impede stream flow.

Based on the discussion above, positive recovery and priorities for maximising future potential are a function of both historical and contemporary stressors combined with the prevention of localised autogenic (biotic) processes such as vegetation switches. The overall condition and resulting values of the wetland are a function of allogenic (abiotic) drivers and the level to which these drivers have been modified by so-called “agents of change” (see Figure 5.3).

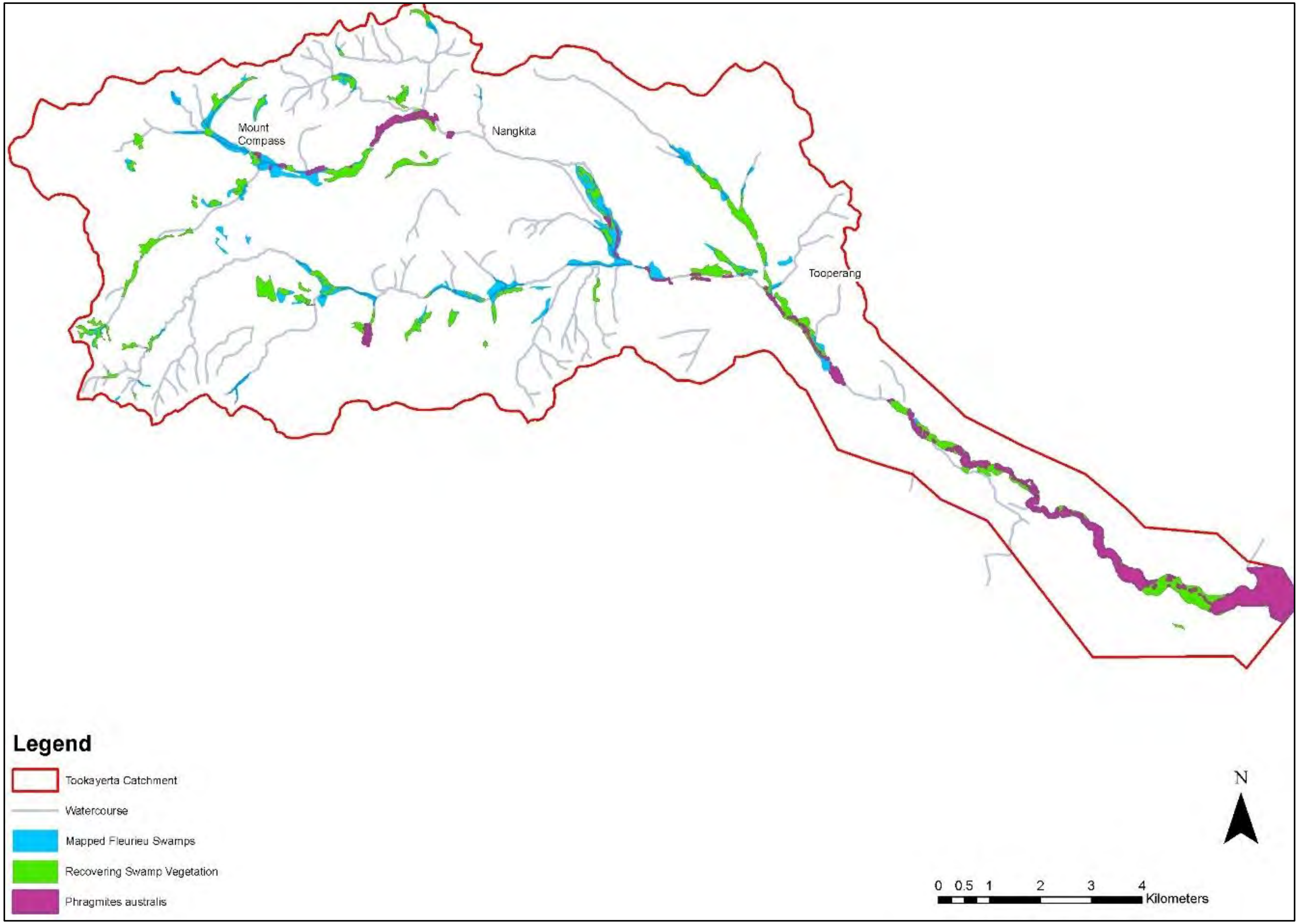

Figure 5.2 Present Phragmites australis distribution throughout the watercourses of the Tookayerta catchment. Map prepared by Tessa Roberts.

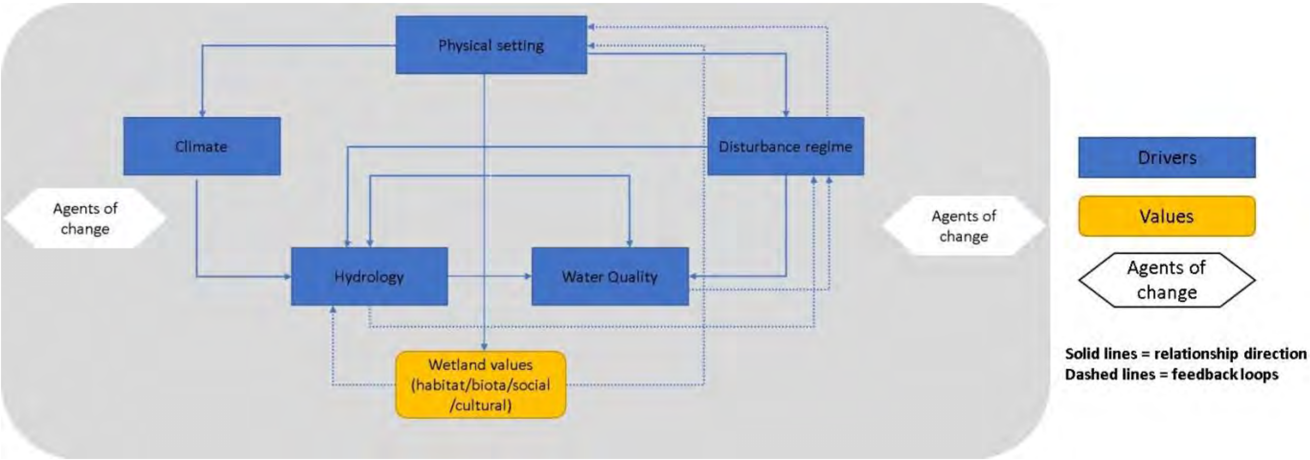

Figure 5.3 Natural wetland system major drivers conceptual model framework (adapted from Harding, 2014)

A logic framework for restoring wetlands (Figure 5.4) should entail a determination of the site's values and management objectives, coupled with identification of symptoms of stress, which in turn justify the need for management interventions. Agents of change can be used to identify threatening processes which will in turn help identify the nature of management interventions required. This then allows an assessment of the feasibility of modifying agents of change so the impacts are minimised and recovery and response can be sustained into the future. A critical aspect of this approach is also identifying which agents cannot be managed and determining if these are likely to compromise the effectiveness of other interventions.

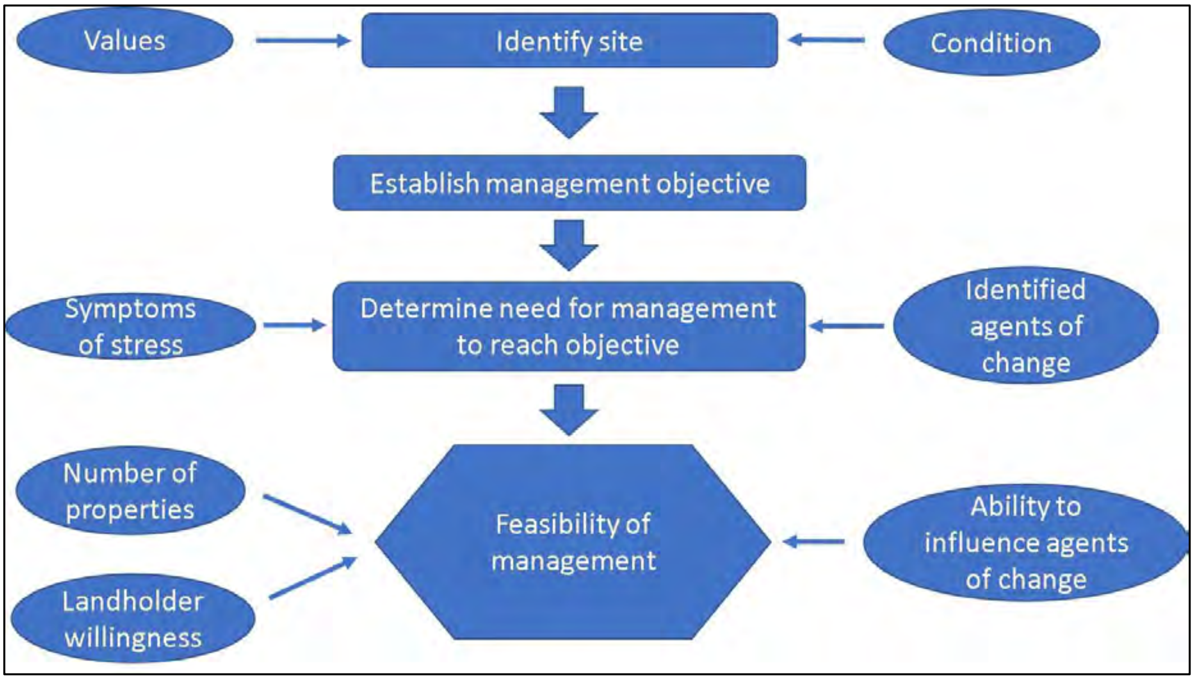

Figure 5.4 Logic framework for identifying wetland restoration priorities

An example of how this process unfolds is illustrated in Figure 5.5, where agents of change (blue) and symptoms of stress (green) are identified. Some of the stressors will not be compatible with short term management interventions (e.g. changing land-use, decommissioning up-stream dams), however issues such as through-site drainage may be amenable to modification and/or trial based approaches in the short-term, as has recently being undertaken at Stipiturus Conservation Park. The preceding sections of this report provide the tools required to undertake preliminary site assessments, paving the way for more detailed assessments at sites that are compatible (based on landholder attitude) to on-site works aimed at minimising hydrological losses and thus increasing overall site resilience.

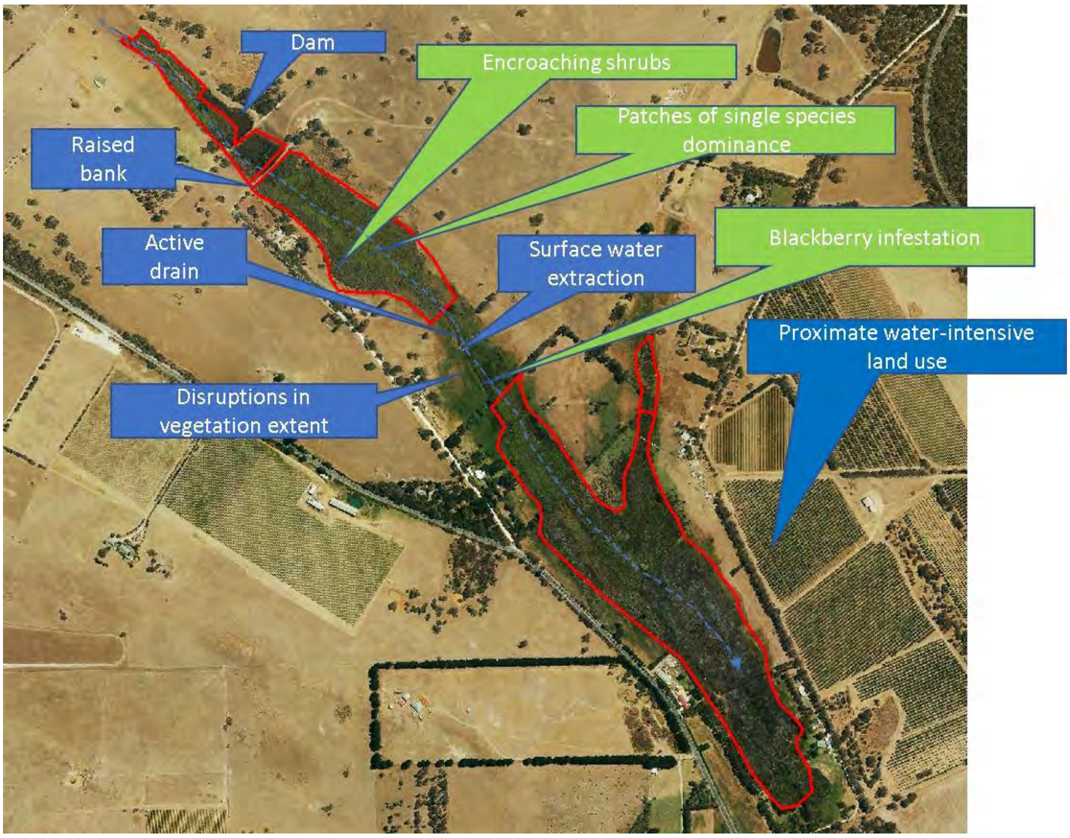

Figure 5.5 A conceptual overview of hydrological and landuse stressors combined with emerging vegetation switches for recovery sites at Swampy Crescent.

In terms of the wetlands of the Tookayerta catchment, one of the most challenging aspects is the number of small property parcels along the watercourses (as a result of the development pattern previously described) and this presents as one of the most constraining factors in terms of feasibility of management and options for intervention. Hence a critical foundation for further restoration work in the catchment stems from a very active background of conservation management. An overview of areas of wetland with some level of involvement in Swamp Recovery Projects is provided in Figure 5.6.

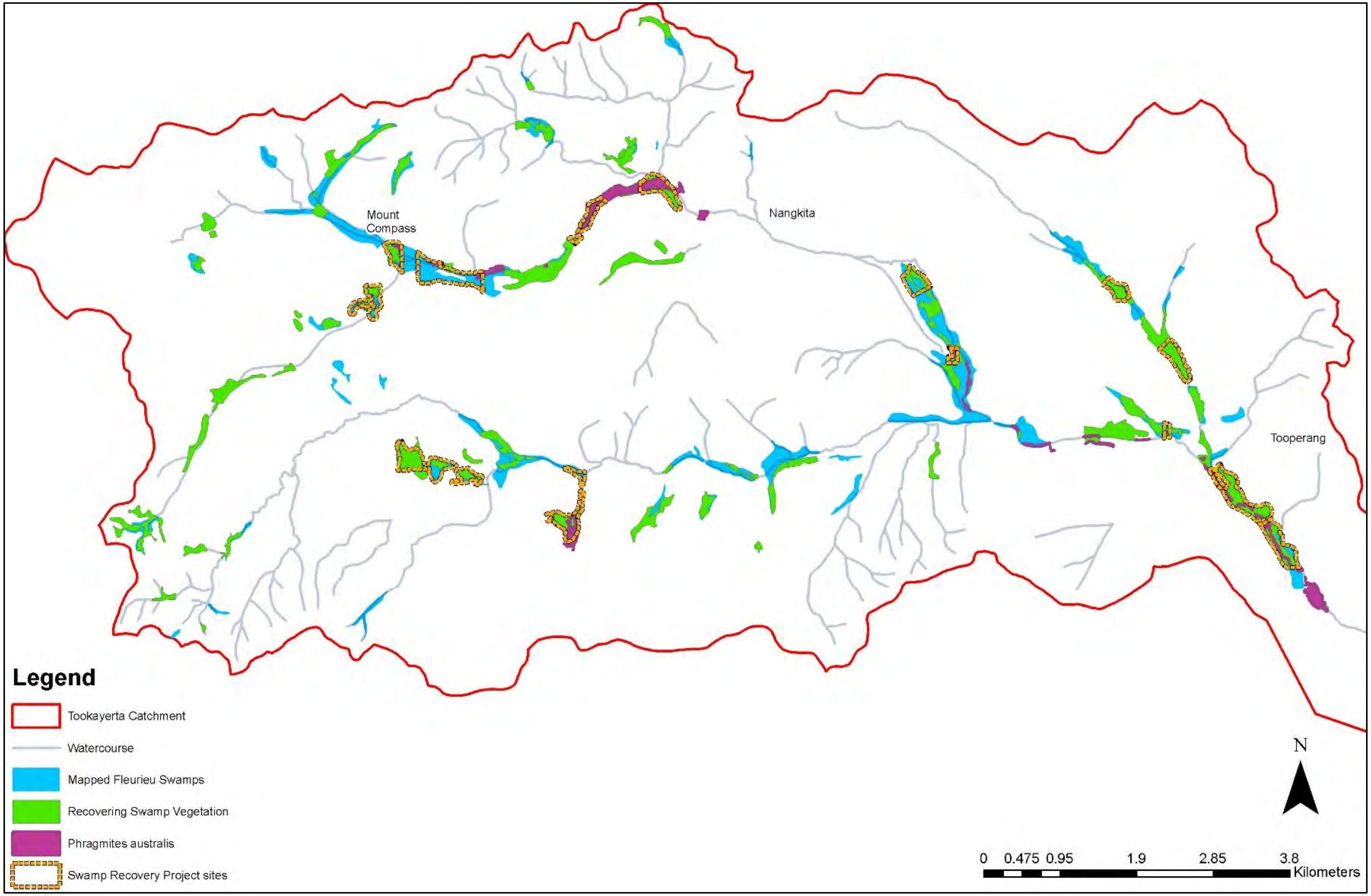

Figure 5.6 Overview of Swamp Recovery Project sites and priority clusters in the Tookayerta catchment.

6 Landscape assessment and prioritisation

6.1 Introduction to the landscape assessment analysis

In order to identify priorities for future investigations into restoration, we have undertaken an assessment of wetland features in the catchment in terms of site resilience (hydrological impacts and feasibility of restoration) along with current values (areas under conservation management and extant of wetland vegetation). This has been undertaken using datasets described in previous sections. The aim of this analysis is to identify sites that have traits amenable to future restoration activities (currently managed for conservation and/or indicators of functional habitat) and which also exhibit traits consistent with, or amenable for restoration toward, future resilience. Our definition of resilience in this context comes from Anderson *et al.* (2014) who defined site resilience as:

> *"the capacity of a site to maintain diversity, productivity and ecological function as the climate changes."*

6.2 Parameters and metrics used in the landscape assessment

Each wetland polygon was scored against seven criteria representing physical stressors, the number of landholders required to work cooperatively, current management and existing values. More specifically, the seven criteria used; including their datasets, calculations and scales for ranking, are provided in Table 6-1.

Table 6-1 Restoration priority scoring criteria, formulae and ranking

	Criteria	Formula	Ranking
Resilience against threats	Dams	Volume within wetland / Wetland Area	Lowest score (5) to Highest score (1)
		(Volume within 200 m buffer - volume within wetland) / Buffer area	Lowest score (5) to Highest score (1)
	Drains	Length of active drains in wetland / Wetland Area	Lowest score (5) to Highest score (1)
	Tenure	Number of different landholdings covering wetland area	Lowest score (5) to Highest score (1)
	Landuse	Area of land under irrigation or plantation within 200 m buffer / Buffer area	Lowest score (5) to Highest score (1)
Values	Conservation	Area of wetland land under conservation management / Wetland Area	Highest score (5) to lowest score (1)
	Vegetation	Area of wetland vegetation (see Section 4.6)	Highest score (10) to lowest score (1)

Rank classes assigned according to natural breaks. Scores and ranks for criteria across all sites provided in Appendix 4.

Data for each component was ranked according to natural breaks along each reach of the catchment. This resulted in a rank of 1 to 5 for all criteria except wetland vegetation, which was ranked from 1 to 10. Scores and ranks for each criterion are detailed in Appendix 4.

The prioritisation metrics were made up of two sub-scores:

Sub-score 1 provided a score of **resilience** against **threats** and was the accumulated total of ranks across each criterion, to a maximum of 25:

$$\textit{Dams within} + \textit{Dams in buffer} + \textit{Drains} + \textit{Number of Landholders} + \textit{Area of irrigation in buffer}$$

Sub-score 2 was for **values** and is calculated as follows, in order to provide additional (but equal overall) weighting to existing environmental values in comparison to resilience scores which capture (threats):

$$((2 \times \textit{Area under conservation}) + \textit{Area of wetland vegetation}) * 1.25$$

The **total score** for each site (out of 50) was the sum of both sub-scores:

$$\textit{Total Score} = (\textit{Threats} + \textit{Site Values})$$

This framework allows for the future adjustment of individual criteria scores as additional information (e.g. ground-truthed assessments of functional wetland vegetation), and also allows for the consideration of effects of management actions (e.g. reducing drainage impacts or applying conservation management agreement) in terms of overall catchment priorities.

We made a general assumption that **drainage**, **dams** and adjacent **water-intensive landuse** have an equal impact on hydrological resilience (cognisant that individual impacts at any specific site will vary depending on the way a remnant swamp interacts with its local hydrogeological context). The area of 200m buffer was chosen to accommodate for influences on groundwater drawdown. While slightly above the recommendation cited in some literature (170m), there are other benefits such as nutrient and pollution filtering which are optimised over buffers of 200m or greater (Newton, 2012).

An increasing **number of landholders** along a discrete wetland reach adds complexity to future management and reduces the likelihood of co-ordinated conservation outcomes, due to increased difficulty in reaching a consensus. Hence fewer landholders increases the probability of achieving 'whole of wetland' outcomes, for less effort or financial investment.

Detailed information on catchment wide **vegetation condition** is not currently available. Our consideration therefore relied on the assumption that any **area under a conservation program** or agreement was subject to activities aimed at reducing threatening processes such as unrestricted **stock access** and **weed infestations**. This is inferred to imply that areas of the sites had better prospects of maintaining biodiversity values into the future.

Wetland vegetation extent is considered physical evidence of maintained values and a positive indicator of reduced threats. There are some areas of monoculture and where these have been reliably mapped (e.g. *P. australis*), these areas have been removed from the overall wetland vegetation estimates. These estimates of vegetation extent are based on 2014 aerial imagery and require further ground-truthing and/or incorporation of existing data to verify the functionality of these vegetation communities.

Wetland size is an important consideration in understanding site resilience as the core habitat is less susceptible to peripheral influences. In our assessments, the use of proportional areas (for dams, drains and landuse) means that large wetlands need to have a greater number of dams, drain lengths and/or adjacent water-intensive landuse to be compromised, when compared to smaller wetlands. However, individual patch retention appears more closely associated with plant species extinction risk in Fleurieu Peninsula Swamps than reductions in patch size (Deane *et al.* 2017).

The recognition and higher weighting of habitat patches (wetland vegetation) thus allows for consideration of the inherent potential for biodiversity retention within a site as opposed to the assumption that values will be restored once threatening impacts can be mitigated and overall resilience improved.

6.3 Results of the landscape assessment

An overview of scores for wetlands of the Tookayerta catchment is shown in Figure 6.1 (also see Appendix 4). For the purposes of defining priority areas, a cut-off score of 30 and above has been applied. This highlights 16 (or 27%) of the catchment's wetlands (Table 6-2).

Table 6-2 Highest ranking wetlands in terms of eco-hydrological restoration priority

Wetland	RESILIENCE	VALUE	TOTAL
S0200663	20	23.8	43.8
S0200664💧	22	20.0	42.0
S0200710💧	22	18.8	40.8
S0200680💧	18	21.3	39.3
S0200709💧	19	20.0	39.0
S0200676💧	19	20.0	39.0
S0200622	19	18.8	37.8
S0200679💧	18	18.8	35.8
S0200678💧	19	17.5	35.5
S0200615	21	12.5	33.5
S0200669	17	16.3	33.3
S0200627	24	7.5	31.5
S0200704💧	10	21.3	31.3
S0200707	21	10.0	31.0
S0200677	20	12.5	30.5
S0200665	23	7.5	30.5

💧 *indicates sites that are potentially amenable to hydrological restoration works*

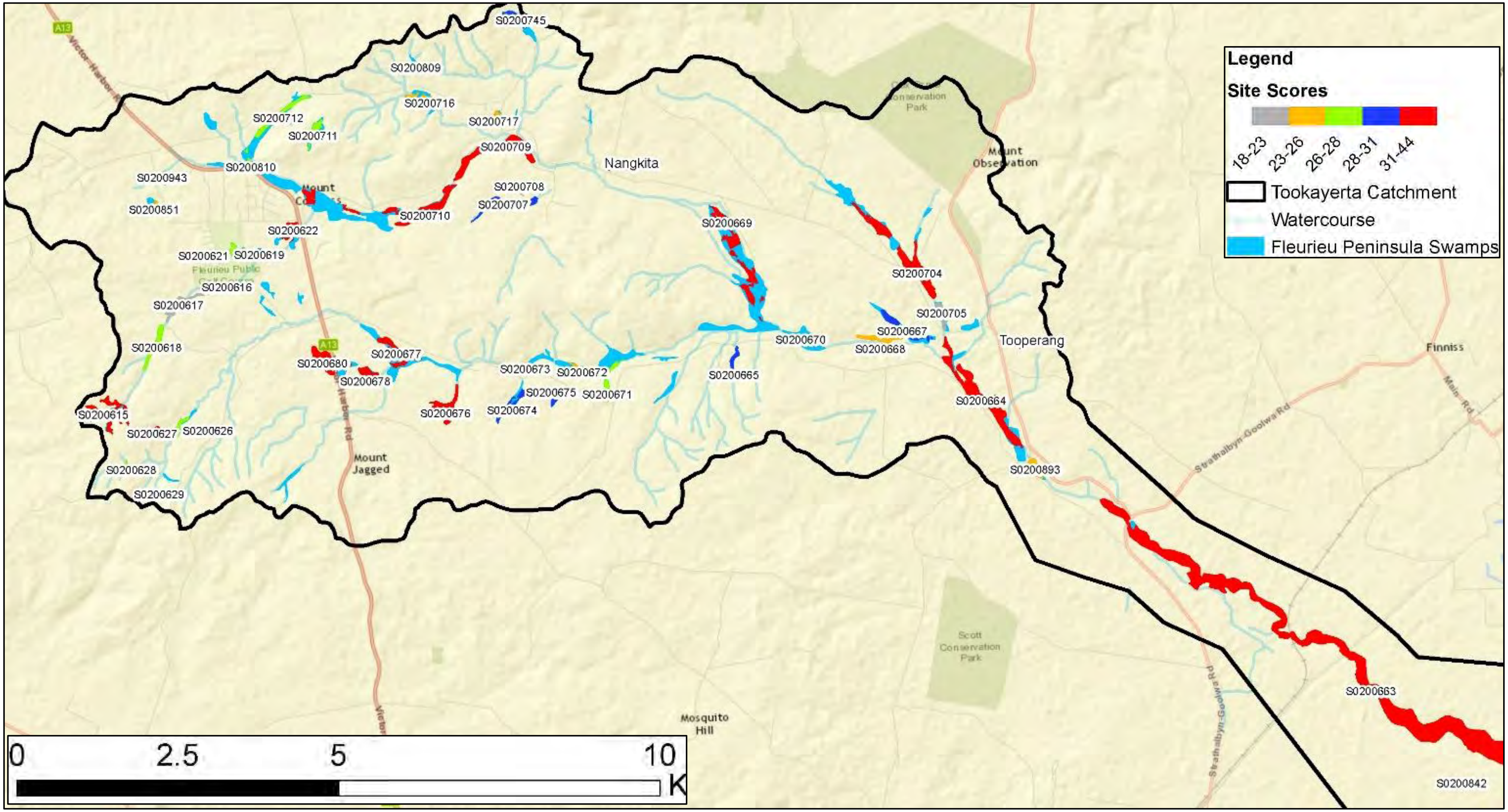

Figure 6.1 Total wetland scores from the landscape assessment

The highest-ranking wetland in the catchment is **Black Swamp (S0200663)**. At this point it has not yet been determined if this site has any need for hydrological restoration works within (or adjacent to) the wetland feature itself. As a receiving system for the entire catchment, it would likely benefit from any upstream works to attenuate high flow events, reducing overall nutrient loads and the sustained release of baseflow through drier seasons.

An additional eight wetland areas immediately present as potential locations for detailed eco-hydrological investigations; i.e. scores > 30 with potential to increase resilience through hydrological restoration works (Figure 6.2). The highest-ranking of these sites **(S0200664)**, which is located below the point of confluence of Swampy Creek and the lower Tookayerta Creek, requires further investigation to more precisely determine the impacts of local drainage. The section of watercourse through this site is meandering but may have been artificially deepened (or eroded) in the past. One landholder reports that historical drains on the floodplain have become inactive due to vegetation recovery since exclusion of stock and that this has increased the area of wetland further up the slope, away from the main watercourse.

Just upstream of this site is the **Swampy Creek tributary (S0200704)** which contains some of the best remaining examples of Fleurieu Peninsula swamp habitat in the catchment. While this system scored particularly low for resilience, its importance to the MLRSEW and FPS Recovery Programs, the relatively higher level of habitat connectivity across the site (and high site value score), makes it a good candidate for further hydrological assessment work, combined with renewed and targeted engagement with landholders to lift the profile of water management to improve wetland conservation outcomes.

The fourth highest ranking site which could benefit from hydrological restoration works is in **Hesperilla Conservation Park (S0200680)**. This site has recently been assessed for hydrological restoration options (Bachmann and Farrington, 2017).

Two wetlands in the Nangkita Creek area between Mt Compass and Nangkita **(S200709 and S200710)** currently have ongoing areas of conservation management and scored highly in terms of both resilience and conservation values, however there are multiple landholders who have previously been reluctant to take up swamp recovery projects; which may present a barrier to hydrological restoration. Further engagement and negotiation is seen as a critical component to wider restoration programs in this area, but reduces the priority assigned to this area for more detailed investigations in the immediate future.

Several other systems have presented as high-value but don’t appear to be under the influence of obvious hydrological threats, based on the desk-top analyses. These sites should be further investigated to identify existing sites values (e.g. threated flora) and any potential restoration or protection activities. Other sites, such as the **Mount Compass School Swamp (S0200622)** are already well studied but, like Black Swamp, should be assessed for potential hydrological modifiers both in terms of quality and quantity of inflows and outflow modification.

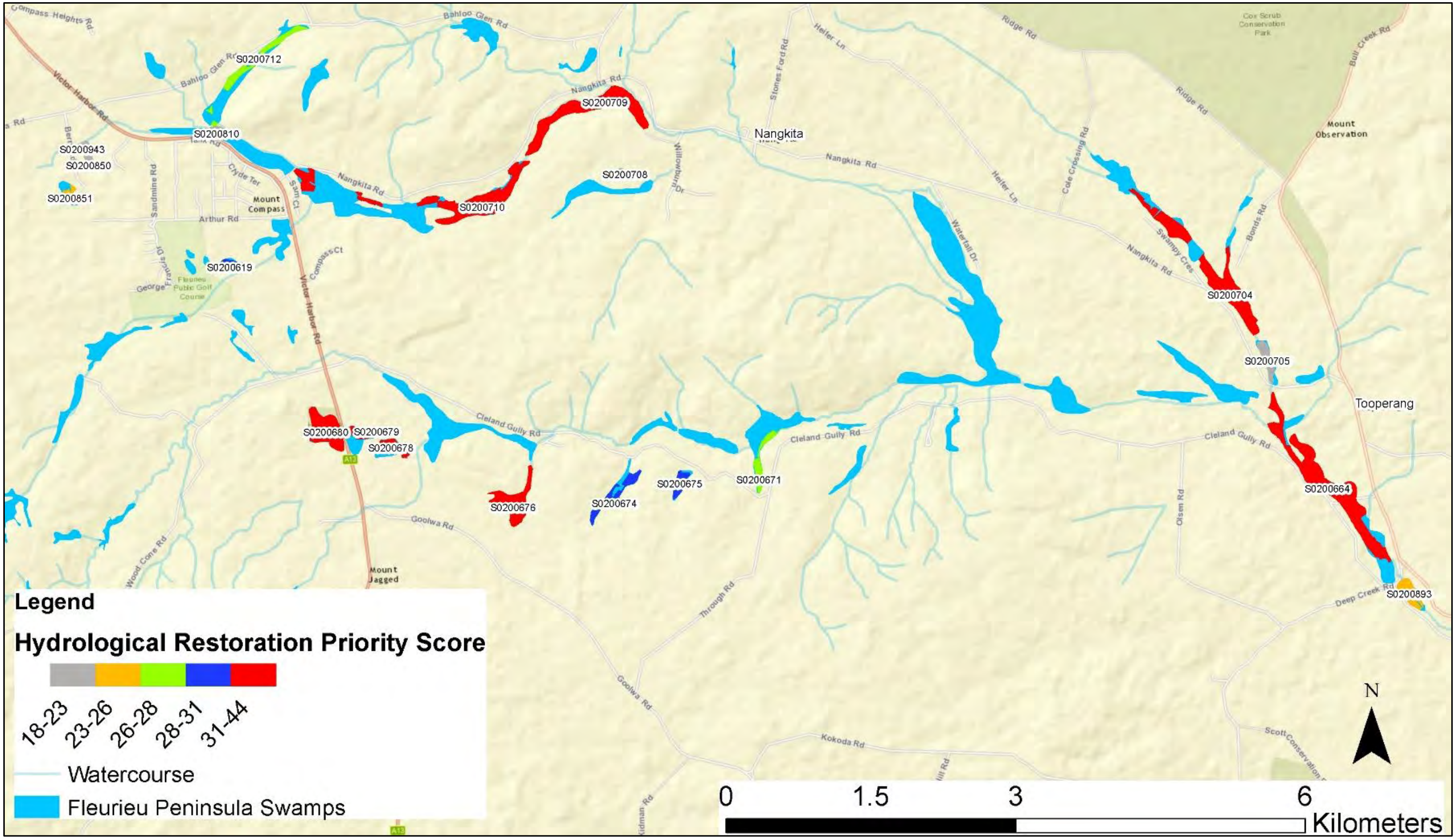

Figure 6.2 Filtered results of sites amenable to more detailed eco-hydrological restoration investigations, in priority order (by colour)

6.4 Initial priorities

Based on the assessment of individual sites against both resilience and values indices, combined with background sites assessments and communication undertaken during this project, a set of recommend actions for high priority sites is presented in Table 6-3. These involve three levels of investigation as follows:

1. Detailed eco-hydrological investigations:
    - Hesperilla Conservation Park (S0200680) – already complete
    - Swampy Crescent (S0200704, 00200705) and Tooperang (S0200664).
2. Reconnaissance field surveys to ground-truth drainage and/or vegetation at high value sites without obvious hydrological modifiers:
    - Black Swamp (S0200663)
    - Headwater systems (S0200615 and S0200627),
    - Mt Compass School Swamp (S0200622) to assess drainage and water quality
3. Additional discussion with landholders that are managing wetlands for stock exclusion and weed control but may have reservations about hydrological works, and where the technical aspects, scope and feasibility of hydrological restoration is not yet clear:
    - Tookayerta headwaters (S0200676),
    - Square Waterhole Swamp complex (S0200678 and S0200679),
    - Mount Compass to Nangkita (S0207009 and S020710).

Table 6-3 Recommended actions for priority wetlands in the Tookayerta catchment

Wetland	RESILIENCE	VALUE	TOTAL	Site reconnaissance	Landholder negotiation	Eco-hydrological assessment
S0200663	20	23.8	43.8	●		
S0200664💧	22	20.0	42.0	●	●	●
S0200710💧	22	18.8	40.8		●	
S0200680💧	18	21.3	39.3		●	● (red)
S0200709💧	19	20.0	39.0		●	
S0200676💧	19	20.0	39.0		●	
S0200622	19	18.8	37.8	●		
S0200679💧	18	18.8	35.8		●	
S0200678💧	19	17.5	35.5		●	
S0200615	21	12.5	33.5	●		
S0200669	17	16.3	33.3		●	
S0200627	24	7.5	31.5	●		
S0200704💧	10	21.3	31.3		●	●

● (red) *Eco-hydrological assessment already completed. See: Bachmann and Farrington, 2017.*

7 Summary

This assessment report establishes the platform necessary for future, detailed, site-specific investigations to guide eco-hydrological restoration projects in the Tookayerta Catchment. It complements the restoration planning process concurrently undertaken within this catchment at Hesperilla Conservation Park (refer to Bachmann and Farrington, 2017).

Key findings from the review of the historic and background information presented in this report are:

- The catchment was largely undeveloped until the 1890s.
- After the 1890s, the peatlands of the valleys were heavily targeted for drainage and clearance.
- The pattern of that early development and subdivision of the peatlands is still evident in both the cadastral pattern today and in the extensive network of over 100 km of artificial drains across the catchment.
- While most of the catchment was subjected to *ad hoc* drainage works, completed within the boundaries of each property, a notable exception was the Nangkita settlement where a more comprehensive (larger, multi-parcel, intensive) and sophisticated drainage network was established.
- The wider catchment (uplands and swamps) experienced a second-wave of development with heightened intensity from the 1920s, with the advent of new pasture establishment technology and mechanised clearance. This wave of clearance and drainage was largely complete by the 1970s.
- Additional changes impacting on catchment hydrology include:
    - construction of dams throughout the catchment – with a dramatic period of increase between 1950 and 1995 that has since plateaued.
    - sinking of groundwater wells, which dramatically increased in number since the mid-1990s; an increase that corresponds with the decline in new dam construction.
- The predominant land use is livestock grazing although this has shown a declining trend, being replaced by irrigated horticulture (through the expansion of wineries and olives) and a large increase in rural-residential properties.
- The development of the uplands, and reduced focus on maintaining all the existing drains through the subsiding peatland, has led to persistence, and in some cases, recovery of wetland biodiversity values over the past 50 years.
- The catchment is home to a large number of threatened flora and fauna species across a number of taxonomic groups, and recent restorations in similar wetland systems suggest many species are likely to respond favourably to restoration works.
- The catchment has seen significant, proactive conservation works (especially stock exclusion and weed control) implemented since the 1990s.

- *Phragmites australis* poses a particular management challenge, where it forms expanding and dominant stands, due to traits (morphology, physiology, reproductive and potentially genetics) that enable it to be a strong competitor; especially in wetland areas where stock have been removed within the past 20 years. Blackberry and pasture grasses are also of major concern.
- Despite these changes impacting water resources, the catchment still produces reliable groundwater-driven base flows that indicate it has strong potential for successful hydrological restoration of important wetland sites.

As a result of a subsequent multi-faceted landscape assessment and prioritisation process, a number of areas within the catchment have been identified for future site-specific hydrological restoration planning, preliminary field surveys and/or landholder liaison.

While each of these is worthy of further consideration and should be pursued subject to funding and landholder interest, two sites are specifically highlighted here:

1. ***Square Waterhole Swamp at Hesperilla CP***

   Restoration feasibility planning has already been completed for this 11 hectare site (see Bachmann and Farrington 2017), with a focus on future works to improve sustainability of water management within and around this public land reserve.

2. ***Swampy Crescent and Tooperang (private land)***

   Of the remaining sites, all situated across multiple private land parcels, Swampy Crescent is an obvious candidate for more detailed follow-up assessment. This is on the basis of existing landholder interest, past project works and technical feasibility. The area also links with areas of wetland habitat under conservation management along the lower Tookayerta Creek at Tooperang, creating an opportunity to pursue the restoration of a large, hydrologically intact and connected reach of wetlands.

The proposed project at Swampy Crescent-Tooperang would be based on a process of genuine consultation and sharing technical information with the landholders in the wetland system: working collaboratively through the steps involved in hydrological restoration feasibility planning. The aim would then be to reach agreement on potential on-ground hydrological restoration solutions for future implementation, across property boundaries to benefit the swamp ecosystem.

Reconnaissance field surveys to ground-truth site conditions (drainage and/or swamp vegetation) at high value sites without obvious hydrological modifiers are also a high priority. Such sites include Black Swamp, two sites in the headwaters of the Tookayerta catchment and the Mt Compass School Swamp. This work could help determine the best course of action, including if a more comprehensive eco-hydrological investigation is required.

Additional discussions are also recommended with landholders that are managing wetlands for stock exclusion and weed control at a number of sites, but may have reservations about hydrological works. At many of these locations, the technical aspects, scope and feasibility of hydrological restoration is not yet clear.

Should any of these actions lead to the implementation of on-ground hydrological restoration projects (across multiple private properties) at Swampy Crescent or one of the other identified priority areas, it would provide an excellent opportunity to demonstrate both (a) the merits of working to restore hydrological processes across multiple property boundaries and (b) the major role private land has to play in the effective recovery of the critically endangered (*EPBC Act 1999*) Swamps of the Fleurieu Peninsula ecological community.

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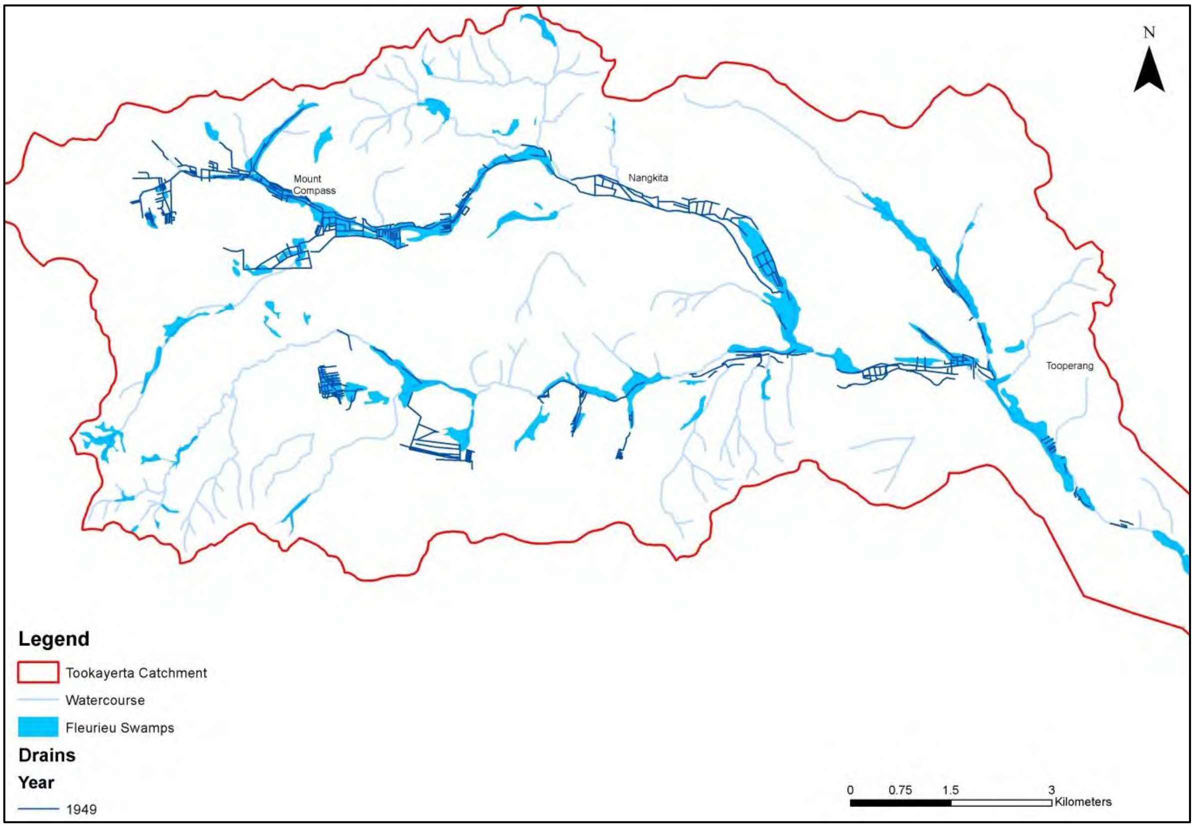
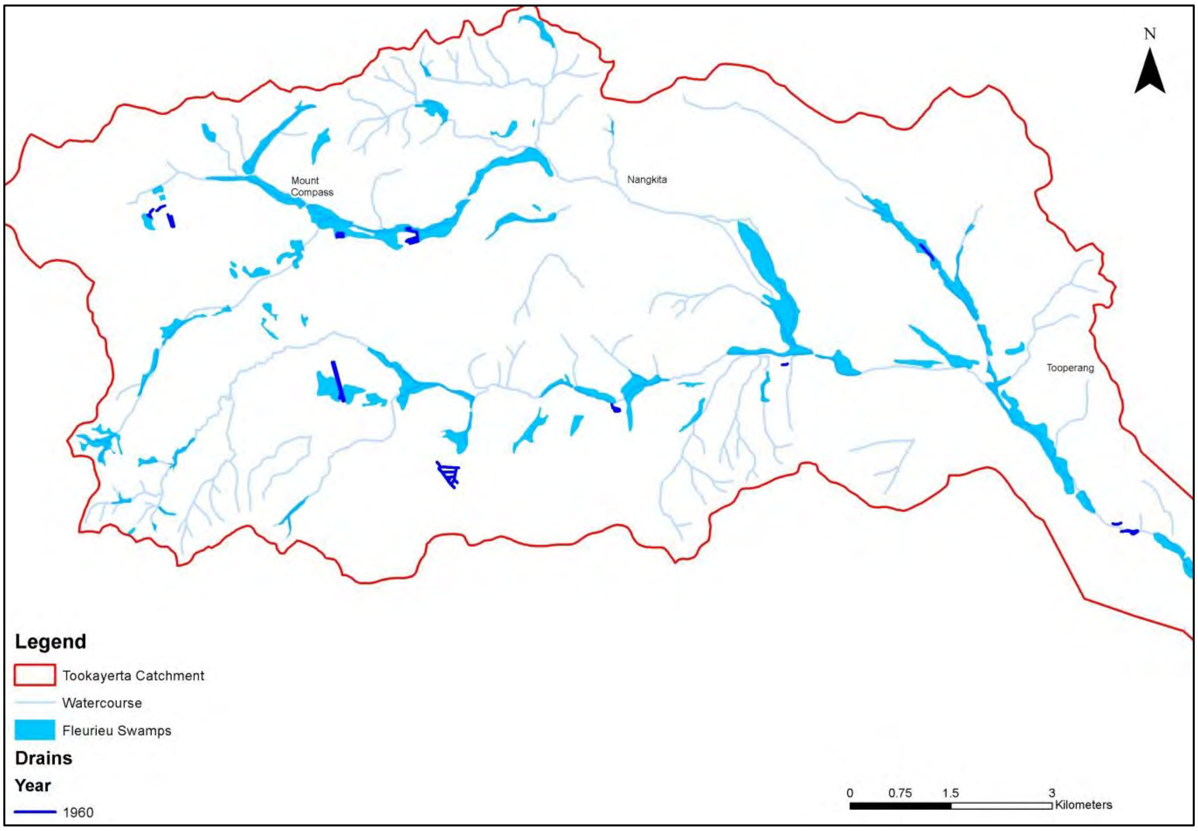
Appendices

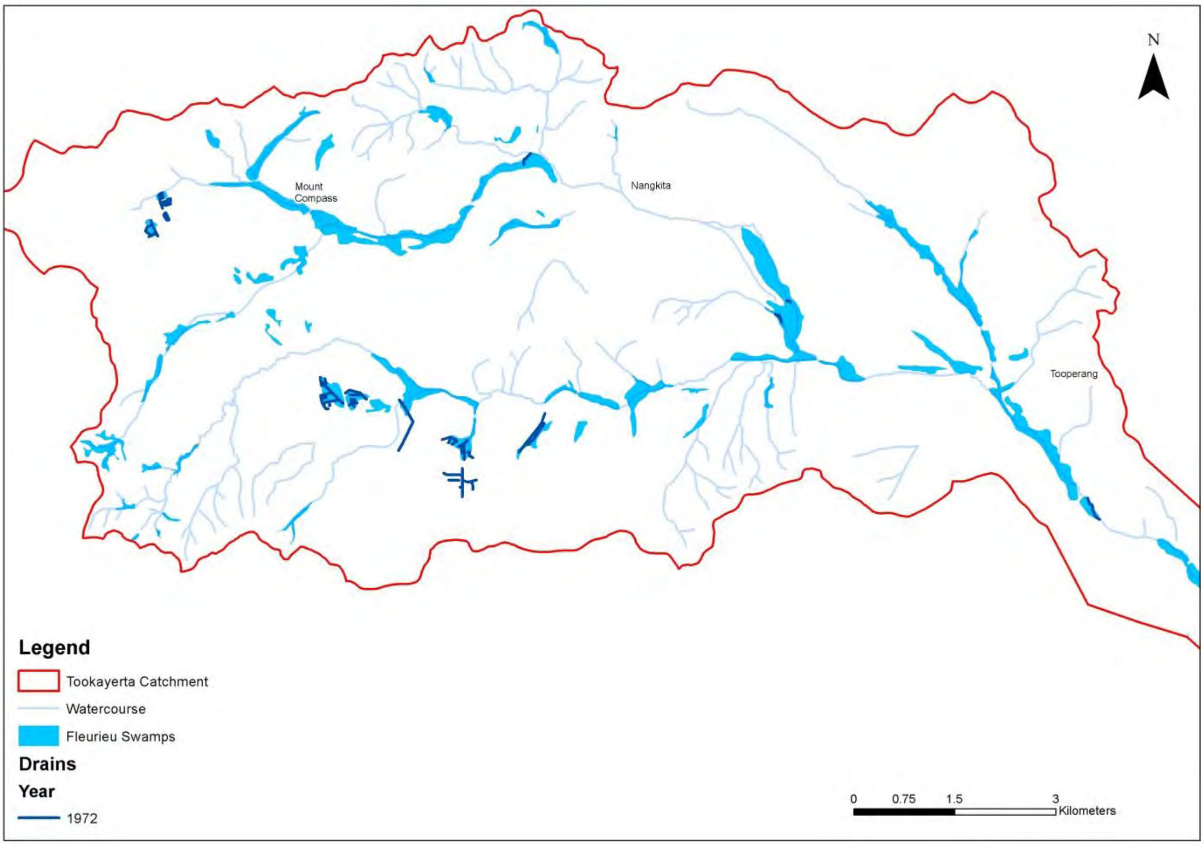
Appendix 1: Artificial drainage by period of construction



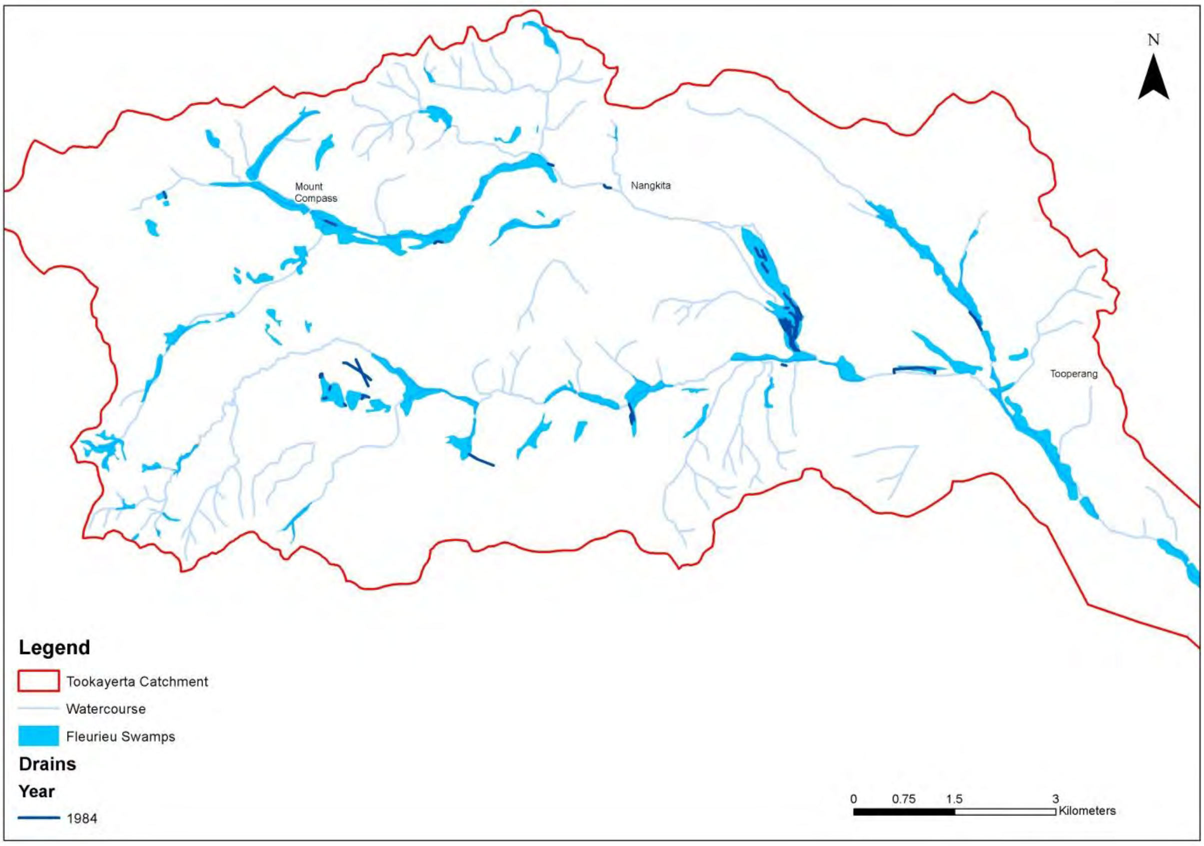
Prior to 1949



1950-1960



1961-1972



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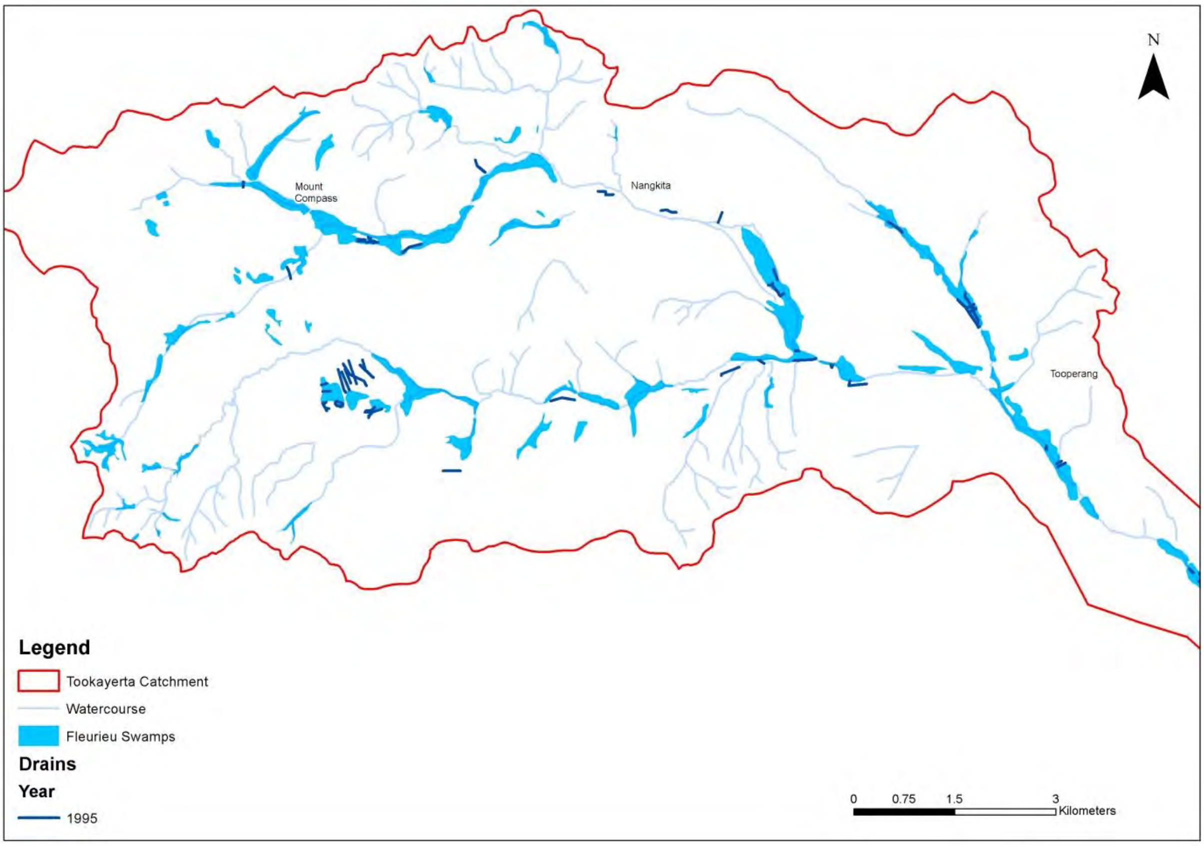
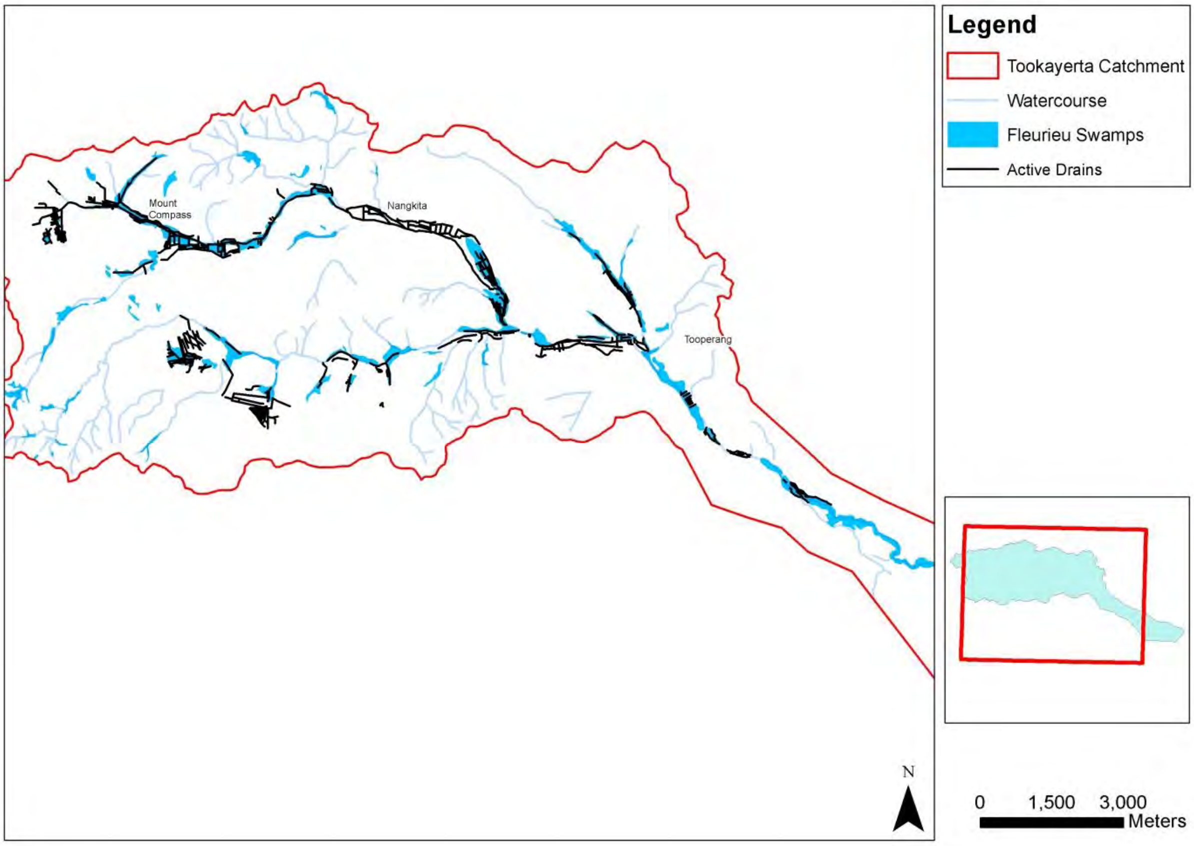


1985-1995



All currently active drains

Appendix 2: Threatened fauna recorded from the Tookayerta catchment (within 100m of mapped Fleurieu Peninsula Swamps)

Class	Scientific Name	Common Name	EPBC	NPWSA	AMLR
Aves	*Stipiturus malachurus intermedius*	MLR Southern Emu-wren	EN	E	CR
Aves	*Anthochaera phrygia*	Regent Honeyeater	EN	E	RE
Mammalia	*Isoodon obesulus obesulus*	Southern brown bandicoot	EN	V	EN
Amphibia	*Litoria raniformis*	Southern Bell Frog	VU	V	RE
Aves	*Ceyx azureus*	Azure Kingfisher		E	RE
Aves	*Excalfactoria chinensis*	King Quail		E	RE
Aves	*Glossopsitta pusilla*	Little Lorikeet		E	CR
Aves	*Hylacola pyrrhopygia parkeri*	Chestnut-rumped Heathwren		E	EN
Aves	*Petroica phoenicea*	Flame Robin		V	CR
Aves	*Lewinia pectoralis*	Lewin Water Rail		V	EN
Aves	*Stagonopleura guttata*	Diamond Firetail		V	EN
Aves	*Neophema chrysostoma*	Blue-winged Parrot		V	VU
Aves	*Stictonetta naevosa*	Canvasback		V	VU
Aves	*Myiagra inquieta*	Restless Flycatcher		R	CR
Aves	*Stagonopleura bella*	Beautiful Firetail		R	CR
Aves	*Falcunculus frontatus*	Crested Shrike-tit		R	EN
Aves	*Gallinago hardwickii*	Latham's Snipe		R	EN
Aves	*Porzana tabuensis*	Leaden Crake		R	EN
Aves	*Zoothera lunulata*	Bassian Thrush		R	EN
Aves	*Ardea ibis*	Cattle Egret		R	VU
Aves	*Egretta garzetta*	Lesser Egret		R	VU
Aves	*Neophema elegans*	Elegant Parrot		R	VU
Aves	*Calamanthus campestris*	Rusty Fieldwren			RE
Mammalia	*Cercartetus concinnus*	Western Pygmy-possum			CR
Actinopterygii	*Gadopsis marmoratus*	Blackfish			CR
Aves	*Melanodryas cucullata*	Hooded Robin			CR
Aves	*Melithreptus gularis*	Black-chinned Honeyeater			CR
Aves	*Microeca fascinans*	Jacky Winter			CR
Aves	*Aphelocephala leucopsis*	Southern Whiteface			EN
Aves	*Chalcites osculans*	Black-eared Cuckoo			EN
Aves	*Climacteris picumnus*	Brown Treecreeper			EN
Aves	*Gliciphila melanops*	Tawny-crowned Honeyeater			EN
Actinopterygii	*Nannoperca australis*	Southern Pigmy Perch			EN
Aves	*Pomatostomus superciliosus*	White-browed Babbler			EN
Aves	*Acanthiza pusilla*	Brown Thornbill			VU
Aves	*Anas superciliosa*	Australian Wild Duck			VU
Aves	*Ardea alba*	Great Egret			VU
Aves	*Ardea pacifica*	Pacific Heron			VU
Aves	*Cincloramphus mathewsi*	Rufous Songlark			VU
Aves	*Circus approximans*	Allied Harrier			VU
Aves	*Cisticola exilis*	Golden-headed Cisticola			VU
Aves	*Cracticus torquatus*	Grey Butcherbird			VU
Aves	*Daphoenositta chrysoptera*	Varied Sittella			VU
Aves	*Epthianura albifrons*	White-fronted Chat			VU
Actinopterygii	*Galaxias olidus*	Inland Galaxias			VU
Aves	*Melithreptus lunatus*	White-naped Honeyeater			VU
Aves	*Merops ornatus*	Rainbow Bee-eater			VU
Aves	*Mirafra javanica*	Horsfield's Bushlark			VU
Aves	*Petroica boodang*	Scarlet Robin			VU
Aves	*Porzana pusilla*	Baillon's Crake			VU
Aves	*Taeniopygia guttata*	Zebra Finch			VU
Aves	*Zosterops lateralis*	Silvereye			VU

Data source: Biological Databases of South Australia (BDBSA)

*Conservation ratings: **EPBC** (Environment Protection and Biodiversity Conservation Act 1999 list of threatened species): CR = critically endangered; EN=endangered; VU=vulnerable; **NPWSA** (State conservation status as listed in the National Parks and Wildlife Schedules): E = endangered, V = vulnerable; **AMLR** (Regional Status Codes – Gillam and Urban, 2014): RE = regionally extinct; CR = critically endangered; EN=endangered; VU=vulnerable.*

Appendix 3: Threatened flora recorded from the Tookayerta catchment (within 100m of mapped Fleurieu Peninsula Swamps)

Family Name	Scientific Name	Common Name	EPBC	NPWSA	AMLR
DILLENIACEAE	*Hibbertia tenuis*	Fleurieu Peninsula Guinea Flower	CR	E	CR
ORCHIDACEAE	*Prasophyllum murfetii*	Maroon Leek-orchid	CR	E	CR
ORCHIDACEAE	*Pterostylis bryophila*	Hindmarsh Greenhood	CR	E	EN
ORCHIDACEAE	*Thelymitra cyanapicata*	Blue Top Sun-orchid	CR	E	CR
SCROPHULARIACEAE	*Veronica derwentiana* ssp. *homalodonta*	Mt Lofty Speedwell	CR	E	EN
CASUARINACEAE	*Allocasuarina robusta*	Mount Compass Oak-bush	EN	E	VU
LABIATAE	*Prostanthera eurybioides*	Monarto Mintbush	EN	E	EN
LEGUMINOSAE	*Acacia pinguifolia*	Fat-leaf Wattle	EN	E	EN
MYRTACEAE	*Eucalyptus paludicola*	Mount Compass Swamp Gum	EN	E	VU
ORCHIDACEAE	*Caladenia argocalla*	White Beauty Spider-orchid	EN	E	CR
ORCHIDACEAE	*Caladenia behrii*	Pink-lip Spider-orchid	EN	E	EN
ORCHIDACEAE	*Caladenia colorata*	Coloured Spider-orchid	EN	E	VU
ORCHIDACEAE	*Caladenia gladiolata*	Bayonet Spider-orchid	EN	E	CR
ORCHIDACEAE	*Caladenia rigida*	Stiff White Spider-orchid	EN	E	EN
ORCHIDACEAE	*Thelymitra epipactoides*	Metallic Sun-orchid	EN	E	RE
SCROPHULARIACEAE	*Euphrasia collina ssp. muelleri*	Mueller's Eyebright	EN	E	RE
SCROPHULARIACEAE	*Euphrasia collina ssp. osbornii*	Osborn's Eyebright	EN	E	EN
ORCHIDACEAE	*Prasophyllum pruinosum*	Plum Leek-orchid	EN	V	EN
ORCHIDACEAE	*Pterostylis sp. Hale*	Hale Greenhood	EN	V*	CR
ORCHIDACEAE	*Caladenia tensa*	Inland Green-comb spider-orchid	EN		RA
COMPOSITAE	*Senecio megaglossus*	Large-flower Groundsel	VU	E	CR
ORCHIDACEAE	*Caladenia ovata*	Kangaroo Island Spider-orchid	VU	E	CR
ORCHIDACEAE	*Corybas dentatus*	Finniss Helmet-orchid	VU	E	NE
ORCHIDACEAE	*Pterostylis cucullata ssp. sylvicola*	Leafy Greenhood	VU	E	EN
ORCHIDACEAE	*Thelymitra matthewsii*	Spiral Sun-orchid	VU	E	RE
ORCHIDACEAE	*Caladenia concolor*	Crimson Spider-orchid	VU	E*	RE
COMPOSITAE	*Olearia pannosa ssp. pannosa*	Silver Daisy-bush	VU	V	EN
COMPOSITAE	*Senecio macrocarpus*	Large-fruit Groundsel	VU	V	RE
LEGUMINOSAE	*Acacia menzelii*	Menzel's Wattle	VU	V	RA
LEGUMINOSAE	*Acacia rhetinocarpa*	Resin Wattle	VU	V	VU
LEGUMINOSAE	*Glycine latrobeana*	Clover Glycine	VU	V	RA
ORCHIDACEAE	*Caladenia brumalis*	Winter Spider-orchid	VU	V	RE
ORCHIDACEAE	*Prasophyllum validum*	Mount Remarkable Leek-orchid	VU	V	NE
ORCHIDACEAE	*Pterostylis arenicola*	Sandhill Greenhood	VU	V	CR
RHAMNACEAE	*Spyridium coactilifolium*	Butterfly Spyridium	VU	V	VU
RUTACEAE	*Correa calycina var. calycina*	Hindmarsh Correa	VU*	V	VU
BLECHNACEAE	*Doodia caudata*	Small Rasp-fern		E	DD
CHENOPODIACEAE	*Maireana decalvans*	Black Cotton-bush		E	EN
COMPOSITAE	*Brachyscome diversifolia*	Tall Daisy		E	EN
COMPOSITAE	*Helichrysum rutidolepis*	Pale Everlasting		E	EN
COMPOSITAE	*Rhodanthe anthemoides*	Chamomile Everlasting		E	RE
CRASSULACEAE	*Crassula sieberiana*	Sieber's Crassula		E	VU
CYPERACEAE	*Tricostularia pauciflora*	Needle Bog-rush		E	CR
DENNSTAEDTIACEAE	*Histiopteris incisa*	Bat's-wing Fern		E	EN
DICKSONIACEAE	*Dicksonia antarctica*	Soft Tree-fern		E	DD
GOODENIACEAE	*Dampiera lanceolata var. intermedia*	Aldinga Dampiera		E	EN
GRAMINEAE	*Austrostipa oligostachya*	Fine-head Spear-grass		E	EN
JUNCACEAE	*Juncus prismatocarpus*	Branching Rush		E	EN
LILIACEAE	*Wurmbea uniflora*	One-flow er Nancy		E	EN
LYCOPODIACEAE	*Lycopodiella serpentina*	Bog Clubmoss		E	CR

Family Name	Scientific Name	Common Name	EPBC	NPWSA	AMLR
LYCOPODIACEAE	*Lycopodium deuterodensum*	Bushy Clubmoss		E	CR
OPHIOGLOSSACEAE	*Botrychium australe*	Austral Moonw ort		E	RE
ORCHIDACEAE	*Caladenia parva*	Small Green-comb Spider-orchid		E	DD
ORCHIDACEAE	*Caladenia valida*	Robust Spider-orchid		E	EN
ORCHIDACEAE	*Calochilus cupreus*	Copper Beard-orchid		E	CR
ORCHIDACEAE	*Corybas fordhamii*	Sw amp Helmet-orchid		E	CR
ORCHIDACEAE	*Diuris brevifolia*	Short-leaf Donkey-orchid		E	VU
ORCHIDACEAE	*Diuris chryseopsis*	Cow slip Orchid		E	RE
ORCHIDACEAE	*Genoplesium ciliatum*	Sw amp Midge-orchid		E	CR
ORCHIDACEAE	*Microtis eremaea*	Slender Onion-orchid		E	CR
ORCHIDACEAE	*Paracaleana disjuncta*	Black-beak Duck-orchid		E	CR
ORCHIDACEAE	*Prasophyllum sp. Enigma*	Goldsack's Leek-orchid		E	CR
ORCHIDACEAE	*Pterostylis falcata*	Forked Greenhood		E	EN
ORCHIDACEAE	*Pterostylis sp. Rock ledges*			E	EN
ORCHIDACEAE	*Pterostylis uliginosa*			E	CR
ORCHIDACEAE	*Thelymitra circumsepta*	Naked Sun-orchid		E	CR
ORCHIDACEAE	*Thelymitra cyanea*	Veined Sun-orchid		E	EN
OSMUNDACEAE	*Todea barbara*	King Fern		E	EN
PSILOTACEAE	*Psilotum nudum*	Skeleton Fork-fern		E	CR
UMBELLIFERAE	*Oreomyrrhis eriopoda*	Australian Carraway		E	EN
VIOLACEAE	*Viola betonicifolia ssp. betonicifolia*	Showy Violet		E	CR
ORCHIDACEAE	*Caladenia sp. Finniss (R.Bates 308)*	Finniss Spider-orchid		E*	RE
ORCHIDACEAE	*Prasophyllum rotundiflorum*			E*	RE
ORCHIDACEAE	*Pterostylis ferruginea*	Bangham Rustyhood		E*	DD
ORCHIDACEAE	*Thelymitra ixioides*	Spotted Sun-orchid		E*	NE
SCROPHULARIACEAE	*Euphrasia scabra*	Rough Eyebright		E*	RE
ADIANTACEAE	*Adiantum capillus-veneris*	Dainty Maiden-hair		V	EN
AIZOACEAE	*Sarcozona bicarinata*	Ridged Noon-flower		V	NE
CAMPANULACEAE	*Pratia puberula*	White-flower Matted Pratia		V	EN
COMPOSITAE	*Lagenophora gracilis*	Slender Bottle-daisy		V	VU
COMPOSITAE	*Olearia glandulosa*	Sw amp Daisy-bush		V	EN
COMPOSITAE	*Podolepis muelleri*	Button Podolepis		V	EN
CRUCIFERAE	*Cardamine gunnii*	Spade-leaf Bitter-cress		V	RE
CYPERACEAE	*Eleocharis atricha*	Tuber Spike-rush		V	CR
CYPERACEAE	*Isolepis producta*	Nutty Club-rush		V	RE
CYPERACEAE	*Schoenus latelaminatus*	Medusa Bog-rush		V	VU
GOODENIACEAE	*Scaevola calendulacea*	Dune Fanflow er		V	CR
GRAMINEAE	*Austrostipa pilata*	Prickly Spear-grass		V	VU
GRAMINEAE	*Deyeuxia minor*	Small Bent-grass		V	VU
HALORAGACEAE	*Myriophyllum crispatum*	Upright Milfoil		V	DD
JUNCACEAE	*Juncus amabilis*			V	EN
JUNCACEAE	*Juncus homalocaulis*	Wiry Rush		V	EN
JUNCACEAE	*Juncus radula*	Hoary Rush		V	VU
JUNCACEAE	*Luzula flaccida*	Pale Wood-rush		V	VU
LEGUMINOSAE	*Cullen parvum*	Small Scurf-pea		V	EN
LEGUMINOSAE	*Glycine tabacina*	Variable Glycine		V	VU
LEGUMINOSAE	*Swainsona behriana*	Behr's Sw ainson-pea		V	CR
LEGUMINOSAE	*Templetonia stenophylla*	Leafy Templetonia		V	EN
LENTIBULARIACEAE	*Utricularia lateriflora*	Small Bladderw ort		V	CR
ORCHIDACEAE	*Caladenia flaccida*	Drooping Spider-orchid		V	CR
ORCHIDACEAE	*Caleana major*	Large Duck-orchid		V	CR
ORCHIDACEAE	*Calochilus paludosus*	Red Beard-orchid		V	CR
ORCHIDACEAE	*Corybas expansus*	Dune Helmet-orchid		V	CR
ORCHIDACEAE	*Cryptostylis subulata*	Moose Orchid		V	CR

Family Name	Scientific Name	Common Name	EPBC	NPWSA	AMLR
ORCHIDACEAE	*Dipodium pardalinum*	Leopard Hyacinth-orchid		V	CR
ORCHIDACEAE	*Diuris behrii*	Behr's Cow slip Orchid		V	VU
ORCHIDACEAE	*Microtis orbicularis*	Swamp Onion-orchid		V	EN
ORCHIDACEAE	*Paracaleana minor*	Small Duck-orchid		V	EN
ORCHIDACEAE	*Thelymitra holmesii*	Blue Star Sun-orchid		V	EN
ORCHIDACEAE	*Thelymitra hygrophila*	Blue Star Sun-orchid		V	CR
ORCHIDACEAE	*Thelymitra inflata*	Plum Sun-orchid		V	EN
ORCHIDACEAE	*Thelymitra latifolia*	Blue Star Sun-orchid		V	RA
ORCHIDACEAE	*Thelymitra peniculata*	Blue Star Sun-orchid		V	VU
PORTULACACEAE	*Montia fontana ssp. chondrosperma*	Waterblinks		V	EN
RANUNCULACEAE	*Ranunculus glabrifolius*	Shining Buttercup		V	CR
RANUNCULACEAE	*Ranunculus papulentus*	Large River Buttercup		V	EN
RUTACEAE	*Correa eburnea*			V	VU
SCHIZAEACEAE	*Schizaea bifida*	Forked Comb-fern		V	EN
SCHIZAEACEAE	*Schizaea fistulosa*	Narrow Comb-fern		V	EN
SCROPHULARIACEAE	*Mazus pumilio*	Sw amp Mazus		V	EN
SCROPHULARIACEAE	*Veronica gracilis*	Slender Speedwell		V	EN
UMBELLIFERAE	*Eryngium ovinum*	Blue Devil		V	EN

Data source: Biological Databases of South Australia (BDBSA)

Conservation ratings:

***EPBC** (Environment Protection and Biodiversity Conservation Act 1999 list of threatened species): CR = critically endangered; EN=endangered; VU=vulnerable; **NPWSA** (State conservation status as listed in the National Parks and Wildlife Schedules): E = endangered, V = vulnerable; **AMLR** (Regional Status Codes – Gillam and Urban, 2014): RE = regionally extinct; CR = critically endangered; EN=endangered; VU=vulnerable; DD = Data Deficient.*

Appendix 4: Wetland scores from the landscape assessment and prioritisation process

Wetland	Multiple landholdings	Drains-Wetland	Dams-Wetland	Dams-Local Catchment	Landuse	RESILIENCE to THREATS	Conservation Management	Native Vegetation	ENV. VALUE SCORE	TOTAL: Priority Order	Hydro-restoration potential
S0200663	5	5	1	4	5	**20**	5	9	**23.75**	**43.75**	
S0200664	5	4	5	3	5	**22**	4	8	**20**	**42**	y
S0200710	3	4	5	5	5	**22**	3	9	**18.75**	**40.75**	y
S0200680	4	4	5	3	2	**18**	5	7	**21.25**	**39.25**	y
S0200709	3	4	4	4	4	**19**	4	8	**20**	**39**	y
S0200676	5	4	5	3	2	**19**	5	6	**20**	**39**	y
S0200622	5	5	4	2	3	**19**	5	5	**18.75**	**37.75**	
S0200679	4	3	5	2	3	**17**	5	5	**18.75**	**35.75**	y
S0200678	4	4	4	2	4	**18**	5	4	**17.5**	**35.5**	y
S0200615	3	5	5	3	5	**21**	1	8	**12.5**	**33.5**	
S0200669	2	5	5	3	2	**17**	3	7	**16.25**	**33.25**	
S0200627	5	5	5	4	5	**24**	1	4	**7.5**	**31.5**	
S0200704	2	4	2	1	1	**10**	4	9	**21.25**	**31.25**	y
S0200707	5	5	3	3	5	**21**	1	6	**10**	**31**	
S0200677	5	3	5	2	3	**18**	2	6	**12.5**	**30.5**	
S0200665	5	5	5	3	5	**23**	1	4	**7.5**	**30.5**	
S0200745	5	5	4	4	4	**22**	1	4	**7.5**	**29.5**	
S0200666	5	5	5	5	5	**25**	1	1	**3.75**	**28.75**	
S0200674	5	4	4	4	3	**20**	1	5	**8.75**	**28.75**	y
S0200667	1	4	4	3	4	**16**	2	6	**12.5**	**28.5**	
S0200675	5	4	5	4	3	**21**	1	4	**7.5**	**28.5**	y
S0200619	5	5	4	3	5	**22**	1	3	**6.25**	**28.25**	y
S0200705	2	2	5	3	1	**13**	3	6	**15**	**28**	y

Wetland	Multiple landholdings	Drains-Wetland	Dams-Wetland	Dams-Local Catchment	Landuse	RESILIENCE to THREATS	Conservation Management	Native Vegetation	ENV. VALUE SCORE	TOTAL: Priority Order	Hydro-restoration potential
S0200618	1	5	5	3	5	**19**	1	5	**8.75**	**27.75**	
S0200711	3	5	4	4	4	**20**	1	4	**7.5**	**27.5**	
S0200628	5	5	2	4	5	**21**	1	3	**6.25**	**27.25**	
S0200621	5	5	5	3	3	**21**	1	3	**6.25**	**27.25**	
S0200620	5	5	5	2	5	**22**	1	2	**5**	**27**	
S0200712	3	4	3	3	4	**17**	1	6	**10**	**27**	y
S0200720	5	5	5	3	5	**23**	1	1	**3.75**	**26.75**	
S0200625	5	5	5	3	5	**23**	1	1	**3.75**	**26.75**	
S0200631	5	5	5	3	5	**23**	1	1	**3.75**	**26.75**	
S0200671	5	3	4	4	3	**19**	1	4	**7.5**	**26.5**	y
S0200626	5	4	5	4	2	**20**	1	3	**6.25**	**26.25**	
S0200629	5	5	5	3	3	**21**	1	2	**5**	**26**	
S0200668	2	4	4	3	4	**17**	1	5	**8.75**	**25.75**	
S0200624	5	5	5	2	5	**22**	1	1	**3.75**	**25.75**	
S0200716	3	5	3	3	3	**17**	1	5	**8.75**	**25.75**	
S0200672	5	3	5	3	3	**19**	1	3	**6.25**	**25.25**	
S0200809	5	5	2	3	5	**20**	1	2	**5**	**25**	
S0200842	2	5	5	5	3	**20**	1	2	**5**	**25**	
S0200719	5	5	5	4	2	**21**	1	1	**3.75**	**24.75**	
S0200713	4	5	5	3	4	**21**	1	1	**3.75**	**24.75**	
S0200893	5	3	3	5	5	**21**	1	1	**3.75**	**24.75**	y
S0200851	5	2	4	3	4	**18**	1	3	**6.25**	**24.25**	y
S0200630	5	5	2	3	5	**20**	1	1	**3.75**	**23.75**	
S0200717	3	5	2	3	3	**16**	1	4	**7.5**	**23.5**	

Wetland	Multiple landholdings	Drains-Wetland	Dams-Wetland	Dams-Local Catchment	Landuse	RESILIENCE to THREATS	Conservation Management	Native Vegetation	ENV. VALUE SCORE	TOTAL: Priority Order	Hydro-restoration potential
S0200616	4	3	4	4	2	**17**	1	3	**6.25**	**23.25**	
S0200617	1	3	4	3	2	**13**	1	6	**10**	**23**	
S0200708	3	4	4	3	4	**18**	1	2	**5**	**23**	y
S0200623	5	4	4	3	3	**19**	1	1	**3.75**	**22.75**	
S0200718	3	5	5	5	1	**19**	1	1	**3.75**	**22.75**	
S0200670	5	5	4	1	3	**18**	1	1	**3.75**	**21.75**	
S0200943	4	1	5	3	2	**15**	1	3	**6.25**	**21.25**	y
S0200673	3	3	4	3	3	**16**	1	2	**5**	**21**	
S0200968	4	5	2	3	3	**17**	1	1	**3.75**	**20.75**	
S0200810	1	3	4	3	3	**14**	1	3	**6.25**	**20.25**	y
S0200681	2	4	2	4	3	**15**	1	1	**3.75**	**18.75**	
S0200850	1	2	4	3	3	**13**	1	2	**5**	**18**	y