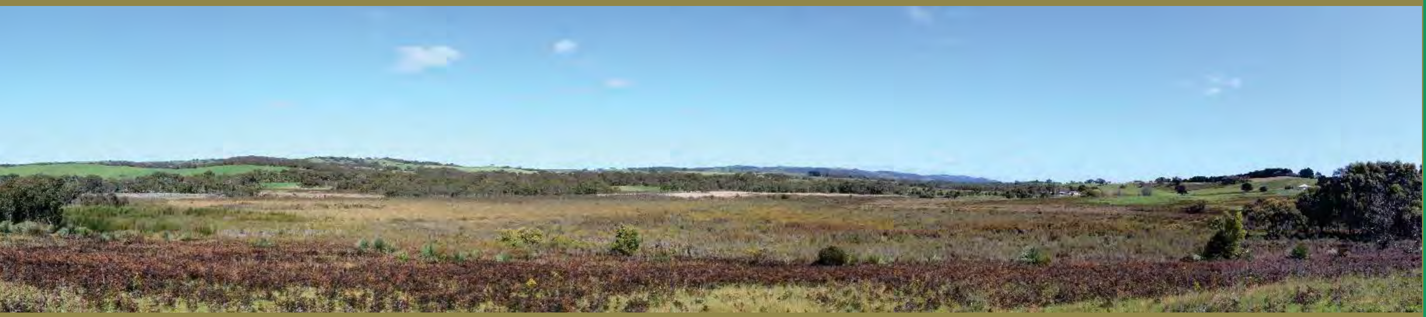
Nature Glenelg Trust

Hydrological restoration options for Glenshera Swamp, Stipiturus Conservation Park.

A case study for investigating the feasibility of restoring the water regime of Fleurieu Peninsula swamps impacted by artificial drainage.

Mark Bachmann and Lachlan Farrington



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Disclaimer

Executive summary

Glenshera Swamp, within Stipiturus Conservation Park, is one of the most important remnants of a nationally threatened ecological community – the swamps of the Fleurieu Peninsula. The site has managed to retain a suite of important biodiversity values, despite attempts over a 50 year period (up to its reservation in 2003) to make the area more suitable for agricultural production through drainage, clearance and grazing activities.

With substantial investment now being made in the traditional approaches to restoration in the Conservation Park, it is timely for the hydrological aspects of site management to also be addressed, to ensure complementary and sustainable zoning for future works – especially revegetation. There is also a high degree of community concern about the observed long-term drying trend in some Fleurieu swamps, including Glenshera Swamp, and hydrological restoration is a legitimate, proactive option for potentially addressing this wider threat to the condition of the ecological community. With these factors in mind, Nature Glenelg Trust was asked to undertake an assessment of the site for DEWNR, to review the feasibility of different hydrological restoration options, with a goal of ensuring the future sustainability of the wetland ecosystem.

The assessment, which occurred from September 2015 until January 2016, culminating in the production of this report, involved: site visits, LiDAR and aerial imagery acquisition, historical research, and, detailed discussions with a wide range of people that have an intimate knowledge of the site. Our assessment found that although the site is underpinned by regional groundwater, it is also strongly influenced by seasonal rainfall and its relationship to localised (surface and groundwater) catchment flows. Past drainage activities that occurred over several decades, commencing in the 1940s, deliberately sought to favour the agricultural use of the site by diverting inflows, drying out the slopes, draining the bed of the swamp and increasing downstream drawdown. These activities were all aimed at significantly speeding up the flow of water out of the system, irrespective of its source.

Restoration goal:

> To trial and implement measures that are capable of significantly slowing down, and making better use of, water within or passing through Glenshera Swamp to preserve (and if possible enhance) its ecological values.

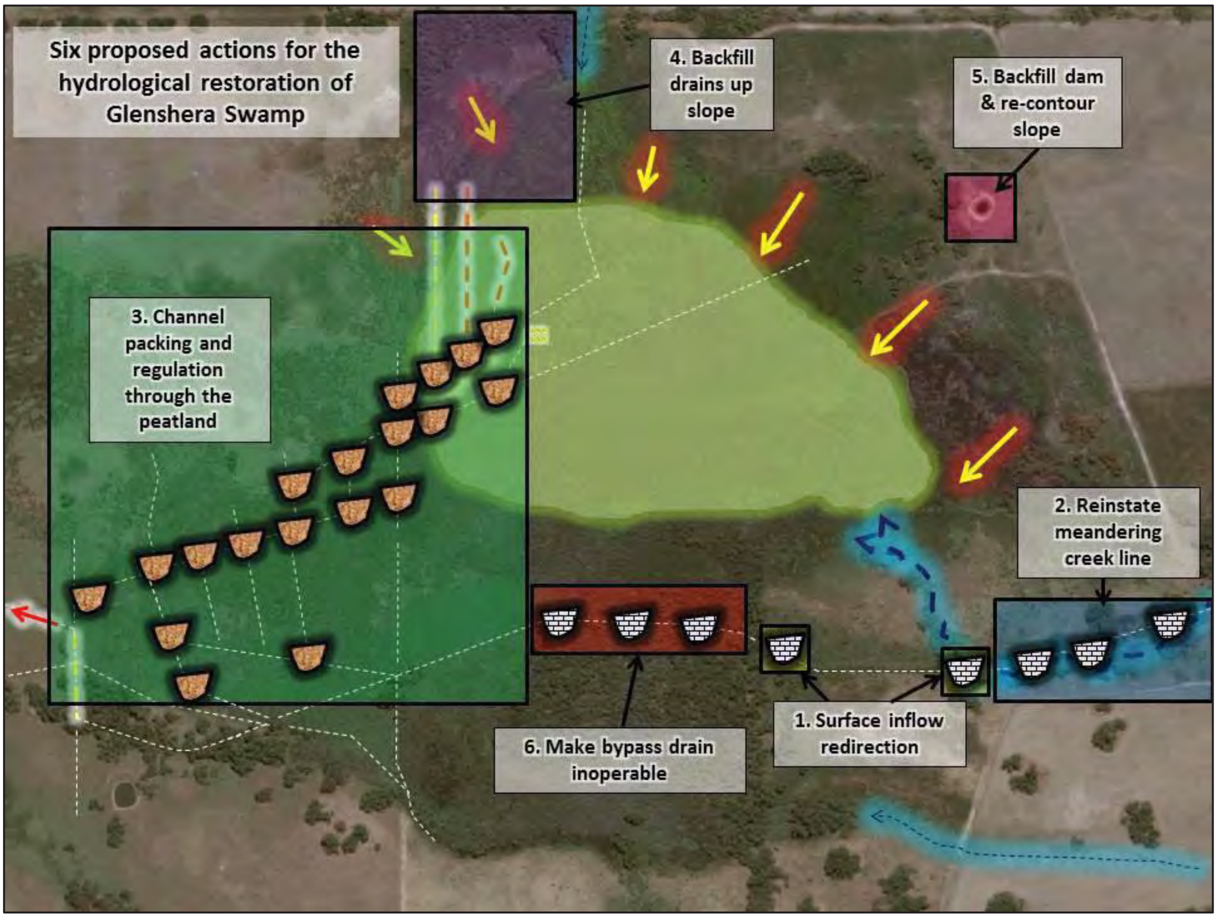
Measures of success:

- increase soil moisture storage capacity across the site, in particular the year-round saturation of peat which drives ecosystem health, enabling environmental values to capitalise on smarter use of inflows;
- use methods wherever possible that cause the lowest possible disturbance;
- cause a positive shift in the trajectory of a set of chosen biological and/or hydrological indicators;
- enhance the site's capacity for natural regeneration and establish a new, wetter benchmark for future restoration actions to build upon; and,

- also consider restoration methods capable, wherever possible, of involving interest groups and the wider community in the works.

As a result of a detailed assessment of site values, threats and options for restoration, six key actions are proposed for implementing the next phase of the project:

ACTION 1:	Flow redirection of the natural creekline
ACTION 2:	Full meandering flow path reinstatement of the natural creekline
ACTION 3:	Channel packing and regulation - measures for slowing and dispersing flow through the core area of peatland
ACTION 4:	Earthworks to physically backfill steep drains that target hillslope seepage
ACTION 5:	Decommission the dam to the north-east of the swamp, reinstating the original bank profile
ACTION 6:	Install a series of blocks to render the bypass drain inoperable



Action 1 can be implemented in the short term with limited resources, while Action 3 will require more significant funding and further planning to successfully implement. Actions 2 and 6 should follow the successful implementation of a trial for Action 1. Finally, Actions 4 and 5 can be completed at any time, subject to funding, and are independent of other tasks.

On the basis of the findings of this investigation, it is recommended that the hydrological restoration of Glenshera Swamp commence as a matter of some priority, with Nature

Glenelg Trust initially willing to lead the first, inexpensive steps (Action 1) before winter 2016.

Additionally, key monitoring requirements that are recommended, subject to available resources, are:

- Installation of surface water level gauge boards and level loggers in both the inflow watercourse, outflow drains and across the swamp;
- Installation of water level loggers into existing observation wells and/or installation of new wells in strategic locations to capture groundwater movement and recharge information, as well as helping to quantify any future changes in peat saturation that result from the decommissioning of drains;
- Establishment of permanent cross sectional vegetation transects and undertaking of baseline monitoring to record the position of dominant species within each strata, through multiples zones of predicted hydrological influence;
- Establishment of long-term photopoints at key locations in each of the zones for works indicated in this report, where possible in conjunction with the gauge board sites mentioned in the points above.
- Review of threatened species monitoring programs to determine likelihood of detecting changes under modified hydrology, and adapting those methods as necessary;
- Identification of any permanent aquatic refuge pools within the wider catchment connected to the swamp and undertake surveys for freshwater fish;
- Establishment of audio recording stations and undertaking of seasonal recordings to establish frog species lists;
- High accuracy mapping of the boundary of the *Phragmites australis* reedland prior to and annually following restoration works and associated with any other potential control works; and,
- Continued control and monitoring of other weeds as necessary.

It is hoped that the logic of the assessment presented in this report may also provide the basis for a wider discussion about the potential for hydrological restoration to be used as a proactive management tool in other swamps of the Fleurieu Peninsula, or indeed to improve the condition of other degraded wetland ecosystems in the wider Adelaide and Mt Lofty Ranges NRM region.

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1 Background

1.1 Site introduction

The original extent of the swamps of the Fleurieu Peninsula is estimated to have exceeded 2000 hectares. Almost half of this area (42%) has been lost through reclamation (drainage and development) and those sites that now remain are quite small (< 5 ha) (Littlely and Cutten, 1994) and highly fragmented, both from one another and also from other remnant vegetation communities. Given the high degree and intensity of human disturbance on the Fleurieu Peninsula, combined with ongoing and demonstrable threats, the swamps of the Fleurieu Peninsula were listed by the Commonwealth as a critically endangered ecological community under the *Environment Protection and Biodiversity Conservation Act 1999* (EBPC Act) in March 2003. In terms of the condition classification of the swamps that remain, 53% are degraded, 21% are in moderate condition and only 2% are in a near-pristine state (Harding, 2005).

One site that constitutes the largest and most intact remaining example of the Fleurieu Swamp community (MLRSEWRP, 2004), occurs within Stipiturus Conservation Park (Figure 1.1) – Glenshera Swamp – approximately 6 km west of Mount Compass.

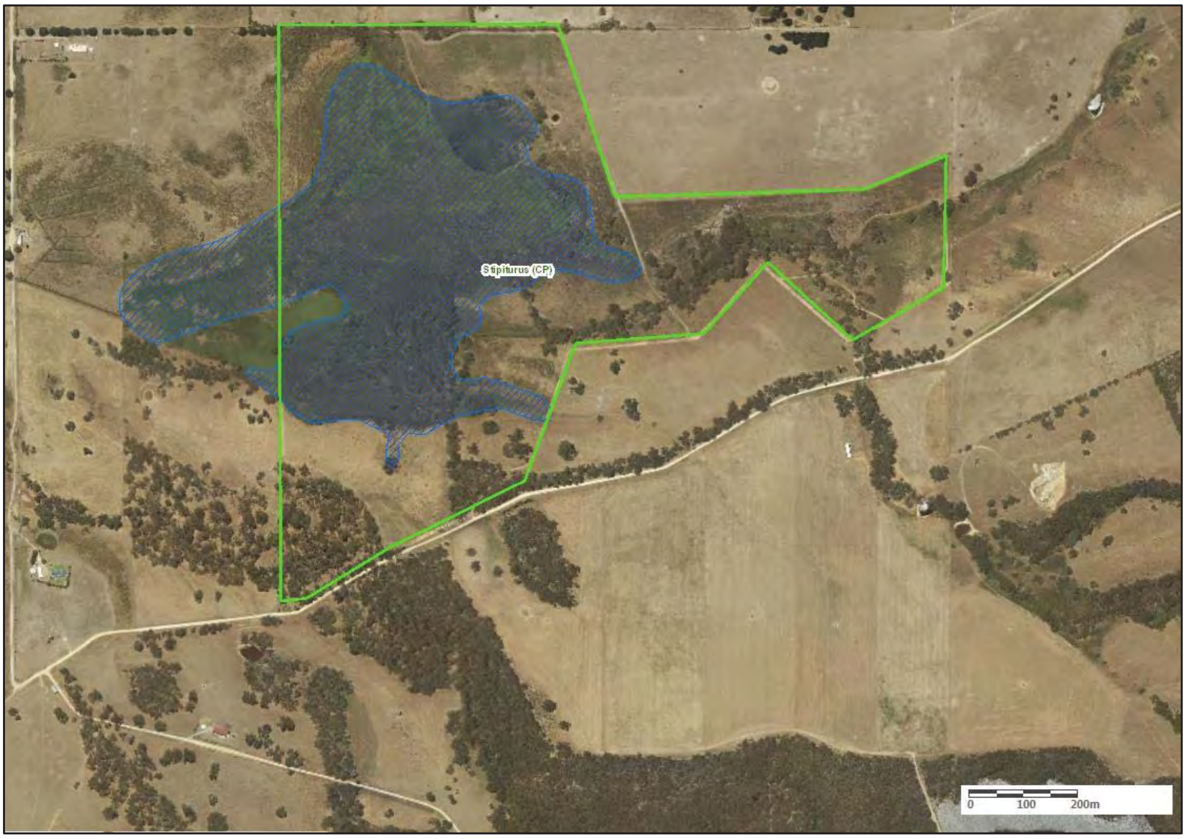


Figure 1.1 – Stipiturus Conservation Park (outlined in green), showing the current mapped extent of Glenshera Swamp (blue shading) in the DEWNR GIS wetland layer.

This wetland, also locally known as Glenshera Swamp (Figure 1.2), occupies 31 hectares (almost half of the park) and is described as a wet heath/sedgeland peat bog (DEH, 2007a).

Figure 1.2 – Panoramic image of Glenshera Swamp.

Stipiturus Conservation Park, named after the genus of the southern emu-wren, was proclaimed on 14th December 2006 under the *National Parks and Wildlife Act 1972*, following its recognition as a unique ecosystem worthy of protection. This was in line with Australia's focus at the time of building a conservation reserve system that was comprehensive, adequate and representative across all Australian bio-regions (DEH, 2007a). The park provides habitat for one of the most significant swamp-based populations of the nationally endangered Mount Lofty Ranges Southern emu-wren (*Stipiturus malachurus intermedius*) and 64% of native plants found in and around the swamp have regional and/or state conservation ratings.

The vision for Stipiturus Conservation Park, as outlined in the park management plan (DEH, 2007), is to maintain a healthy wetland ecosystem that supports a flourishing Mount Lofty Ranges southern emu-wren population and that provides important habitat for other species of conservation significance. In recognising the need to maintain wetland health, implicit within this vision is the requirement to maintain a long-term hydrological regime for the site capable of supporting a diverse and functional swamp community into the future. This is a particularly important consideration given forecast declines in rainfall, runoff and recharge (due to the predicted impacts of climate change) that, combined with artificial drainage networks present throughout the site, may not be sufficient to meet the ongoing water needs of the swamp community.

Observations of Glenshera Swamp over several decades of visits by native flora enthusiasts present a story of significant change as the catchment appears to have dried over time (Bates, 2015; Clive Chesson, pers. comm.). In recognition of the lack of certainty regarding future water security for the site and to ensure complementary and sustainable zoning for upcoming planned works, Nature Glenelg Trust was engaged by the Department for Environment, Water and Natural Resources in June 2015 (project manager, Jason van Weenen), to undertake a review of site hydrology and prepare a *Hydrological Restoration Plan for Stipiturus Conservation Park*. The resultant work, presented in this document, has a particular focus on the elements negatively influencing hydrology that can be actively managed (such as artificial drainage), and assessing potential remedial works aimed at minimising or eliminating these impacts into the future.

2 Project Overview and Requirements

2.1 Project objective

The overall objective of this report and the body of work it summarises is to outline an assessment of hydrological restoration options for Glenshera Swamp in Stipiturus Conservation Park, by providing a detailed investigation of:

- Current hydrology;
- Restoration options; and
- Consequences of restoration options.

2.2 Requirements

Key information requested to be included in this restoration plan includes:

- Summary of Stipiturus Conservation Park and intent of the restoration plan.
- Brief synopsis of similar restoration approaches undertaken in south eastern Australia detailing their objectives and outcomes.
- Mapping of current wetland areas in Stipiturus CP detailing:
    - vegetation associations
    - probable historic hydrology
    - current altered hydrology
- Water budget for Stipiturus CP
    - Potential hydrological management options and their associated inundation scenarios, with particular reference to:
        - Impact scenarios for vegetation associations
        - Impact scenarios for key threatened species
        - Impact on park infrastructure such as vehicle tracks
- Contextualised restoration options in regard to effect on:
    - relevant Water Allocation Plans for the site.
    - the hydrology in the surrounding landscape.
- Provide a list of future steps necessary for implementing the plan.
- Seek peer review on the plan.

2.3 Project deliverables

- Electronic copies of the final report
- Electronic copies of any literature cited (papers, fact sheets, etc.)
- Presentation of the restoration options to Natural Resources, AMLR.

3 The logic of wetland restoration as a conservation tool

3.1 Modification of wetland hydrology and impacts on biodiversity

By far, the most significant issue facing the sustainable management of wetlands in Australia is hydrological management, or water regime, which is influenced by a wide range of factors including climate, land use planning, water allocation policy, and physical changes to local aquifers, site drainage or upstream catchments. In relation to the last point, a long history of modification of wetlands on private land through artificial drainage or diversions has resulted in the temperate agricultural zone of southern Australia retaining only a fraction of its original wetland extent. This pattern of change also extends into many protected areas where drainage works in wetlands often predate the reservation of land for conservation purposes.

The cost, time frames and practical difficulties often associated with trying to recreate self-sustaining terrestrial habitats in highly modified landscapes is a major issue that can present a real deterrent to practical restorative on-ground action. In contrast, and providing that water availability has not been excessively or irreversibly compromised, drained (or hydrologically degraded) wetlands offer more rapid, sustainable restoration potential. In addition, wetland restoration offers the possibility of a less rigid management approach which is capable of engaging with land managers and the wider community.

The impacts of reducing the depth and duration, including physical presence, of wetlands in the landscape have been severe and far-reaching. From impacting on the distribution, status and viability of locally occurring species of freshwater fish, frogs, flora and other wetland dependent species, many of which are now listed as threatened, through to influencing the availability of resources for migratory waterbirds and waders; wetlands have been found to contribute to the conservation of biodiversity at multiple scales. When local catchment services such as aquifer recharge, water purification, nutrient and sediment removal and downstream flood buffering are fully taken into account, these additional factors strongly justify the case for reversing the trend of wetland degradation and loss, through restoration.

3.2 Nature Glenelg Trust's approach to wetland restoration

Nature Glenelg Trust (NGT) has been actively involved in wetland restoration projects in south-eastern Australia since commencing operations in January 2012. Several current NGT staff also having been involved in an additional suite of wetland restoration projects through their previous employment since 1999. For selected examples over this period, please see the Appendices in Section 8.

Of relevance to this project, NGT has particular expertise and experience in planning and undertaking wetland restoration activities on public land. In these situations, existing biodiversity values often lead to heightened sensitivities to the idea of a management intervention that alters water regime. Hence NGT applies a flexible, collaborative and often staged approach to wetland restoration; capable of accommodating the wide range of situations where artificial drainage or diversions have impacted on a wetland's original hydrological regime.

The ultimate approach and restoration methods that are employed at any given site vary according to a wide range of characteristics that are initially assessed; including documenting, investigating and evaluating the following:

- Land tenure (public or private land, or both):
    - Sentiments and/or goals of the landowner/manager and neighbours; and,
    - In the case of public land, close consultation with other interested parties.
- History:
    - Original site character and time since disturbance; and,
    - Evidence of artificial drainage, upstream diversions, adjacent land use change, or other hydrological impacts;
- Existing conservation value of the site:
    - Landscape context;
    - Intactness of native vegetation (grazing and vegetation clearance history);
    - Noteworthy conservation attributes (e.g. threatened species) – extant and historic; and,
    - Identification of any other biotic (e.g. weeds) or abiotic (e.g. nutrient) threats.
- Eco-hydrological character:
    - Wetland eco-type and associated hydrological regime;
    - Relative contributions of surface and/or groundwater;
    - Long term climatic trends (e.g. rainfall data, flow gauging of surface inflows, groundwater elevation change, etc.)
    - Catchment context and water security;
    - Temporal and spatial variability of wetland extent, based on digital elevation data; and,
    - Natural regeneration capacity and potential (i.e. likelihood of reaching a desired environmental outcome).

Capturing this information enables a detailed feasibility assessment that evaluates the:

- Desirability of hydrological restoration;
- Suitability of different restoration methods and parameters for meeting the goals of restoration, based (when possible) on inundation or impact scenario modelling;
- Impact on any neighbours to the wetland edge, as well as hydrological impacts both upstream and downstream; and,
- Identification of suitable ecological and/or hydrological measures for assessing post-restoration wetland response.

3.3 The merits of wetland restoration on public and private land

3.3.1 Modification of wetlands for agriculture

Wetlands provide examples of some of the most productive, adaptive and diverse ecosystems in southern Australia. Despite being relatively limited in geographic extent, the productivity of wetland soils has led to their extensive, often targeted development for agriculture. This has caused the loss of the vast majority of wetlands in the agricultural zone, and has left many remnant wetlands with highly compromised hydrology. The broad effect of this change has been to cause a general drying of the landscape, often reflected in reduced depth and duration of inundation of those wetlands that do remain.

This process of development has tended to follow a limited number of pathways, leading to several predictable ‘states’ for altered wetlands. This information is critical for understanding wetland restoration potential, by anticipating recovery trajectory and hence likely future condition. Examples of common pathways include:

a) **Private land**

Many comprehensively drained wetlands on private land were cleared and sown to introduced pasture species, while others have also subsequently been cropped. The bare summer surface of these sites greatly aids the identification of diversion points, drainage channels and breached banks, as well as simplifying digital terrain modelling (using processed LiDAR data in GIS software) to accurately evaluate a site’s physical attributes for restoration planning.

b) **Public land**

However on public land sites, often drained decades ago to improve stock access and the grazing potential of existing native vegetation (when previously leased or privately owned), the evidence of hydrological modification can be significantly more difficult to detect. In situations where stock grazing was removed long ago, perennial native vegetation can (subject to the wetland type) obscure the land surface, making the evidence of artificial drainage considerably less obvious to the naked eye during a site visit or indeed from analysis of aerial photography. This obscuring effect is further amplified by drainage usually resulting in larger, woodier types of perennial vegetation naturally establishing in response to a drying water regime – a process we describe as ‘terrestrialisation’.

By contrast, occasionally wetlands or waterways on public land have had their depth and duration of inundation (hence water storage capacity) increased, through the construction of levees, stop-banks, dam walls or weirs. A few noteworthy South Australian examples and the reasons for their creation (in brackets) include Bool Lagoon in the South East (for waterfowl hunting), Torrens Lake in Adelaide (for aesthetics and recreation) and a number of reservoirs (for the establishment of reliable potable urban water supplies).

3.3.2 Wetland ecosystem adaptability

The inherent adaptability of these ecosystems means that as long as a site continues to experience some form of semi-regular inundation (even if depth and duration has been greatly reduced), it will continue to function and appear as a wetland and support aquatic species. At physically uncleared sites typical of public land, this inherent flexibility to cope with variable climatic trends enables the rapid transition of native vegetation, with the physical shift of species down the elevation gradient in response to the new water regime.

As a result of the seamless efficiency of this natural response, many people in the scientific (let alone wider) community are often oblivious to the extent of hydrological modification that may have occurred on what is now reserved and perpetually protected public land. This can lead to an inadvertent, passive acceptance of existing threats to hydrology, locking in a trajectory of change that reflects the new, altered water regime rather than historic conditions, and which can then be readily exacerbated by other contemporary threats to water availability.

Key advantages of hydrological manipulation as a restoration technique include:

- the ability to introduce change in a deliberate, measured, staged and (if necessary to manage perceived risks) reversible way;
- the flexibility to choose and set a new hydrological regime that is likely to produce the desired ecological response, and that fits within the new socio-political landscape context;
- the knowledge that the ecosystem will, in all likelihood, rapidly adapt to the new water regime;
- the ability to choose from a range of responsive biotic indicators, based on what is the most appropriate measure (or surrogate measures where necessary) for defining the chosen goal state or simply for detecting a positive trajectory of change;
- the ability, wherever possible, to implement eventual permanent solutions based on the principle of having a ‘set and forget’ design, minimising ongoing management inputs and preventing unwanted interference in future operation;
- the fact that restoration works of this type leads to self-sustaining outcomes for nature conservation that will result from the new, prevailing water regime; and,
- the capacity to buffer against a drying climatic trend, surface flow interception, extractive use of groundwater and land-use change, which are all impacting on the availability (reliability and volume) of flows to wetland ecosystems.

3.3.3 Past wetland restoration works on private and public land – informing the restoration approach for swamps of the Fleurieu Peninsula

Over the last ten years a growing number of wetland restoration projects, specifically involving hydrological regime manipulation, have occurred across public and private land in South Australia and Victoria. A series of six examples that illustrate a diversity of potential situations in which artificial drainage can impact on wetland values and the way that these threatening processes were addressed, are presented in the **Appendices in Section 8**.

These examples, which involved Nature Glenelg Trust staff through their current or former employment, provide useful reference material because they represent a range of different:

- *Land tenures* – private and public land, as well as sites that straddle both or may have transitioned from private to public ownership.
- *Agricultural land development scenarios and histories* – varying across sites that were totally cleared, partially cleared, grazed or were undisturbed.
- *Drainage methods and impacts* – ranging across (or indeed combining) surface water diversions or drainage, breached sills and/or groundwater drainage.
- *Current conditions and hydrological scenarios*.
- *Socio-political circumstances*.
- *Restoration methods* – from inexpensive temporary works and trials, through to higher-cost permanent works or structures.

Perhaps most importantly, the case studies provide a clear reminder of the value of an 'ecosystem approach' to wetland management and restoration. While traditional environmental management approaches have tended to be sectoral, considering and addressing individual ecosystem components in isolation; hydrological processes in wetlands (by their very nature) demand a different scale of thinking and hence management philosophy.

The Ecosystem Approach:
is an integrated management philosophy that considers all ecosystem components; such as past and present human activities, habitats and species, and physical processes.

It is important to recognise that according to this approach, a lack of perfect scientific knowledge in itself is not a sufficient justification not to act to address agreed underlying threats to hydrology, where the detrimental impact of past human actions is clearly observable. Hence the ecosystem approach relies on learning by doing and developing a comprehensive, integrated management and monitoring regime through time, based on best available scientific knowledge about the ecosystem and its dynamics, and available resources.

4 Assessing Glenshera Swamp, Stipiturus Conservation Park as a test case for wetland restoration planning in Fleurieu Peninsula Swamps

4.1 Description of Stipiturus Conservation Park

Stipiturus Conservation Park is located on the Fleurieu Peninsula of South Australia, approximately 50 km south of Adelaide and six kilometres west of Mount Compass (Figure 4.1). The 68 hectare reserve is set within an agricultural landscape which has undergone a subsequent recent transition, in parts, to forestry plantations and extractive industry (mining of sand). The site itself was formerly used for grazing and dairy farming (DEH, 2007a). The local climate is temperate and falls within one of the wettest regions in South Australia, the Mt Lofty Ranges, where the majority of annual rainfall occurs throughout the winter months.

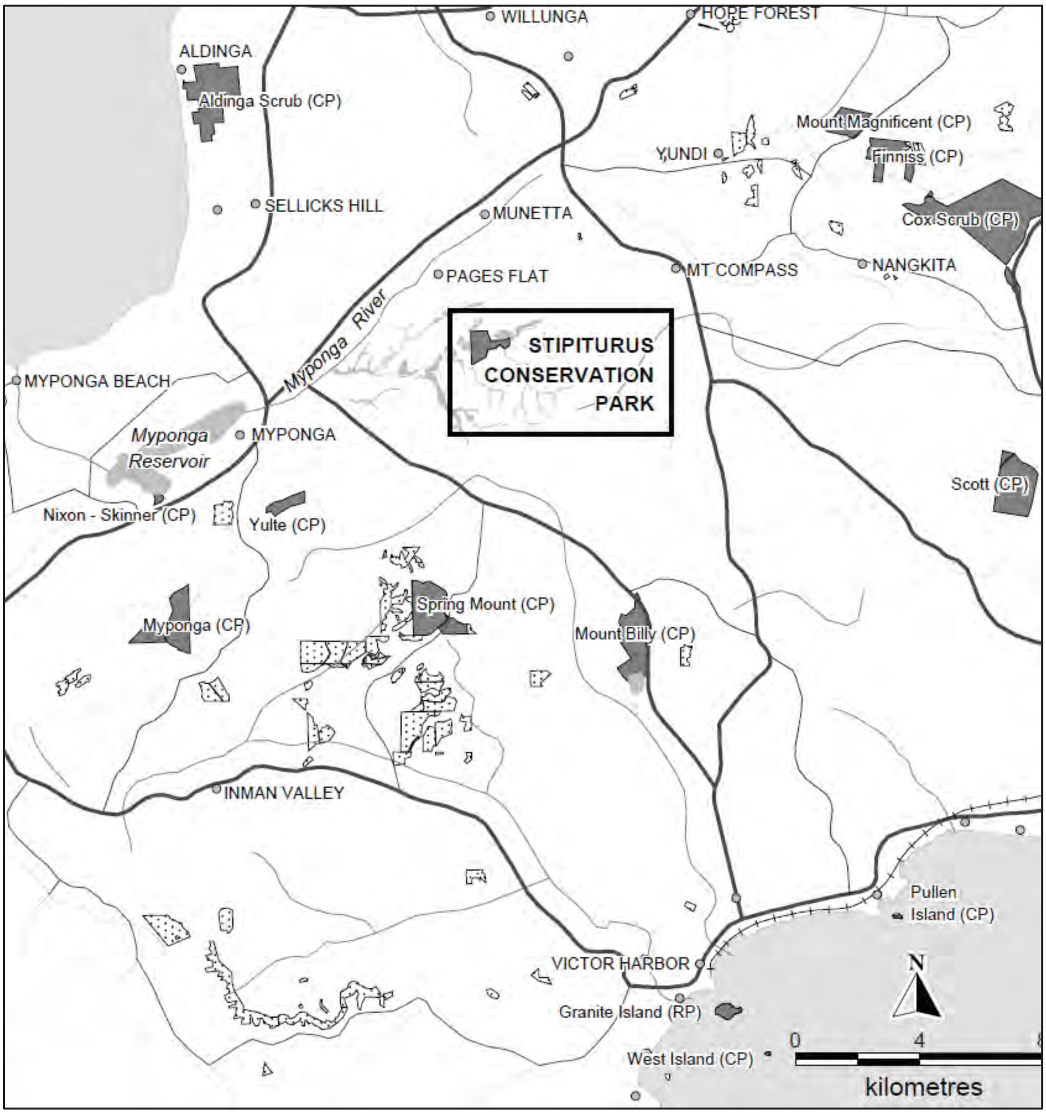


Figure 4.1 – The location of Stipiturus CP (from DEH, 2007a).

4.2 Land tenure and management considerations

4.2.1 Public land managers

Stipiturus Conservation Park was proclaimed in 2006, with an interim management plan in place from September 2004 (MLRSEWRP, 2004) and a formal management plan (under the NPW Act) endorsed and publicly released in 2007 (DEH, 2007a). From the reserve management perspective, local DEWNR staff have a particular interest in ensuring the priorities in the Stipiturus Conservation Park Management Plan are implemented (Steve Johnson, Senior Ranger NR AMLR, pers. comm.). The overall vision of the plan is:

to have a healthy wetland ecosystem that supports a flourishing Mount Lofty Ranges southern emu-wren population and that provides important habitat for other species of conservation significance.

This project partially addresses a number of strategies that fall within the following key objective in the plan that relates to hydrology: *"Maintain an appropriate hydrological regime to conserve the biological values of the park"*.

In particular the final strategy, *"investigating the possibility of inducing changes to the hydrological regime, to assist in managing internal threats, providing that this does not adversely affect other conservation values"* (DEH, 2007a), provides the key objective for this report.

4.2.2 Adjacent private landowners

Although predominantly situated with the reserve, Glenshera Swamp actually straddles the park boundary, with approximately 10-15% of the currently mapped wetland area occurring to the west of the reserve, on the downstream private property.

Nature Glenelg Trust staff have not yet been in direct contact with the private downstream landowner; however, Natural Resources AMLR staff maintain regular contact and after recent discussions have confirmed a willingness to include the property in the restoration options suggested in this document (Jacqui Best, District Officer NR AMLR, pers. comm.). This is an extremely positive development and a key consideration in this report, because meeting the hydrological requirements for wetlands that straddle cadastral boundaries requires a high degree of neighbourly cooperation and understanding. The management flexibility this provides over time will ensure that the best possible hydrological options for the site can be tested and delivered.

4.2.3 Wider consultation

Stipiturus CP is one of the most important remaining sites for a nationally threatened wetland ecological community, which in turns hosts a range of threatened species of regional, state and national significance. Hence, it is not surprising that a wide range of government agencies, NGOs, research organisations, interest groups and individuals have a stake in ongoing survey, research and conservation management activities in the park. As a result, a wide range of people have been consulted over the course of this short project; through liaison on-site (during NGT visits in September and October 2015), and through other communication activities, including presenting on the progress of the eco-hydrological investigation at the October 2015 Mount Lofty Ranges Southern Emu-wren / Fleurieu Peninsula Swamps (MLRSEW/FPS) Recovery Team meeting at Willunga.

Meeting with key experts on site (e.g. Figure 4.2) provided an opportunity to capture a wide range of perspectives on management, distribution data for key species and observations of how the site has changed over time. It also gave us an opportunity to talk over the logic of wetland restoration in the context of the site and its hydro-ecological characteristics, while looking at the on-ground evidence of past drainage activities. A great deal of progress was made towards development of the hydrological restoration approach for the site through these informal discussions, as reflected in later sections of this report.

We are extremely grateful to the following individuals and groups for speaking with us to share their ecological knowledge of the site:

- Jason van Weenen, ecology (DEWNR)
- Jacqui Best, land management (DEWNR)
- Rebecca Duffield, ecology (CCSA)
- Julie Schoefield, ecology (CCSA)
- Marcus Pickett, avian ecology (CCSA)
- Tim Vale, ecology (CCSA)
- David Deane, hydrology (Adelaide Uni)
- Martin Stokes, water planning (DEWNR)
- Steve Johnson, public land management (DEWNR)
- Clive & Claire Chesson, flora (Friends of Parks)
- Tim Jury, flora (NCSSA)
- Rick Davies, flora (DEWNR)
- Tim Fearon, avian ecology (Adelaide Uni)
- Penny Paton, weed management
- The MLRSEW/FPS Recovery Team

Figure 4.2 – On-site meeting with flora experts on the 10th of September 2015

Left to right: Tim Jury, NGT's Lachlan Farrington, Clive and Claire Chesson, and Rick Davies

4.3 Property history and development

4.3.1 Management history prior to 1949

In 1925, the first portions of what became known as the Glenshera property were purchased by Mr Fred N. Simpson, with a series of subsequent purchases until the mid-1950s further enlarging the property (Jeff Merritt, pers. comm.). Fred Simpson, Figure 4.3, was a businessman and director of A. Simpson & Son, a manufacturing business founded by his grandfather Alfred Simpson in 1853 (The Register, 1928); later widely known for its whitegoods. His sons and grandson continued family control of Glenshera until it was gradually subdivided and sold from the early 1990s, up until 2004 (Jeff Merritt, pers. comm.). It was during this period, in 2003, that Glenshera Swamp was purchased by the South Australian Government.

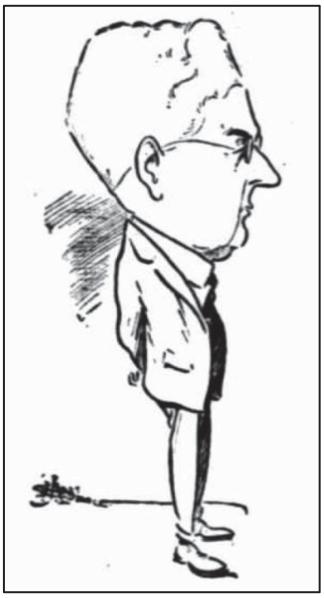


Figure 4.3 – An impression of Fred Simpson by the cartoonist at The Register in 1928.

The groundwork for opening up the lands not previously considered worth developing for agriculture, including the parts of southern Mt Lofty Ranges dominated by sandy soils of lower natural fertility, was being undertaken around the time of Fred Simpson's purchase in the 1920s. For example, when giving a lecture on "Scientific Agriculture" in May 1928, Mr W. R. Birks from the Roseworthy Agricultural College described how land had trebled in value over a 15-20 year period up to that point since the introduction of farming systems based on superphosphate and clover. He stated that "land which had previously carried half a sheep to the acre now carried five with ease". He went on to express the opinion that in South Australia "millions of acres of land now considered worthless would in the near future be brought into bearing" (Chronicle, 1928).

Ultimately it turned out to be a very accurate prophesy, after a series of trials in the Mount Compass district enabled and encouraged clearance in the region to accelerate over subsequent decades. For example, a few years after the property was purchased, an article in the Register from 1929 describes pasture trials being conducted by Fred Simpson on the Glenshera property; while an article from a year later in the Chronicle (1930), describes in great detail a before and after portrait of the land in the vicinity of Mount Compass, as it was converted from "Scrub to Pasture Fields":

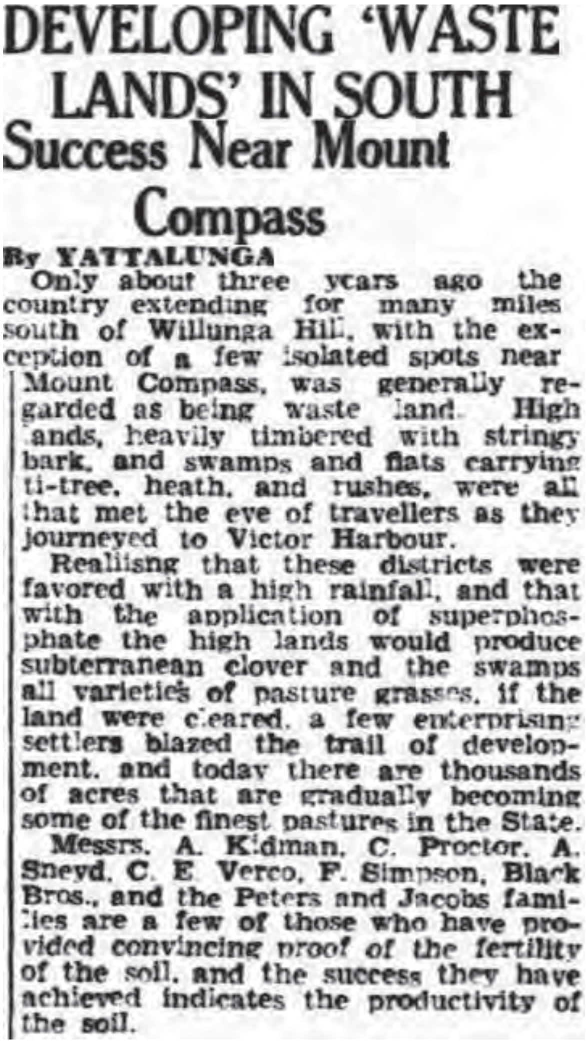
> *"here was the first striking instance of what the land, regarded in the past as useless, will produce. Stunted stringybark, and bull oak, yacca, heath and broom bush, covered the slopes, and dense ti-tree occupied the swamps. The soils on the slopes and hills comprise light sand with a clay subsoil, and an ironstone gravel, and in the swamps heavy sands and land of a black peaty like substance."*

The article goes on to say that the:

> *"aim was to bring this land into production with the least possible expense, and the first task was to roll and burn the scrub. By using a heavy roller studded with iron spikes, the soil was broken to an extent sufficient to permit a drill to be used. From 8 to 12 pounds of subterranean clover, according to the grade of the seed, was planted, with a bag of superphosphate, to the acre, and in parts perennial rye grass was also sown with the clover. The results have been entirely satisfactory, and the 600 acres put down in clovers will, when established, carry at least two sheep to the acre. In addition to the sown pastures, the top dressing has resulted in a splendid growth of native clovers and grasses."*

On the 3rd of November 1934, the Advertiser ran an article (below right) about the development of the country near Mount Compass, again mentioning the owner of the Glenshera property, Mr Simpson:

> *"Only about three years ago the country extending for many miles south of Willunga Hill, with the exception of a few isolated spots near Mount Compass, was generally regarded as being waste land. High lands, heavily timbered with stringy bark, and swamps and flats carrying ti-tree, heath, and rushes, were all that met the eye of travellers as they journeyed to Victor Harbour. Realising that these districts were favoured with a high rainfall, and that with the application of superphosphate the high lands would produce subterranean clover and the swamps all varieties of pasture grasses, if the land were cleared, a few enterprising settlers blazed the trail of development, and today there are thousands of acres that are gradually becoming some of the finest pastures in the State."*



DEVELOPING 'WASTE LANDS' IN SOUTH

Success Near Mount Compass

By YATTALUNGA

Only about three years ago the country extending for many miles south of Willunga Hill, with the exception of a few isolated spots near Mount Compass, was generally regarded as being waste land. High lands, heavily timbered with stringy bark, and swamps and flats carrying ti-tree, heath, and rushes, were all that met the eye of travellers as they journeyed to Victor Harbour.

Realiisng that these districts were favored with a high rainfall, and that with the application of superphosphate the high lands would produce subterranean clover and the swamps all varieties of pasture grasses, if the land were cleared, a few enterprising settlers blazed the trail of development, and today there are thousands of acres that are gradually becoming some of the finest pastures in the State.

Messrs. A. Kidman, C. Proctor, A. Sneyd, C. E. Verco, F. Simpson, Black Bros., and the Peters and Jacobs families are a few of those who have provided convincing proof of the fertility of the soil, and the success they have achieved indicates the productivity of the soil.

We are fortunate that the area encompassing what today is Stipiturus Conservation Park, was broadly surveyed in 1881 and again in much greater detail in 1899, as well as being photographed while still largely intact in 1949.

Figures 4.4 and 4.5 confirm the description in the previous articles, of high, sloped country supporting sandy stringybark scrub, and swampy flats in the wettest part of the valley "covered with low tea-tree, sedge grass and rushes". The upslope seepage zone surrounding Glenshera Swamp was considered to be "inferior peaty land covered with low tea-tree".

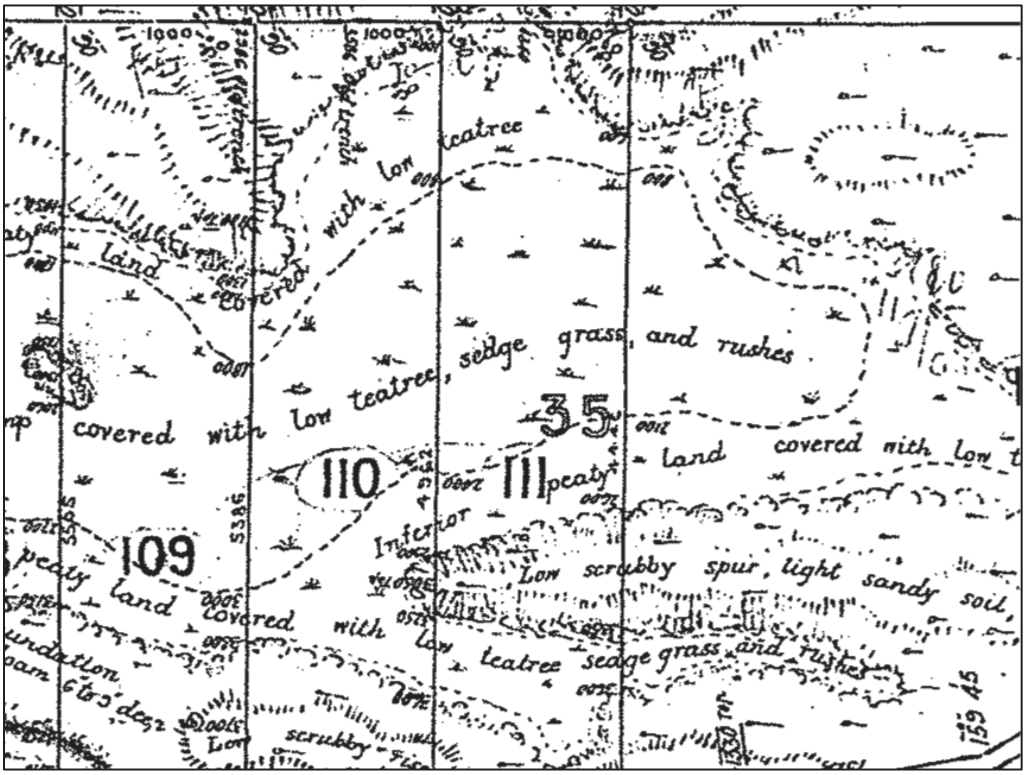


Figure 4.4 – February 1899 survey diagram of Glenshera Swamp.

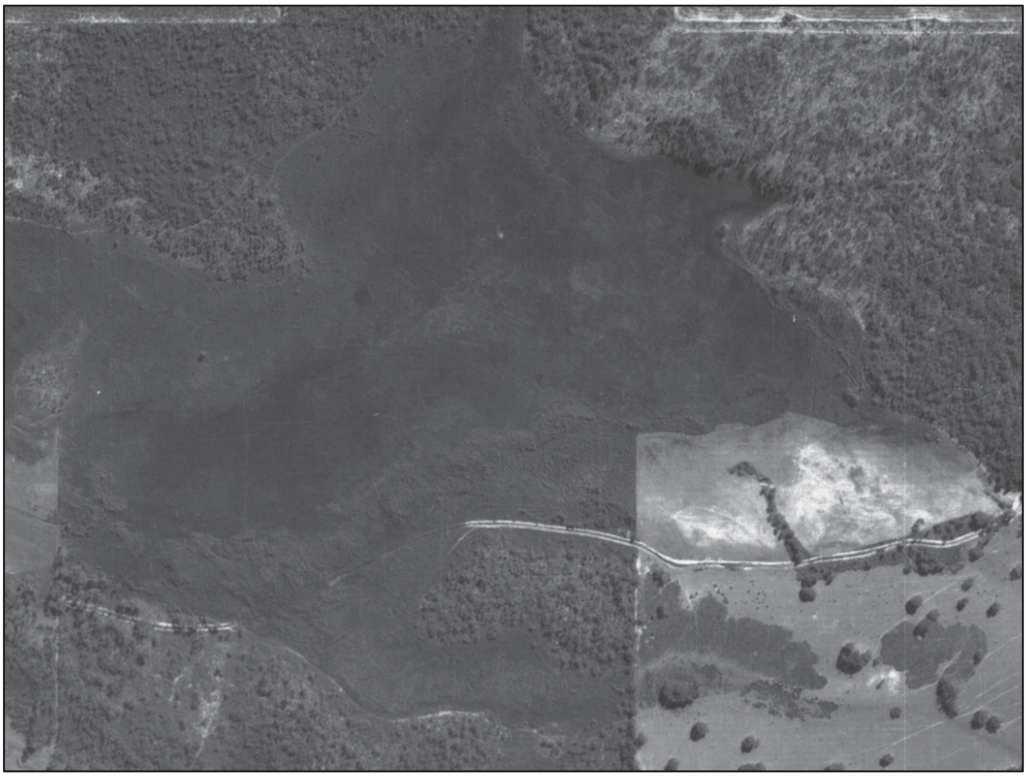


Figure 4.5 – April 1949, the first aerial image of Glenshera Swamp (same extent as image above)

In December 1936, the Chronicle published an article about a visit by the Minister for Agriculture to the Mount Compass District which featured the Glenshera property:

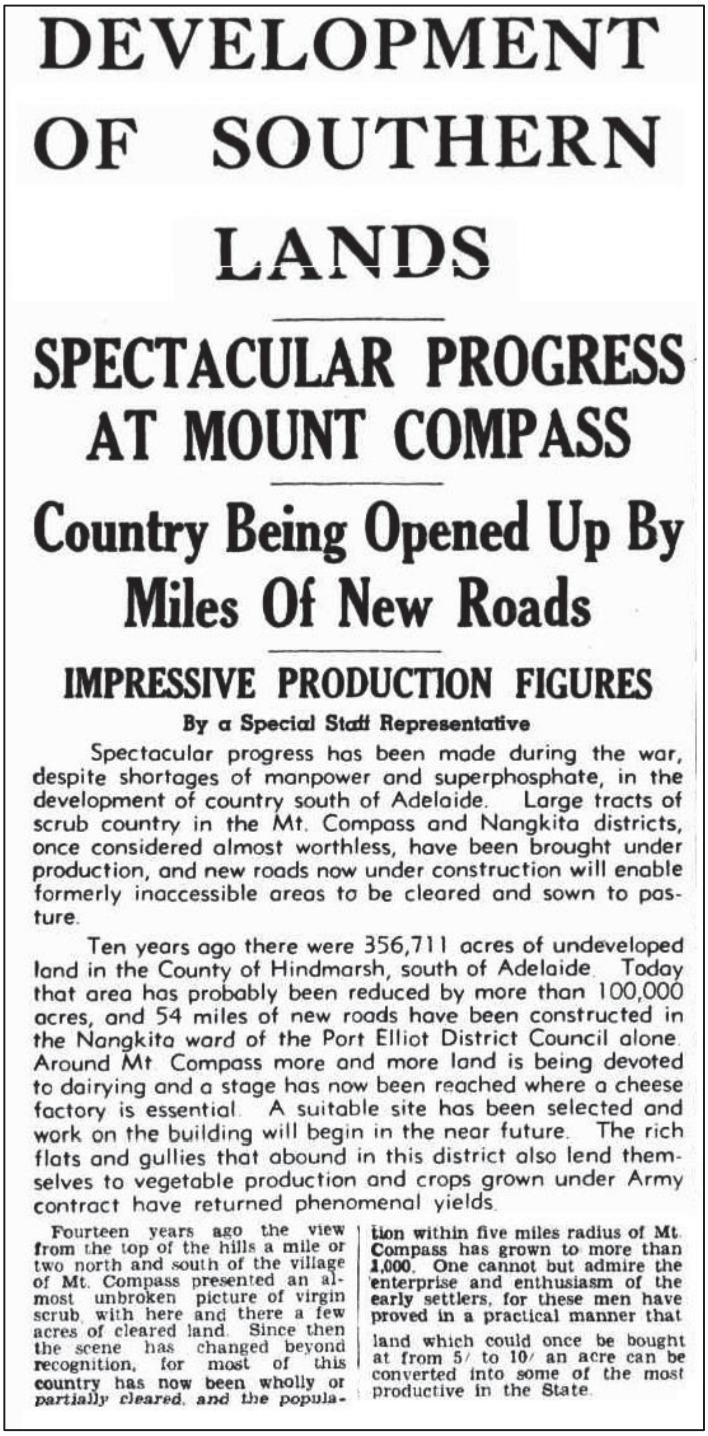
> *“Most of the time available to the Minister was taken up in a detailed inspection of the work being done at 'Glenshera', the property of Mr. F. N. Simpson; where about 2,000 acres of former scrub are now carrying pastures or are to be seeded next autumn. Mr. Simpson is convinced that after breaking down the scrub it should be burnt, thoroughly ploughed and then treated as fallow for some months before seeding is carried out. Following this method, and being liberal with superphosphate at seeding and also each following year, great success had been attained by Mr. Simpson.*

The final historical article (right) presented from that era is from January 1946, and provides an overview of land development that had occurred over the preceding 10 years, up until just before the date when the aerial photograph presented in Figure 4.4 was taken.

The article estimates that over a 10 year period approximately 100,000 acres (or 40,000 hectares) of land had been cleared and developed “despite shortages of manpower and superphosphate” during the war years:

> *“Fourteen years ago the view from the top of the hills a mile or two north and south of the village of Mt. Compass presented an almost unbroken picture of virgin scrub, with here and there a few acres of cleared land. Since then the scene has changed beyond recognition…”*

Again the owner of Glenshera, Mr Simpson is mentioned as a pioneer of development in the article.



DEVELOPMENT OF SOUTHERN LANDS

SPECTACULAR PROGRESS AT MOUNT COMPASS

Country Being Opened Up By Miles Of New Roads

IMPRESSIVE PRODUCTION FIGURES

By a Special Staff Representative

Spectacular progress has been made during the war, despite shortages of manpower and superphosphate, in the development of country south of Adelaide. Large tracts of scrub country in the Mt. Compass and Nangkita districts, once considered almost worthless, have been brought under production, and new roads now under construction will enable formerly inaccessible areas to be cleared and sown to pasture.

Ten years ago there were 356,711 acres of undeveloped land in the County of Hindmarsh, south of Adelaide. Today that area has probably been reduced by more than 100,000 acres, and 54 miles of new roads have been constructed in the Nangkita ward of the Port Elliot District Council alone. Around Mt. Compass more and more land is being devoted to dairying and a stage has now been reached where a cheese factory is essential. A suitable site has been selected and work on the building will begin in the near future. The rich flats and gullies that abound in this district also lend themselves to vegetable production and crops grown under Army contract have returned phenomenal yields.

Fourteen years ago the view from the top of the hills a mile or two north and south of the village of Mt. Compass presented an almost unbroken picture of virgin scrub, with here and there a few acres of cleared land. Since then the scene has changed beyond recognition, for most of this country has now been wholly or partially cleared, and the population within five miles radius of Mt. Compass has grown to more than 1,000. One cannot but admire the enterprise and enthusiasm of the early settlers, for these men have proved in a practical manner that land which could once be bought at from 5/ to 10/ an acre can be converted into some of the most productive in the State.

4.3.2 Site development and change after 1949

4.3.2.1 Vegetation clearance

The trend of development previously described, that was already underway in the 1920s and 30s, saw a dramatic increase through upscaling of mechanised land clearance after World War II. The result for the remnant biodiversity of the Mt Lofty Ranges was drastic, leading to the loss of over 60% of the native vegetation that still remained in 1945, by just 35 years later in 1980 (see Figure 4.6).

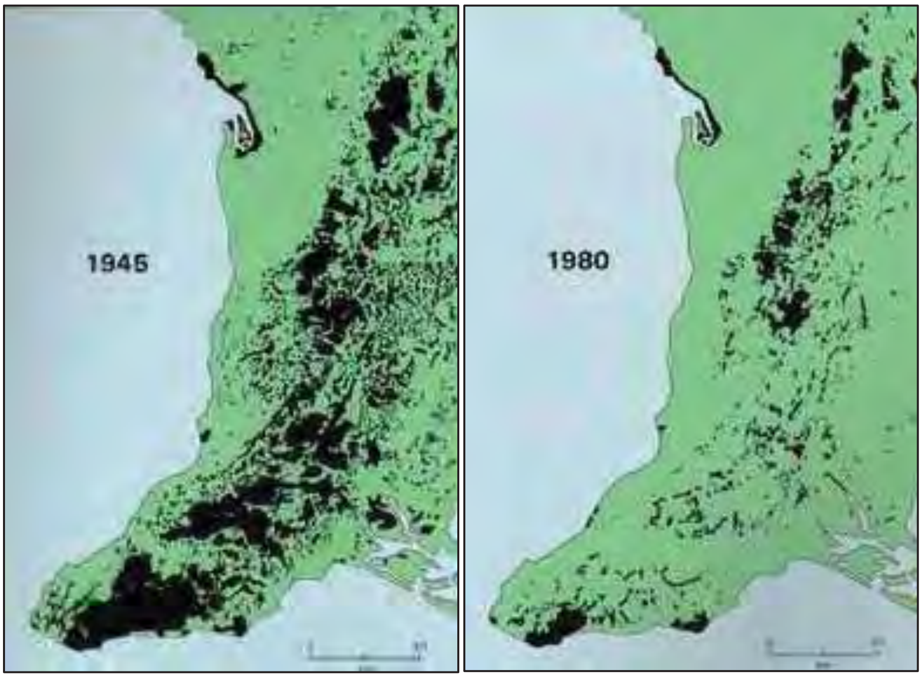


Figure 4.6 – Of 240,000 hectares of native vegetation present in the Mt Lofty Ranges in 1945, only 90,000 hectares remained in 1980, a decline of 62.5%.

Although it is clear from the references provided that the wider Glenshera property was under progressive development before this time, the portion that contains Glenshera Swamp is fortunate to have largely escaped modification until the first aerial photograph was taken in 1949 (Figure 4.5). At this time, only a small part of the swamp margin has been cleared, and the first (at that time clearly recent) evidence of artificial drainage is also evident, with the construction of a channel that diverts surface flows from the creek – bypassing the bulk of the remnant swamp that remains today.

Regular aerial photography since that time has made it possible to construct in detail a timeline of change, most of which corresponds with the 35 year period highlighted in Figure 4.6, before the advent of legislated native vegetation protection measures in 1983 and 1985. Indeed, the accelerating rate of loss observed in the agricultural districts of South Australia in the 1970s was one of the primary reasons for the state being the first in Australia to introduce such measures.

Figure 4.7 shows the sequential change in Glenshera Swamp over a 50 year period of the aerial photographic record, while Figure 4.8 presents this consolidated information for the wider catchment on a single map.

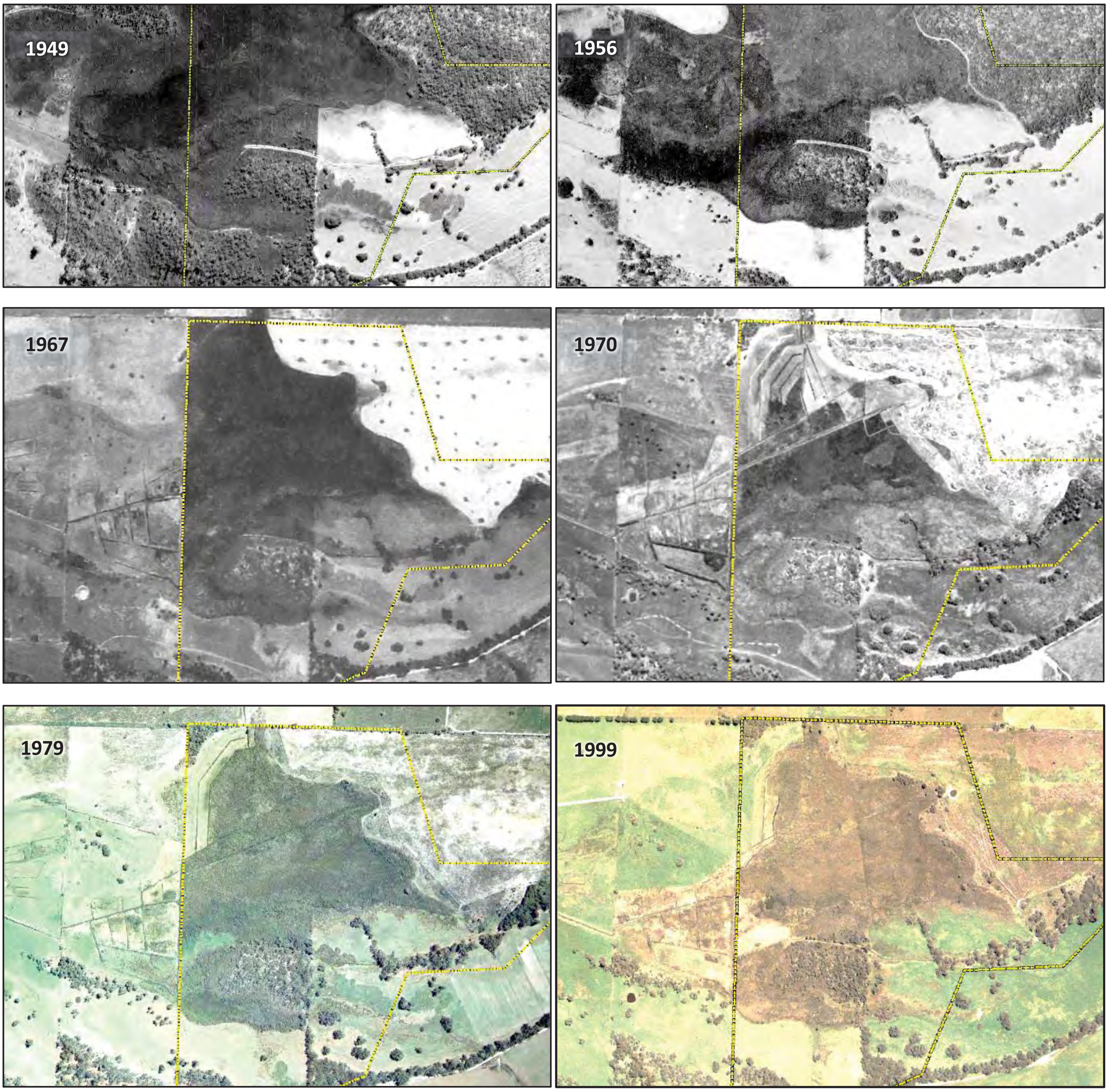


Figure 4.7 – An aerial view of Glenshera Swamp, showing development in and around the swamp (clearance of native vegetation) between 1949 and 1999. Note the reduction in clearance activities after 1979.

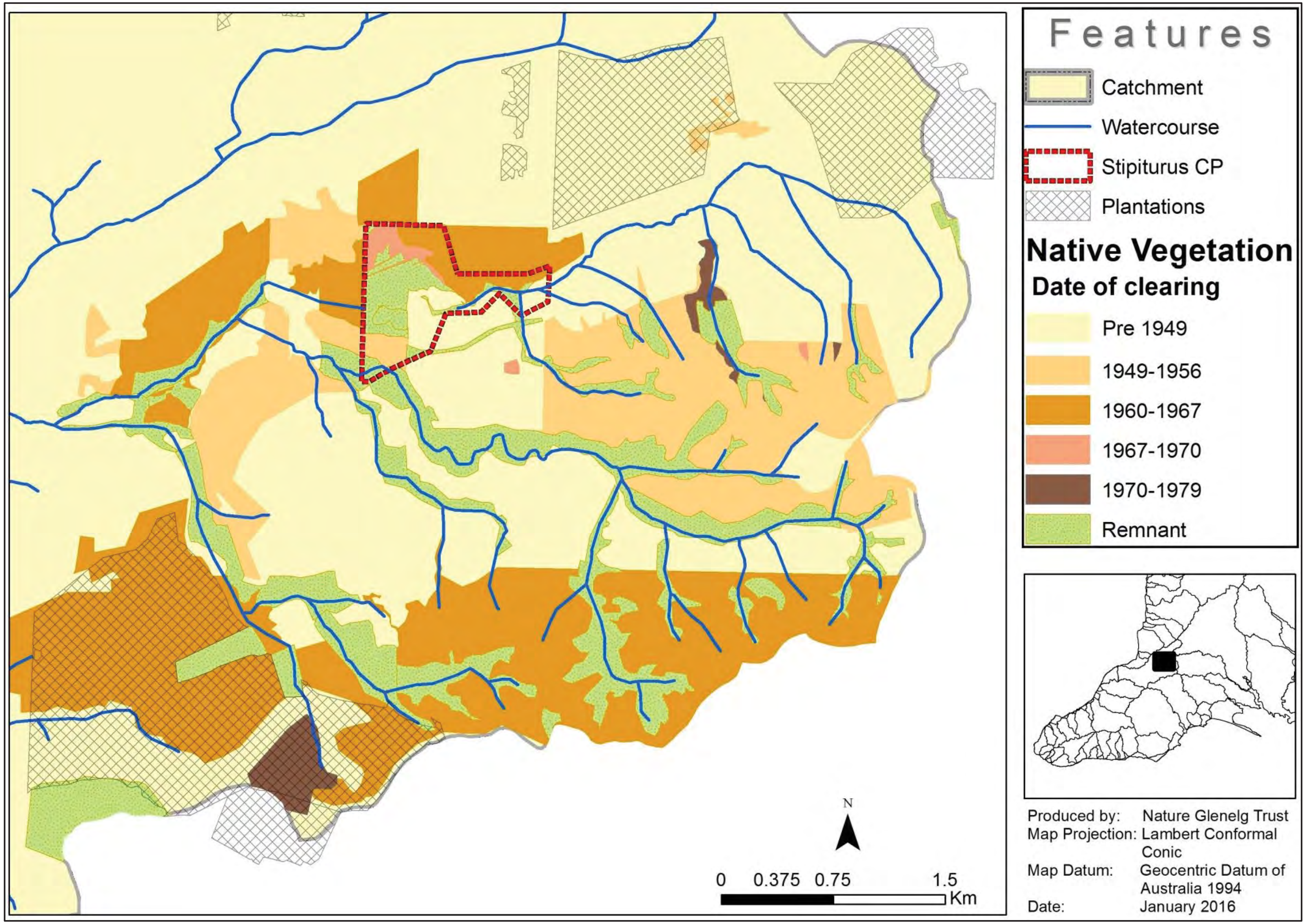


Figure 4.8 – A timeline of modifications to vegetation cover in the catchment of Glenshera Swamp.

4.3.2.2 On-site changes to drainage

The history of clearance in wetlands is usually closely associated with modifications to site drainage, given the relationship between the two activities – i.e. improved drainage provided both access to enable clearance and the conditions necessary for subsequent pasture establishment.

A specific analysis of hydrological changes across the property based on the aerial photographic record (see Figures 4.9 and 4.10) corresponds with the anecdotal information verbally provided by Jeff Merritt, the former manager of Glenshera for 18 years (from 1985-2003). Prior to that time, he also worked on the property as a farm hand from 1979-1982 (Jeff Merritt, pers. comm.).

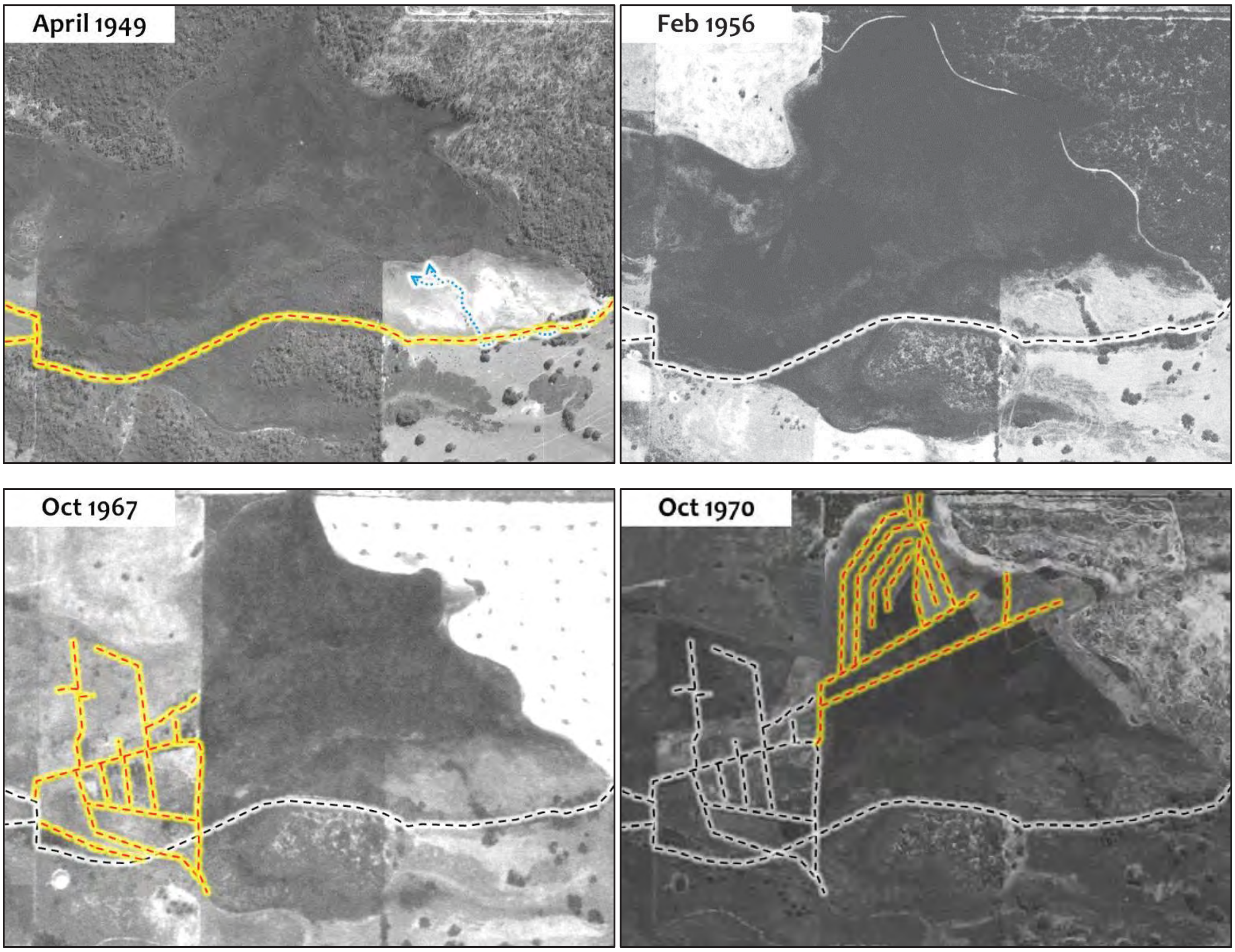


Figure 4.9 – An aerial view of Glenshera Swamp, showing a timeline of artificial drainage in and around the swamp from the 1940s to 1970.

General direction of flow is east to west (right to left across the image).

The red lines indicate a new drain that was dug since the last image, while the black lines are pre-exiting drains. The blue line on the first image is the original course of the natural creekline.

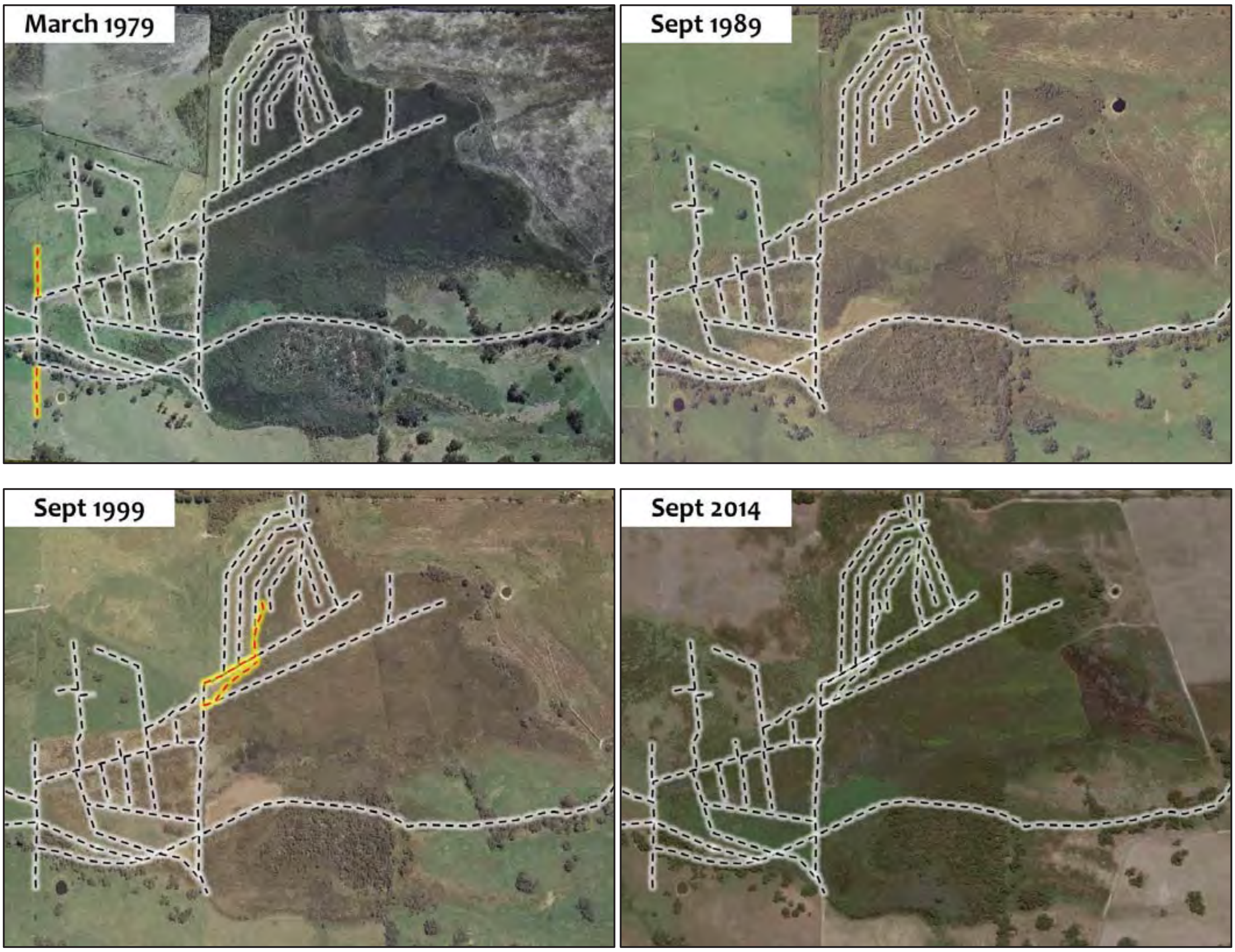


Figure 4.10 – An aerial view of Glenshera Swamp, showing a timeline of artificial drainage in and around the swamp from the 1979 to present. The red lines indicate a new drain that was dug since the last image, while the black lines are pre-exiting drains.

Jeff stated that not long after taking over property management in the 1980s, several of the drains in the swamp were cleaned out to improve stock access for grazing, but that no further drain maintenance or construction works occurred after that time; with the exception of a small amount of extra drainage installed on the northern edge of the swamp in the late 1990s (see Sept 1999 image in Figure 4.10 for confirmation). The contractor who undertook this work in the 1980s, Bob McAllan, was the same operator who had excavated the drains throughout Glenshera Swamp over the previous two decades. Apparently Bob McAllan was the main contractor responsible for working with landholders to achieve the effective drainage of the swamps in and around the Mount Compass district during that era of agricultural development (Jeff Merritt, pers. comm.).

Earlier drainage works undertaken within and immediately downstream of the site are evident by assessing the images in Figures 4.9 and 4.10. The first flow management modifications were made to the creek which enters the swamp from the east. This meandering inflow was channelised prior to 1949, forcing inflows to effectively bypass the central swamp area. Aerial imagery reveals a greater level of vegetation zonation in later years and also indicates changes in saturation or inundation zones.

Sometime between 1960 and 1967, extensive drainage works were undertaken on the western boundary of what is now the park, at the outflow edge of the main swamp, feeding into the main arterial drains that were established prior to 1949. In doing so, this activity attempted to more comprehensively drain the western part of the swamp. This area to the west of the park is still privately owned today, but is fenced to exclude livestock and managed in a complementary way (Jacqui Best, pers. comm.) to the Conservation Park. Despite this, the disturbance history of this area (apparent in Figure 4.7) is clearly evident from its more degraded current condition.

Between 1967 and 1970, further drainage works were undertaken in the section of the swamp that falls within the current Conservation Park boundaries. These works were aimed at both draining the swamp bed and facilitating water movement from the northern slopes via drains running through the lower flats and channels contoured to the slopes. Imagery reveals that vegetation cover had returned by 1979, suggesting that efforts to reclaim some portions of the swamp through these activities were ultimately unsuccessful.

Other works on the wider property overseen by Jeff Merritt that influenced the catchment included the construction of a small number of dams across the Glenshera estate, including the one situated to the north-eastern side of the swamp in the 1980s (Figure 4.11 – which can also be seen from the air by comparing the 1979 and 1989 images in Figure 4.10). Also note the gradual reduction in dam volume at the same time of the year in the photos since 1989 in Figure 10, providing a form of basic evidence to support the notion that the catchment has been undergoing a drying trend over recent decades.

Figure 4.11 – The dam in Stipiturus CP, of 1980s construction, which intercepts hill-side seepage.

This observation is also reflected in the data collected from the groundwater observation well network, with nearby monitoring wells (6627-09127 and 6627-09500) recording groundwater level declines between 2000 and 2007. Groundwater levels did not fully recover in the wetter period from 2010 to 2012, and have since remained stable (but below historic levels) for the past five years (DEWNR, unpublished data).

Specifically in terms of the management of Glenshera Swamp, Jeff Merritt explained that the drains were maintained in order to make the swamp more accessible, and hence viable, for stock grazing. The swamp was stocked with dairy cattle, while sheep grazing was restricted to the higher sandy country on the surrounding hills. No attempts were made to physically clear the swamp during his time on the property from 1979 to 2003, as it was not considered viable due to the depth to shallow groundwater which persisted year-round (Jeff Merritt, pers. comm.).

4.3.2.3 Upstream catchment changes

In order to better understand upstream catchment changes (which influence runoff and recharge), aerial imagery was used to determine changes in vegetation cover and surface flow interception since 1949. By using images from 1949 through to the present day, an overview of both the extent and timeline of changes within the local catchment has been produced (Figure 4.12). As shown in the time sequence data presented in Figure 4.8, large amounts of native vegetation clearance had already occurred by the time the first aerial imagery was collected in 1949 and continued to occur at a significant rate through to 1956.

Further small losses of riparian vegetation occurred between 1960 and 1976 but the general subsequent trend over the last 20 years has been an increase in vegetation cover, albeit non-native, primarily through the establishment of hardwood plantations. These Tasmanian blue-gums were planted along deep ripped mounds that follow the contours of the hills, at right angles to the slope, causing an instant change in catchment behaviour as a result of the plantations intercepting almost all available runoff (Jeff Merritt, pers. comm.). Dams on tributaries were mostly constructed since 1961, and there has been a notable increase since 2000 (Figure 4.12), corresponding with a period of reduced water availability and below average rainfall.

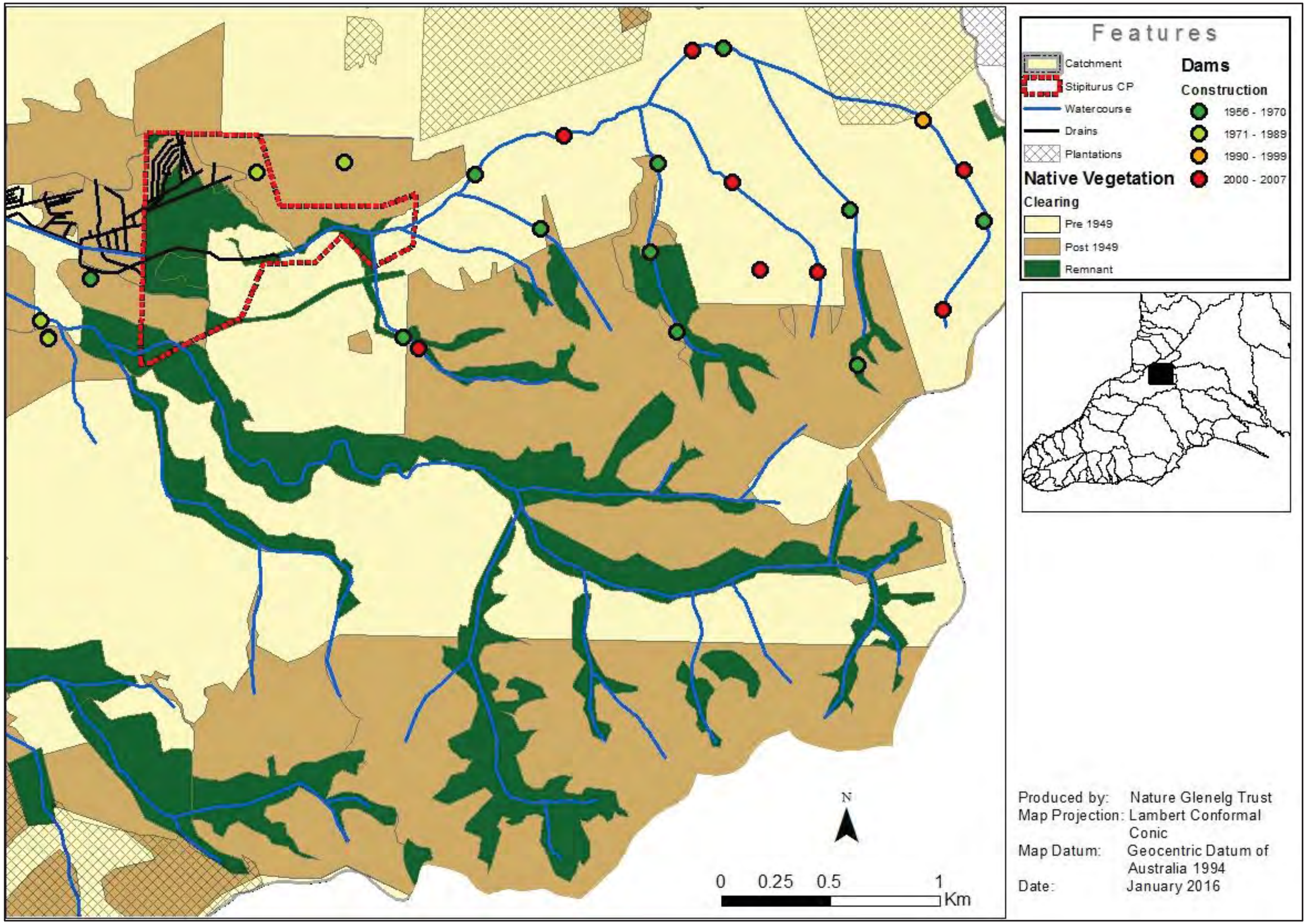


Figure 4.12 – Dam construction and vegetation clearance in the catchment for Glenshera Swamp since 1949

4.4 Conservation values

4.4.1 Vegetation Associations

The critically endangered swamps of the Fleurieu Peninsula (EPBC Act 1999) are densely vegetated, associated with waterlogged soils around low lying creeks and flats, and are characterised by reedy or heathy vegetation growing on peat, silt, peat silt or black clay soils (DEH, 2007b). In their natural form, Fleurieu Peninsula swamps are characterised by a mosaic of varied structural formations which merge into one another across ecotones, depending on soil, hydrology and terrain. Tree life forms are mostly absent, and are replaced by a shrub habit.

Dominant or co-dominant overstorey species include the sclerophyllous shrubs *Leptospermum continentale*, *Leptospermum lanigerum*, *Melaleuca squamea*, *Melaleuca decussata*, *Sprengelia incarnata* and *Acacia provincialis* and *Viminaria junce*a. *Viminaria juncea* and *Acacia provincialis* can also be present as an emergent species rather than dominant overstorey. Dominant understorey species are typically sedge and rush genera such as *Baumea*, *Juncus, Eleocharis*, *Lepidosperma*, *Empodisma* and *Gahnia* species and ferns *Gleichenia microphylla*, *Blechnum minus* and *Pteridium esculentum* (Duffield *et al.* 2000).

The highest stratum is a medium to tall shrub layer, the medium stratum is a tall sedge and/or fern layer and the ground layer stratum can be a variety of herbaceous, grass or low-lying sedges. Scattered gums (e.g. *Eucalyptus ovata* and *Eucalyptus cosmophylla*) are sometimes found around the drier edges. Vegetation has been mapped previously and the functional groupings for zones of the swamps has been inferred based on dominant vegetation types, according to wetland functional groups proposed by Brock and Casanova (1997) and applied locally (Casanova and Zhang, 2007; Vanlaarhoven and van der Wielen, 2009) (Figure 4.13). Under this classification, polygons mapped by Duffield and Bailey (2010) were retrospectively assigned to one of four groups:

1. **Ate** – amphibious tolerator / emergent;
2. **Se** – submerged / emergent;
3. **Tda** – terrestrial damp; and,
4. **Tdr** – terrestrial dry.

An additional assignment (weedy) was made for areas where weed cover was greater than 50% and functional grouping is unlikely to inform future conservation priorities. Not surprisingly, the wettest vegetation (Se and Ate) occupies the lower elevation areas of the wetland area and/or areas where surface inflows are concentrated. A majority of the area which has been historically cleared and/or disturbed contains communities at the drier end of the hydrological requirement spectrum and/or those which have become predominantly covered by exotic species.

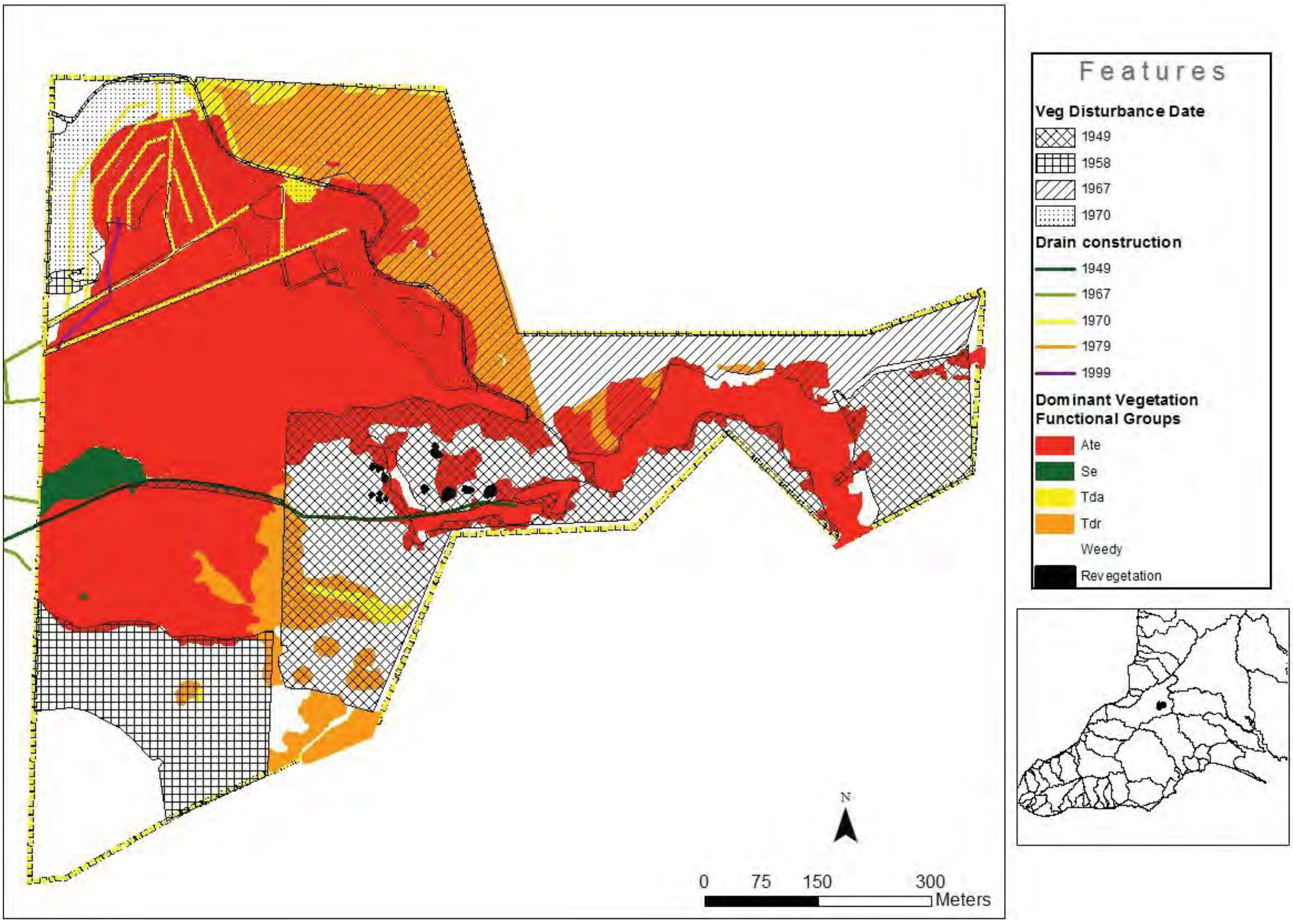


Figure 4.13 – Functional groups for dominant vegetation types (adapted from Duffield and Bailey, 2010), overlayed with the year and area of historical land disturbance, or more recent revegetation areas, within Stipiturus Conservation Park

4.4.2 Significant flora and fauna

Terrestrial Fauna

Stipiturus Conservation Park is probably best regarded for its diversity of native birds. It formerly contained the second largest swamp population (~15 pairs in 1999–2000, but 2–4 pairs in 2015) of the Mount Lofty Ranges southern emu-wren (*Stipiturus malachurus intermedius*) (Pickett, 2015a), the species after which the park was named. The park is also the most north-westerly occurrence and last remaining swamp population of southern emu-wren in the Adelaide and Mount Lofty Ranges NRM region (noting that the Fleurieu Swamps ecological community straddles NRM regional boundaries, also occurring in the SA Murray Darling basin NRM region).

Stipiturus Conservation Park supports three other bird species of conservation significance i.e. golden-headed cisticola (*Cisticola exilis exilis*), Latham's snipe (*Gallinago hardwickii*) and Lewin's rail (*Lewinia pectoralis*). Other significant terrestrial fauna include the nationally endangered southern brown bandicoot (*Isoodon obesulus obesulus*) and at least two significant invertebrates, the donnysa sedge-skipper (*Hesperilla donnysa donnysa*) and flame sedge-skipper (*Hesperilla idothea clara*).

The southern emu-wren is of particular significance in the management focus of the park as the species has limited capacity to move between what are now fragmented habitat units across the Fleurieu Peninsula and also appear to have developed specific habitat preferences in the region – likely linked to site productivity (Tim Fearon, pers. comm.).

They typically reside in dense, low vegetation and in Stipiturus Conservation Park are found in areas dominated by prickly tea-tree *Leptospermum continentale*, silky tea-tree *Leptospermum lanigerum*, *Empodisma minus*, red-fruit cutting-grass *Gahnia sieberiana*, sedges (e.g. *Baumea* spp., *Lepidosperma* spp.) and ferns (e.g. *Blechnum minus*, *Gleichenia microphylla*) (Littlely and Cutten 1994), but with an apparent preference for those areas still dominated by sedges as opposed to areas where shrubs and/or coral fern dominate (Tim Fearon, pers. comm.). An indication of habitat importance for the Mount Lofty Ranges southern emu-wren is provided below in Figure 4.14 (from Pickett, 2015b).

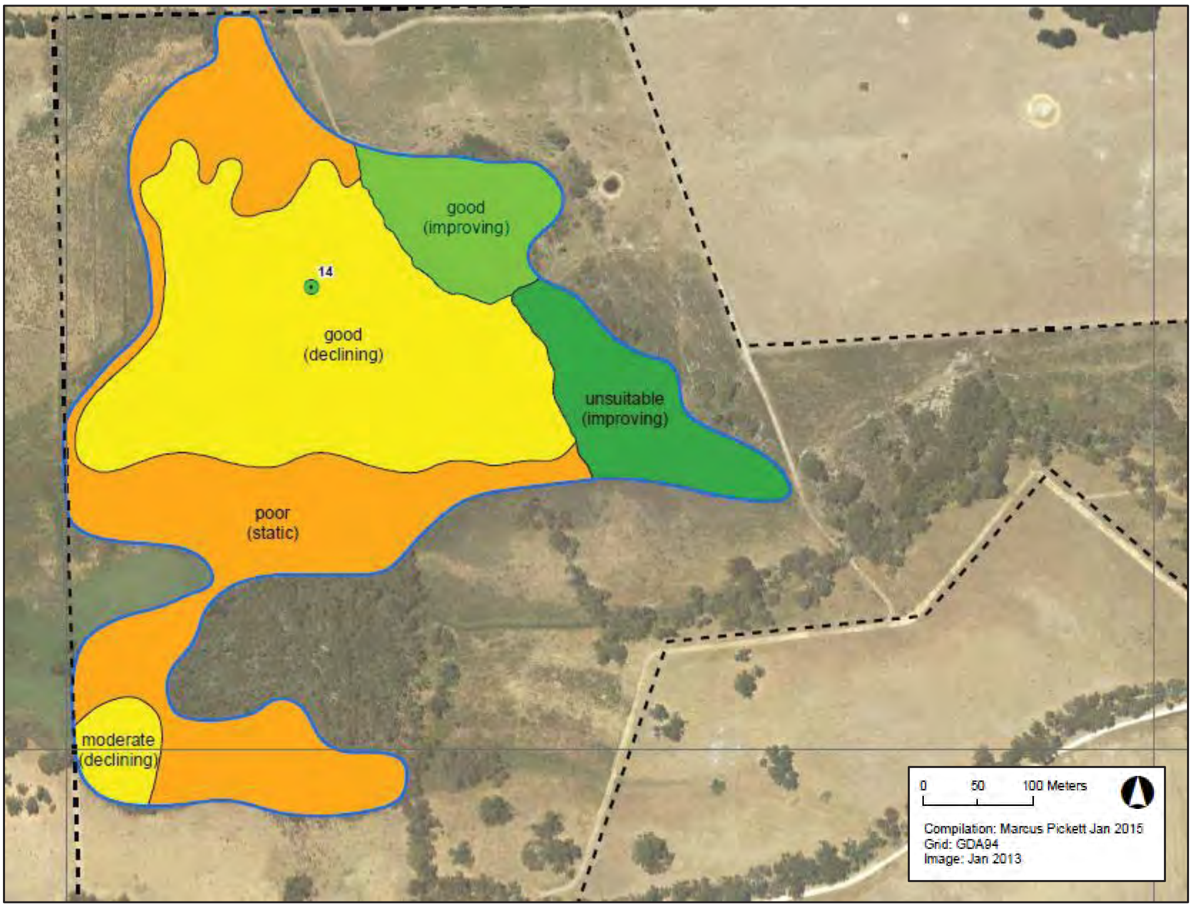


Figure 4.14 – Habitat value for the southern emu-wren in Glenshera Swamp, as recorded in December 2014 (from Pickett, 2015b).

Key: ***Yellow*** *– occupied breeding habitat;* ***Light Green*** *– occupied habitat that was prescription burnt 19th April 2012;* ***Orange*** *– potentially occupied breeding habitat;* ***Dark Green*** *– potentially occupied breeding habitat that was prescription burnt 8th October 2014.*

It should be noted that the extent / distribution of indicative habitat zones shown in Figure 4.14 is a temporal snapshot. Many areas currently considered to be relatively poor were previously providing far better habitat; for example in late-1990s to early 2000s, most of the northern section appeared to be providing optimal MLRSEW habitat. These areas may be able to be improved in future through habitat manipulation, through the experimental use of fire and possibly, in some areas, through hydrological means (Pickett, pers. comm.).

Aquatic Fauna

Sampling undertaken throughout waterways of the Southern Fleurieu Peninsula has revealed that spring-fed swamps and nearby stream habitats are occupied by native freshwater fish. Indeed a section of drain, immediately downstream of Glenshera Swamp was found to contain climbing galaxias (*Galaxias brevipinnis*) and mountain galaxias (*Galaxias olidus*) during a survey by Hammer (2006). These fish were found in quite shallow water with no flow.

Based on these records, the artificial channel sections throughout and adjacent to the Conservation Park offer potential habitat for both species. Given the recent trend of these channels completely drying in the vicinity of the park, any works that increase hydrological retention times across the swamp are actually likely to enhance the potential for these aquatic habitats to persist. One practical issue worth brief consideration is the impact that drain blockages and channel realignments (necessary to achieve restoration and increase water retention) might simultaneously have on the up-stream and downstream connectivity of these potential habitats for both species.

Climbing galaxias, as the name would suggest, are adept at negotiating small instream barriers and are therefore unlikely to be impeded by the type of works suggested in this report. Likewise, mountain galaxias also exhibit a strong capacity to negotiate instream barriers and, in areas where introduced species such as trout occur, are predominantly distributed above such barriers (e.g. Lintermans et al. 2001).

The value of the site in providing potential future fish refuge habitat is worthy of further consideration. These features are more likely to be created and sustained, after the suggested restoration works have been completed, within the static reaches of decommissioned drains and channels that will remain. An effort to both identify and monitor these features through time is recommended after the restoration works have been completed.

Flora

On-site discussions with botanical experts in September 2015 led to some detailed discussion about the range of threatened or other important flora that have been observed on the site, and the opportunity to look around the swamp to visit the locations where they either occur now or were known to occur in the past.

The range of important flora species that occur at the site is made up of those which are listed in any classification under the *Environment Protection and Biodiversity Conservation Act 1999* or as vulnerable or endangered under the South Australian *National Parks and Wildlife Act 1972*, as shown in Table 4.1.

Table 4.1 – Threatened flora species that occur in Stipiturus Conservation Park listed in any classification under the EPBC Act 1999 or as vulnerable or endangered under the SA NPW Act 1972.

COMMON NAME	SPECIES	EPBC ACT 1999	NPW ACT 1972
Mount Compass oak-bush	*Allocasuarina robusta*	EN	E
Moose orchid	*Cryptostylis subulata*		V
Short-leaf donkey-orchid	*Diuris brevifolia*		E
Mount Compass swamp gum	*Eucalyptus paludicola*	EN	E
Osborn's eyebright	*Euphrasia collina ssp. osbornii*	EN	E
Swamp daisy-bush	*Olearia glandulosa*		V
Maroon leek-orchid	*Prasophyllum murfetii*	CR	E
Hale greenhood	*Pterostylis uliginosa*		E
Large river buttercup	*Ranunculus papulentus*		V
Forked comb-fern	*Schizaea bifida*		V
Narrow comb-fern	*Schizaea fistulosa*		V
Veined sun-orchid	*Thelymitra cyanea*		E
Blue star sun-orchid	*Thelymitra holmesii*		V
Small bladderwort	*Utricularia lateriflora*		V

Additionally, the South Australian *National Parks and Wildlife Act 1972* also includes a much longer list of species considered rare, whose true conservation status in any one location (or indeed at the state level) tends to be more highly variable than the other categories due to a lower threshold required for listing and the arbitrary impact (for species that also occur interstate) of state borders.

A few species considered more noteworthy in the local area by the flora experts we have consulted with, such as the hard water-fern (Figure 4.15), are listed in this category, and included in Table 4.2.

Figure 4.15 – A photograph of Blechnum sp. aff. wattsii taken within an elevated artificial drainage line in the northern portion of the park in 2011. (Image: Clive & Claire Chesson)

Table 4.2 – Rare species under the SA NPW Act 1972, considered noteworthy in Stipiturus Conservation Park by the flora experts consulted. Note: * included for reasons explained in text.

COMMON NAME	SPECIES	EPBC ACT 1999	NPW ACT 1972
Hard water-fern	*Blechnum wattsii*		R
Sphagnum	*Sphagnum novozelandicum*		*
Austral lady's tresses	*Spiranthes australis*		R
Pink swamp-heath	*Sprengelia incarnata*		R
Alcock's water-ribbons	*Triglochin alcockiae*		R

This table also includes sphagnum, which is unlisted, but has a restricted range in South Australia and is a valuable indicator species in swamp habitats due to its sensitivity to hydrological conditions (requirement for permanent saturation). The species requires a reliable supply of groundwater and impeded drainage that keeps the water table permanently at or near the surface (DEWHA, 2009).

Bates (2015), who has visited the site regularly since the 1960s, now considered a number of species, in addition to those listed in the tables above, to be either lost from the site or in critically low numbers. They include *Corybas fordhamii* and *C. unguiculatus*, considered lost; while those considered to be in critically low numbers include *Thelymitra lucida*, *Microtis* *rara*, *Caleana major*, *Calochilus paludosa* and *C. campestris*, *Eriochilus* sp., *Dipodium* sp. and *Gastrodia sesamoides*.

4.5 Potential threats and disturbances

4.5.1 Stock grazing and trampling

Unrestricted stock access to the swamp was a long-term threat to the site that was removed with the SA Government purchase of Glenshera Swamp in 2003 (MLRSEWRP, 2004). This was an important step in the conservation management of the site as there are multiple aspects to the damage caused by cattle, particularly in peat wetlands which remain saturated year-round and are especially sensitive. These include physical damage to both the vegetation (caused by browsing) and the peat sediment (through pugging and trampling), as well as causing dual impacts on water quality and weeds; as a result of all excrement being nutrient enriched, while manure specifically provides a potential incursion pathway for weed seeds.

With the stock grazing threat removed, a potential contemporary, albeit lesser threat to the swamp community is the amount of human trampling through the wettest parts of site, where – despite rapid vegetation growth potential in the permanently wet conditions – the swamp vegetation and saturated peat is particularly susceptible to physical damage. Given its status as public land and widespread knowledge of it being one of, if not the best example of the Fleurieu Peninsula Swamps ecological community that remains, unrestricted access has led to a number of special interest groups or individuals visiting the site. While in no way comparable to the multitude of prior threats associated with stock grazing, the evidence of physical disturbance associated with the current level of human traffic through the site is still quite apparent, and is at a level that probably justifies at least some future discussion to improve awareness among the many parties with a shared interest in its conservation.

Particular emphasis should be placed on protecting the top of small peat mounds within the swamp, upon which a high number of water dependent but inundation sensitive species occur (e.g. Figure 4.16).

The visible impact of tracks through the swamp vegetation can be seen in the recent aerial photograph taken as part of this project in October 2015, shown in Figure 4.17. It is worth mentioning that a number of the tracks through the swamp are also being utilised and maintained as a result of the movements of western grey kangaroos, as observed during site visits in spring 2015.

Figure 4.16 – Example of a mound, providing habitat for water dependent and inundation sensitive species such as orchids.

Figure 4.17 – Tracks across main swamp in Stipiturus Conservation Park, as seen from the air. Image captured October 2015.

4.5.2 Weeds of significance

There are many introduced flora species recorded at Stipiturus Conservation Park, but only a small number of woody weeds in particular warrant a specific mention in this report because of their highly aggressive habits, including an ability to cause a substantial ecological impact through causing structural and compositional change to vegetation and soils. These weeds were identified and highlighted in the first management plan for the site in 2004 (MLRSEWRP, 2004).

Gorse and Montpellier broom

Although a few small patches of gorse (*Ulex europaeus*) occur on the property, Montpellier broom (*Genista monspessulana*) is a more serious concern due to it being more established across the property at the time of reservation. After initial control of all mature plants, many thousands of recruits continue to emerge from vast amount of soil stored seed (Penny Paton, pers. comm.), including a strong germination response after prescribed burning, a known disturbance trigger. Due to the longevity of the seedbank (over 20 years) and the masses of seed produced, management of this species remains a long-term proposition (Cherry, 2011). Over the past 10 years, an exceptional amount of work has been undertaken on the property, but the species will continue to be a management priority for many years to come.

Montpellier broom is most prolific on the sandy soils and remnant stringybark woodland areas, but is also invading downslope from these primary infestations into the damp, seepage-fed zone of the swamp that intergrades up the hillsides. Smaller numbers of plants have also been detected and controlled in the bed of the swamp (Penny Paton, pers. comm.); despite conditions being less suitable for the species in a permanently saturated habitat such as this.

Blackberry

Blackberry (*Rubus spp.*) is the other key introduced woody weed threatening the swamp that is reasonably widespread and has been the subject of long-term control work in the reserve. A map showing the extent of blackberry and broom from when the area was first reserved is shown in Figure 4.18.

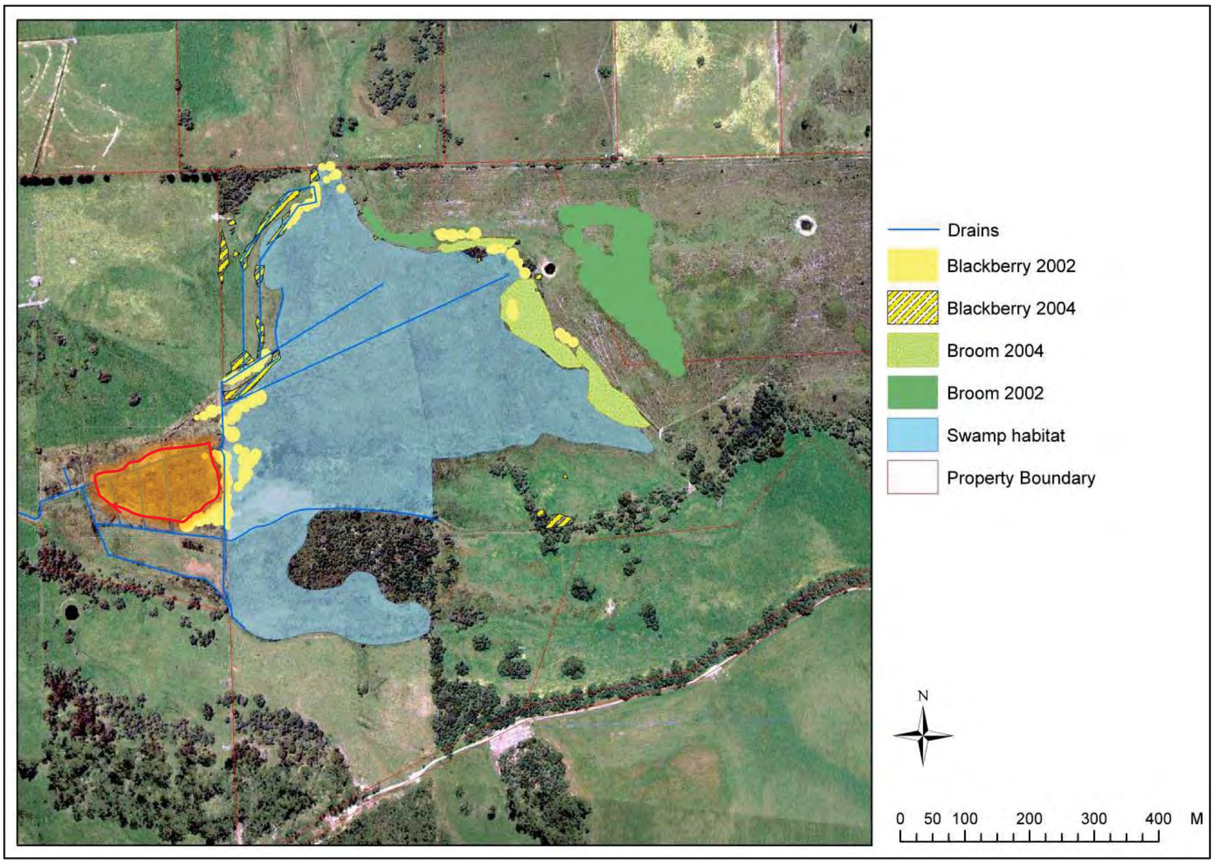


Figure 4.18 – The distribution of significant weeds (map from MLRSEWRP, 2004 - based on surveys by Pickett in 2002 and Drew in 2004). Follow-up treatment works have focussed on these areas. The dense zone of blackberry (currently also subject to treatment) on the private land to the west of the Conservation Park has been marked (superimposed) on the map (for illustrative purposes) and is outlined in red.

There is a clear correlation between the distribution of blackberry and the disturbance associated with the drainage and clearance activities in the north-western corner of the property. Note that the original version of this map did not represent the full extent of blackberry on the private land to the west of the Conservation Park Boundary, and hence has been marked separately (outlined in red). This private area has also been the subject of recent targeted control (Jacqui Best, pers. comm.).

Monitoring and control of blackberry, in response to (or in conjunction with) the restoration works suggested in this report, should be undertaken; noting that the change in hydrological conditions may present an opportunity to better target and manage this weed species. Ideally these works would encourage formerly infested habitats to be recolonised by native swamp species as the blackberry is controlled and/or displaced.

Common reed

A cosmopolitan emergent aquatic species, the common reed *Phragmites australis*, although native to Australia has significant weediness potential because of its ability to invade wetland habitats from where it was previously absent and displace other communities. The species forms dense impenetrable monocultures with rhizome mats that alter soil and habitat conditions, out-competing other less vigorous species (Robinson, 2002). Invasion by this species is a developing concern for the wider management of swamps of the Fleurieu Peninsula (Rebecca Duffield, CCSA, pers. comm.), particularly given its capacity for rapid expansion after stock are excluded from a site.

An area of dense *P. australis* reedland occurs on the western edge of the park boundary, at the point where the southern drain (that has bypassed the swamp since the 1940s) is now less incised. Inspection of the available aerial imagery shows that this area of reed vegetation was absent for a couple of decades after the channel was constructed. From the time it first appeared in the 1967 image, it has continued to expand, both along the termination point of the inflow channel and also throughout the property to the west. We have traced the boundary of this reedland from the aerial imagery since it first appeared, to demonstrate its change in extent over a 50 year period, as shown in Figure 4.19.

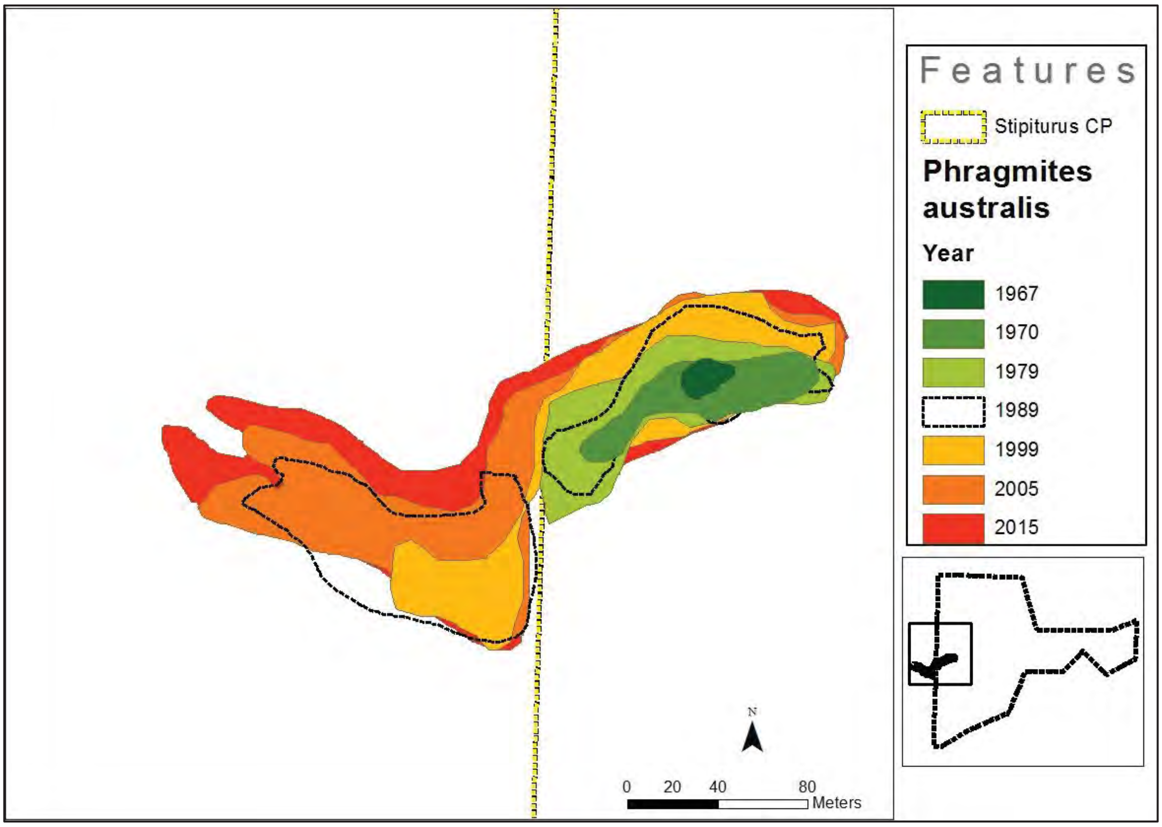


Figure 4.19 – <u>Phragmites australis</u> expansion on the western boundary of Stipiturus Conservation Park. Note the decline in extent, likely as a result of active management, from 1989 to 1999.

Despite the global concern surrounding the expansion of *Phragmites australis* and its formation of monocultures in wetlands, the precise mechanisms by which the species initially gains a foothold are relatively poorly understood. The most likely causes are as a consequence of physical disturbance, hydrological regime shift and eutrophication, all of which are symptoms consistent with land-use change and compromised catchment management. In addition, recent research suggests that allelopathy, as a result of gallic acid being secreted from the rhizomes of *P. australis* (which when exposed to ultraviolet light also produces mesoxalic acid, both of which are toxic to other plants) may play a significant role in the expansion of the species once established at a site; enabling the displacement of diverse wetland vegetation communities with *P. australis* monocultures (Rudrappa et al., 2009; Uddin et al., 2014). Hence, the expansion of *P. australis* within Glenshera Swamp is likely to continue under any hydrological regime and warrants specific further attention in order to avoid declines in both vegetation and structural diversity over more of the swamp.

It is noteworthy that the area of *P. australis* actually declined between 1989 and 1999. The precise mechanism for this is uncertain but is probably associated with cattle grazing and/or physical control during that time and demonstrates that, even with suppression interventions, the capacity for the species to re-establish is high.

4.5.3 Water quality of catchment inflows

Given the degree of native vegetation clearance, drainage and agricultural development in the wider Myponga catchment (described in Section 4.3.2), there has been an inevitable negative effect on catchment water quality through the introduction of pesticides, fertilisers, pathogens and suspended sediments (EPA, 2008). Resulting eutrophication, through an increase in the concentration of nitrogen and phosphorus, can lead to excessive plant or algal growth and in the case of Glenshera Swamp, the potential exists for eutrophication from diffuse sources across the catchment, particularly animal manure and nitrogen and phosphorus compounds in fertilisers from agricultural land (Figure 4.20).

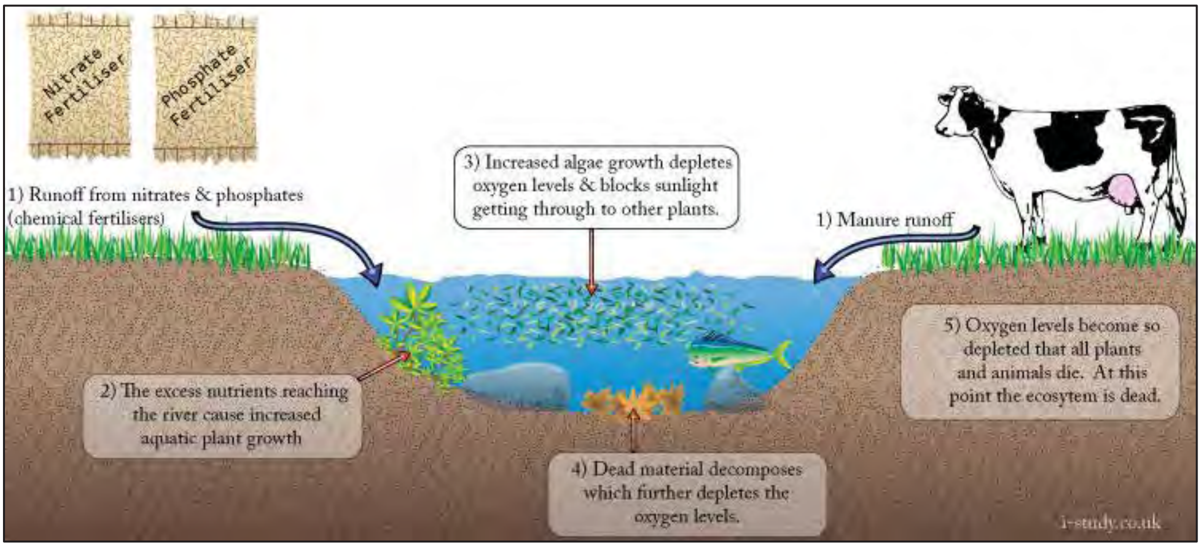


Figure 4.20 – The contributors to, and process of, eutrophication in rivers or wetlands in agriculture dominated catchments (from www.i-study.co.uk)

4.6 Eco-hydrological character

4.6.1 Hydrological context

Of the four broad categories of groundwater dependent ecosystems identified by Barnett and Rix (2006) in the Fleurieu Peninsula, Glenshera Swamp, which falls within the Myponga River catchment (Figure 4.21), is considered to be a Permian Sands aquifer dependent wetland.

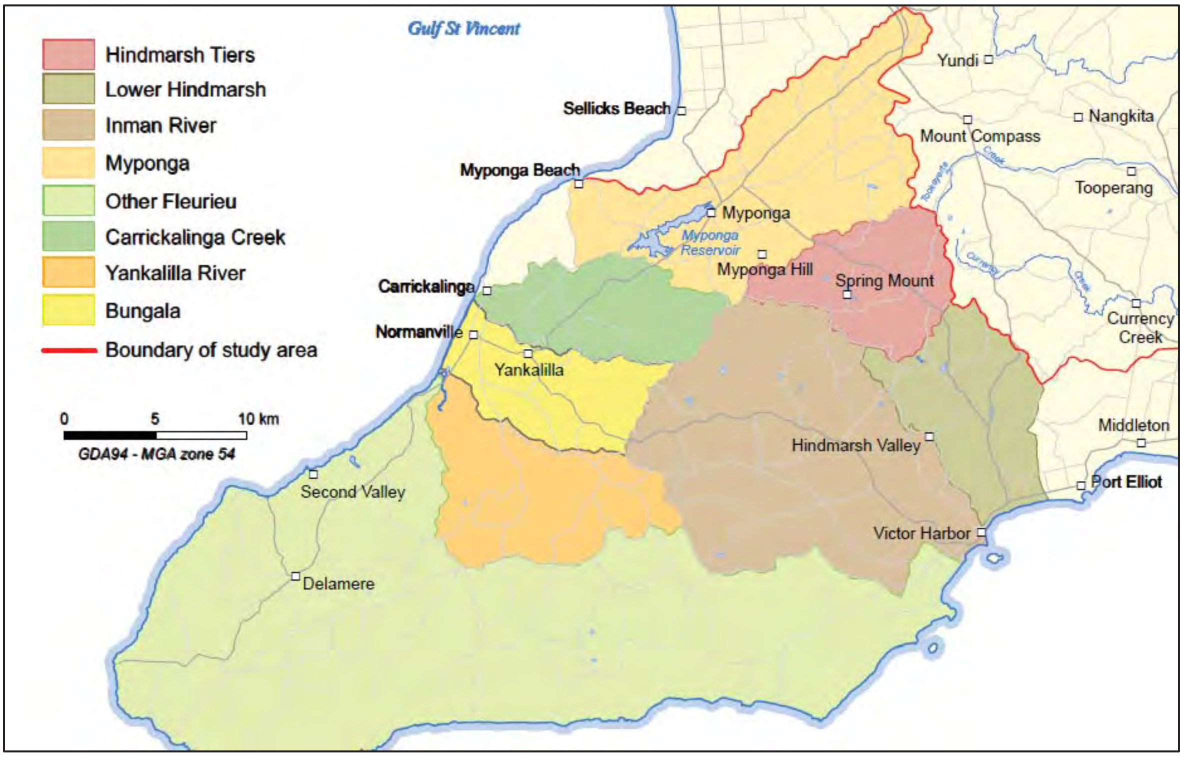


Figure 4.21 – The location of the Myponga catchment (from Barnett and Rix, 2006).

This type of wetland usually occurs in the lowest parts of the landscape, in valleys and depressions, where they are in direct contact with groundwater (Figure 4.22). As a result of the sandy soils typical of Permian Sands catchments, there is usually assumed to be very little surface runoff, with groundwater providing almost all of the wetland water requirements (Deane et al. 2010). Less than 20% of the wetlands of the Fleurieu Peninsula are considered to be Permian Sands wetlands (Barnett and Rix 2006).

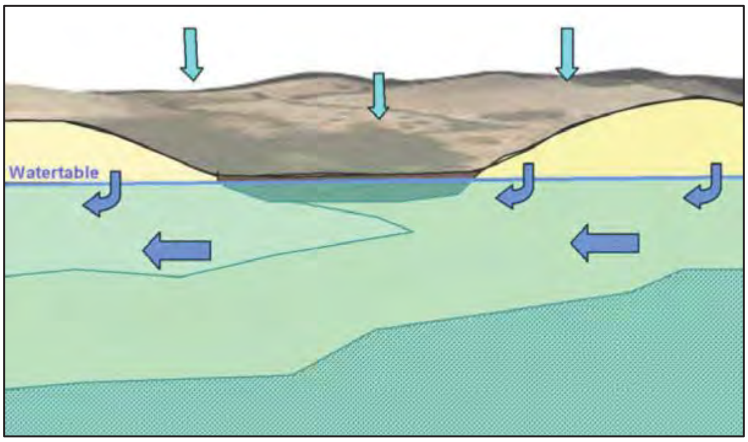


Figure 4.22 – A conceptualised cross-section of how a Permian Sands aquifer fed swamp interacts with groundwater (from Barnett and Rix, 2006).

These Permian Sands valley formations are the result of glacial carving of basement rocks some 280 million years ago and subsequent glacial deposition of unconsolidated sand, silt and clay with occasional gravel beds (Barnett and Rix, 2006). More recent (Quaternary) alluvial deposition has resulted in layers of dark grey silts, clays, reworked Permian sand and significant thicknesses of more recently formed peat occurring at the lowest points in the catchments and adjacent to drainage lines, all of which act as a confining layer over the top of the Permian Sands aquifer (Barnett and Rix, 2006).

Regional landscape and soil mapping identifies at least three primary soil groups across the site: Deep bleached siliceous sands (H3) along the valley walls and slopes, loam over brown of dark clay (F1) along the primary watercourse and peat (N1) across swamp areas located parallel to the primary surface water flow path. Information from groundwater well drillers logs (https://www.waterconnect.sa.gov.au, accessed 10th September, 2015) further supports this morphology with records from wells on the outer slopes of the swamp showing deeper sands (and gravel) and those from the valley floor showing mud or silt to 0.3m over a layer of clay. A peat thickness of at least 1.8 m has been recorded within Glenshera Swamp (Whinam and Copley, 2011). A conceptual diagram of soil morphology and hydrological drivers specific to Glenshera Swamp is shown in Figure 4.23.

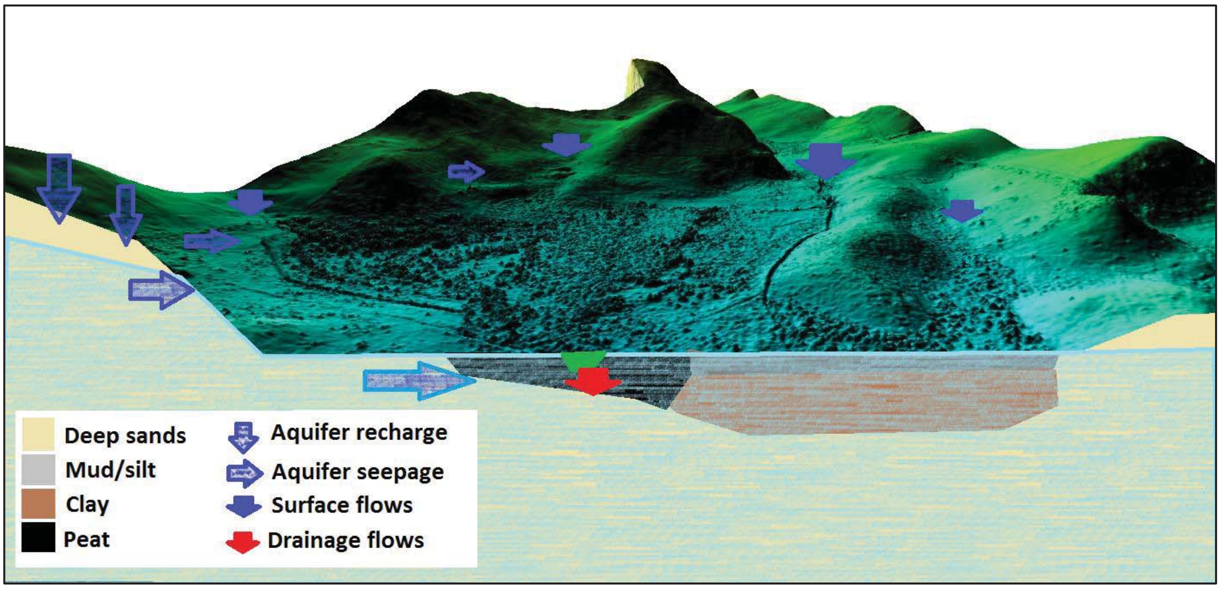


Figure 4.23 – New conceptual 3D cross section of Glenshera Swamp proposed by NGT, showing underlying soil profiles and primary water sources.

By comparing Figures 4.22 and 4.23, one can see that Glenshera Swamp is an interesting case study that does not neatly fit the theoretical description for a wetland of this type, with several confounding factors. A key observation, based on apparent underlying soil types and coupled with field observations, is that it appears to receive water in a number of different ways, despite those sources likely to be strongly, if not directly, influenced by the behaviour of the underlying Permian Sands aquifer in the catchment.

1. **Surface flows:**
    a. Low volume, temporary flows from minor valleys to the north and south-east.
    b. Higher volume, seasonal surface flows from the upstream catchment to the east.
2. **Groundwater:**
    a. Hillside seepage from infiltrated rainfall through the surrounding sandy hills being discharged laterally, from either an elevated local water table under the hills or even possibly as a result of reaching an impermeable sub-surface layer.
    b. Direct interaction between the swamp bed and the Permian Sands aquifer.

The different, albeit inter-related, water pathways or sources described here and shown in the three dimensional cross-section in Figure 4.23 are also depicted below in a two dimensional map, in Figure 4.24.

Figure 4.24 – A theorised 2D visual representation of the water sources for Glenshera Swamp

It is worth mentioning that there is a high probability that a proportion of surface water that reaches the site from upstream catchments may itself be ‘liberated’ groundwater, as a result of Permian Sands aquifer discharge or hillside seepage flows from further up the valley. A distinction between the different flows however, and a clue as to their origin, is the period over which they are generated.

Based on field observations in 2015, minor local surface flows appear to be generated after heavy rainfall and do not last for long beyond the event (a few days), in contrast to the natural creek line flows, which benefit from having a larger upstream catchment that facilitate an extended period of flow (days to weeks). Rates of hillside seepage also appear to be closely linked to seasonal rainfall patterns, but due to the likely delays associated with infiltration may cause lateral seepage over a longer period after heavy rainfall (weeks to months, depending on rainfall patterns and distance down the slope), which explains the development of peat sediment a considerable distance up the elevation gradient (i.e. up-slope) from the swamp bed. Finally, the Permian Sands aquifer, which is apparently fed by groundwater recharge from higher in the catchment, is far less likely to be influenced by shorter term climatic trends, underpinning the bed of the swamp with permanent saturation, but obviously also directly supplemented by water from all the other sources described that ultimately reach the same destination. This aquifer appears to be the key underpinning attribute that has enabled the site to persist in the face of the range of attempts to drain and develop the swamp since the 1940s. Indeed it is these permanently water-logged conditions over a long period of time that has facilitated the development of a deep peat sediment profile at the site.

In summary, the hydrological character of the swamp appears to be predominantly underpinned by the deeper Permian Sands aquifer (regional Permian Sands groundwater) and its associated expression within the wetland basin, with significant seasonal fluctuations in surface inundation or ‘freshes’ being largely driven by seasonal rainfall that drives tributary inflows (local surface water) and hillside seepage from infiltrated rainfall (local Permian Sands groundwater).

Working on the assumption that the theorised representation of the surface and groundwater sources for the swamp – shown in Figure 4.23 and as described above – is correct, it provides a useful guide for understanding:

- the likely relative contributions of ground and surface water across the site;
- how the artificial drainage network superimposed on the site is interacting with the different water sources and influencing site hydrology; and,
- the potential effect that remedial works are likely to have across the site.

In terms of the potential impact of catchment changes, original clearing of native terrestrial vegetation could have initially increased the volume of water issuing from both local and regional aquifers (Casanova & Zhang, 2007). However, in more recent decades, the diversions of surface water through dams and drainage, combined with increased rainfall interception and root-zone soil water use in forestry plantations, all have recognised potential to reduce both runoff and recharge, exacerbating the impacts of below average rainfall or a drying climate (Barnett & Rix, 2006, Casanova & Zhang, 2007, Clark *et al.* 2007).

4.6.2 Climatic context

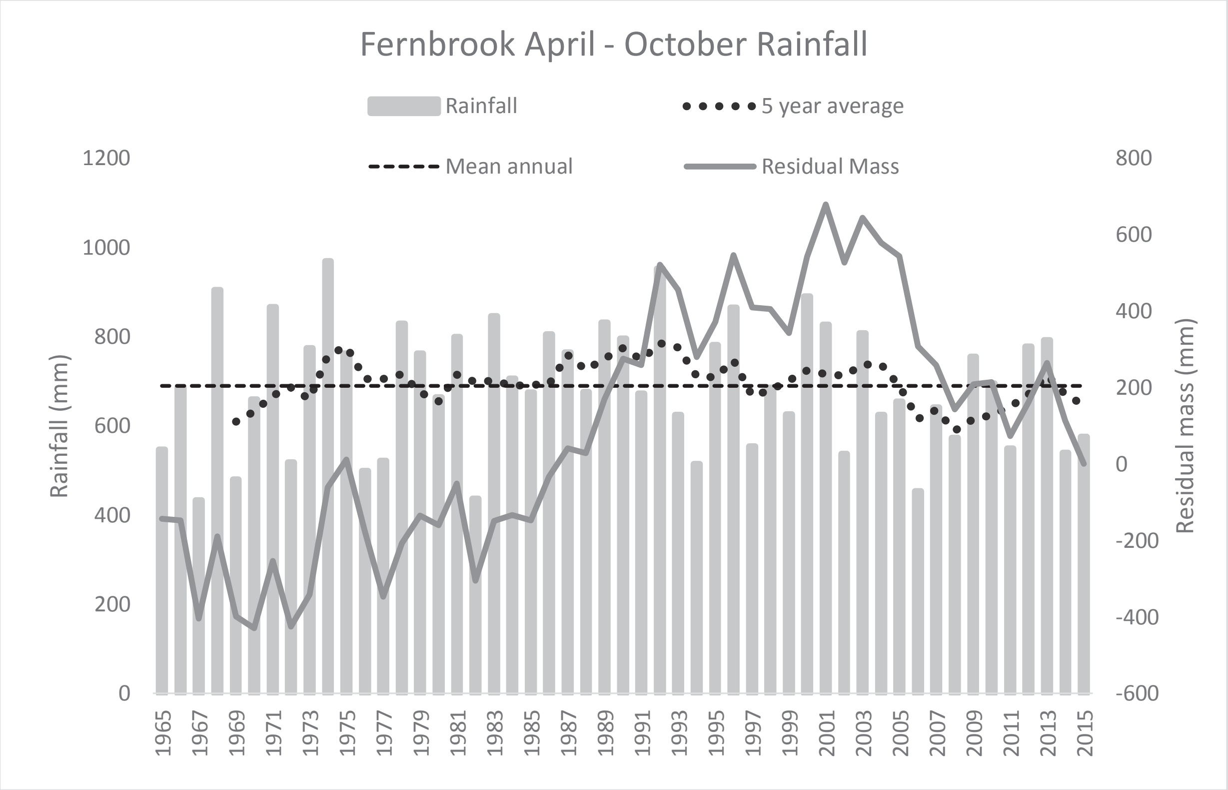
Because most summer rainfall is lost to evaporation in a temperate Mediterranean climate, winter rainfall (April–October) is considered to be a better indicator of the water balance in a catchment than average annual rainfall (Barnett and Rix, 2006), and therefore a more reliable measure of maintenance of base flows and frequency of freshes.

Figure 4.25 (over the page) provides an overview of rainfall trends, at the two closest BOM weather stations across these months and suggests that the catchment has been experiencing a deficit from average rainfall over the past two years and that, despite wetter years in 2009, 2012 and 2013, continues a trend of reduced rainfall apparent since the start of the millennium. Hence the frequency of seasonal rainfall driven freshes is likely to be decreasing, while the impact on base flows is more difficult to determine but likely to be much longer term (due to longer lag times involved in regional groundwater systems). The previously mentioned declines in local groundwater levels between 2000 and 2007 correspond with a period of below average rainfall. Although groundwater levels have since stabilised, because they have not recovered to pre-2000 levels, this is likely to continue to have some influence upon the availability of future base flows.

It is also interesting to note that the peak rainfall year shown in 1992, corresponds with an event in the early 1990s recalled by Jeff Merritt when upstream dams overflowed and the whole flat in the vicinity of Glenshera Swamp went under six inches of water, with the flood lasting several days. This is the only occasion he recalls seeing a flood of that magnitude in the area from 1979 to the present day (Jeff Merritt, pers. comm.).

Jeff also relayed during the course of conversation that based on his observations over many years, he feels that climate, and in particular seasonal rainfall, plays a primary role in influencing just how wet Glenshera Swamp appeared in any given year. Interestingly, having seen the swamp regularly wet over the years in the presence of artificial drains, he has never come place the same level of importance on the potential negative impact of artificial drains in altering the water regime of the wetland (Jeff Merritt, pers. comm.); despite clearly describing their purpose as being to help dry the swamp out for improving access for grazing livestock.

In the context of, and consistent with, the suggested mechanisms for how seasonal rainfall strongly interacts with local catchment (surface and groundwater) flows in the previous section, these are important observations.



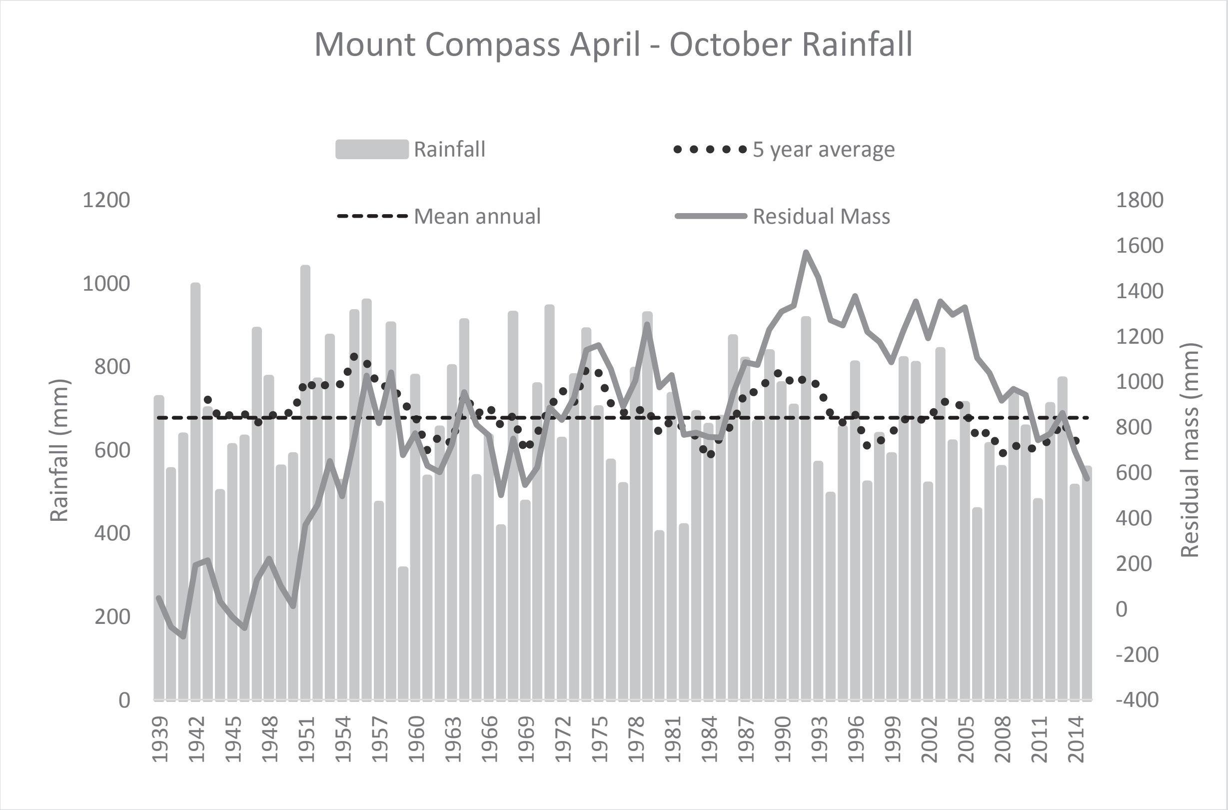


Figure 4.25 – Effective (April – October) rainfall and deviation from average for Fernbrook BOM station (23823), 1965 –2015 and Mount Compass BOM station (23735), 1935 – 2015.

NOTE: The residual mass is the cumulative departure from the average over time.

4.6.3 Recent flow observations

Given the current long-term drying trend, including recent blow average rainfall years, we were fortunate to have the opportunity to time our first field inspection of Stipiturus Conservation Park between the 8th and 10th of September 2015. Although skewed somewhat by above average autumn rains; nearby Mount Compass had experienced a close to average rainfall period from April to August 2015, with 500.9 mm of rain recorded – only slightly below the long-term average over these five months of 523.4 mm. In addition, the first 8 days of September, up to and including the first day of our visit, had produced a further 33.6 mm of rain. As a result, we had the opportunity to observe the catchment in the vicinity of Glenshera Swamp under what appeared to be moderate flowing conditions, see Figure 4.26, based on this recent rainfall data.

Figure 4.26 – The flow down the main bypass drain that skirts the southern edge of Glenshera Swamp on 8th September 2015.

In addition to mapping all of the natural watercourses and artificial drains in the vicinity of the swamp, we also subjectively assigned relative values to flows observed in each waterway. Areas with particularly sudden drops in elevation (again based on observed flow characteristics – see evidence of a moderate drop with the area of faster flow displayed above in Figure 4.26) were also mapped.

The resultant map with schematic overlay (Figure 4.27) provides an overview of the flows observed in early spring 2015.

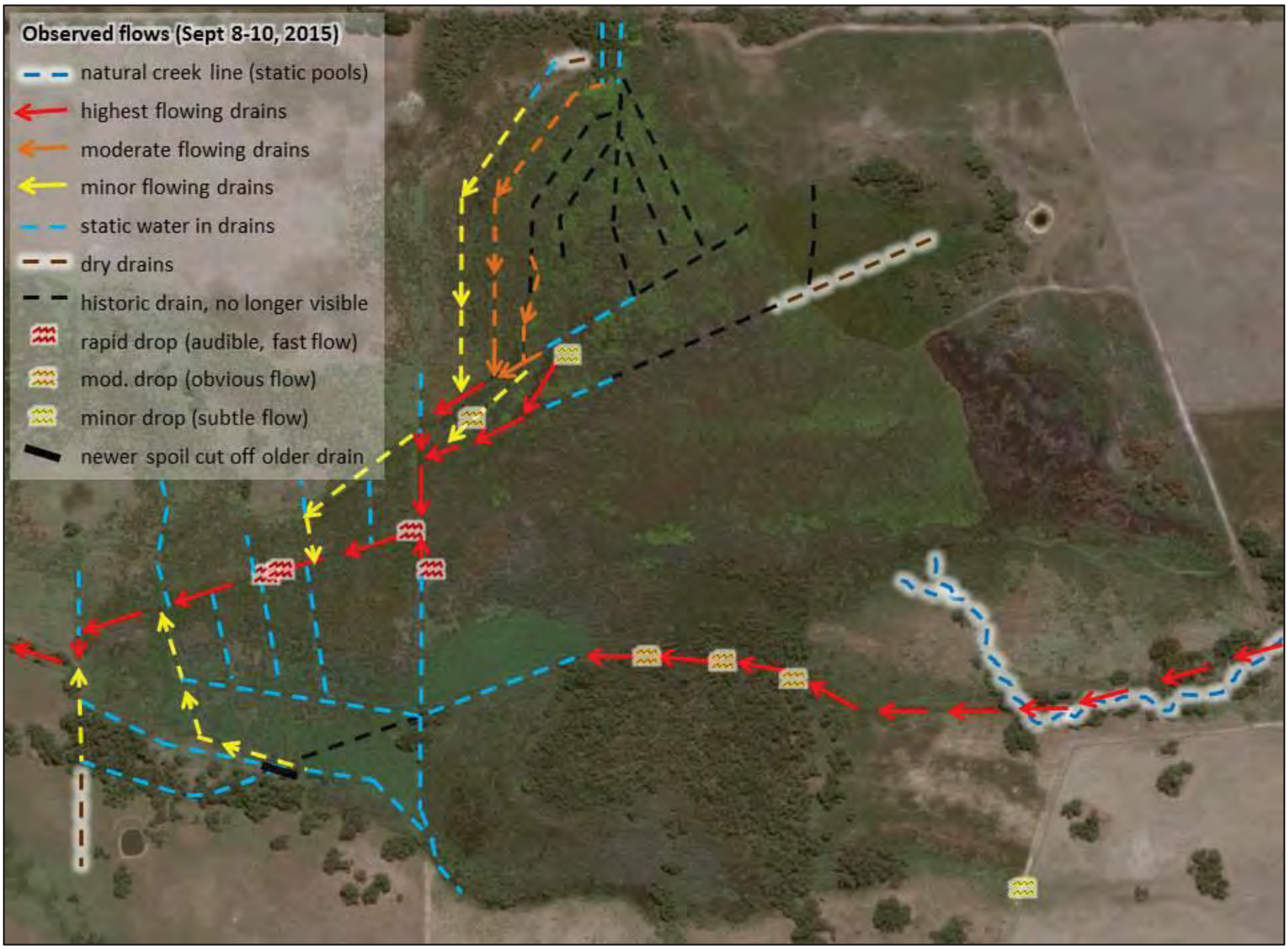


Figure 4.27 – Location of drains and characteristics of catchment flows observed under what are (based on recent rainfall statistics) assumed to be moderate flow conditions.

Despite only being a snapshot view of the site under those specific conditions, the most useful aspect of this investigation is an understanding of the relative contribution of the different drains situated across the property towards the trend of accelerated, artificial, seasonal drying (i.e. the purpose of their construction). As previously described, this impact has been progressively enhanced since the first drains were constructed in the 1940s. The evaluation also provides an understanding of the main direction of water movement through the site, the gradient or fall through the swamp and the depth and profile of the drains. In such a densely vegetated environment, where precise digital elevation data for the surface is notoriously difficult to obtain, this understanding is critical.

A subsequent site visit in October 2015, after a six week period with virtually no further rainfall (only 6.4 mm recorded over that period at Mount Compass), revealed some interesting changes. Demonstrating the responsiveness of both the local surface and groundwater catchments to seasonal rainfall, drain flows had all but ceased – with static pools evident in a few channels. The regional groundwater-table under the swamp itself was still within close proximity to the surface, but the up-slope peat seepage zone on the north-eastern side of the swamp was rapidly drying in comparison to the previous visit.

4.6.4 Channel gradient data based on LiDAR

Another key piece of information obtained, using LiDAR data and aerial imagery obtained in a flight over the site in October 2015, was the production of a detailed digital elevation (or terrain) model for the site. The data generated in the recent flight has extremely high point density (with the aim of reducing the potential for false surface elevation readings in the swamp itself, being such a densely vegetated environment) and hence provides a particularly useful complement to the field observations shared in the previous section.

The resulting digital terrain model generated from this method should still to be treated with some caution (due to the limitations described), but has been particularly helpful for identifying or confirming features such as natural waterways and drains, and for calculating gradients (within those features) across the site, a process that (in averaging a larger number of data points over a set distance) helps to reduce the margin of error.

The specific drains selected for assessment were those observed to be the primary carriers of flow in September 2015 (Figure 4.27), as highlighted and labelled against the backdrop of the digital terrain model in Figure 4.28. Gradients for each are presented in Figure 4.29.

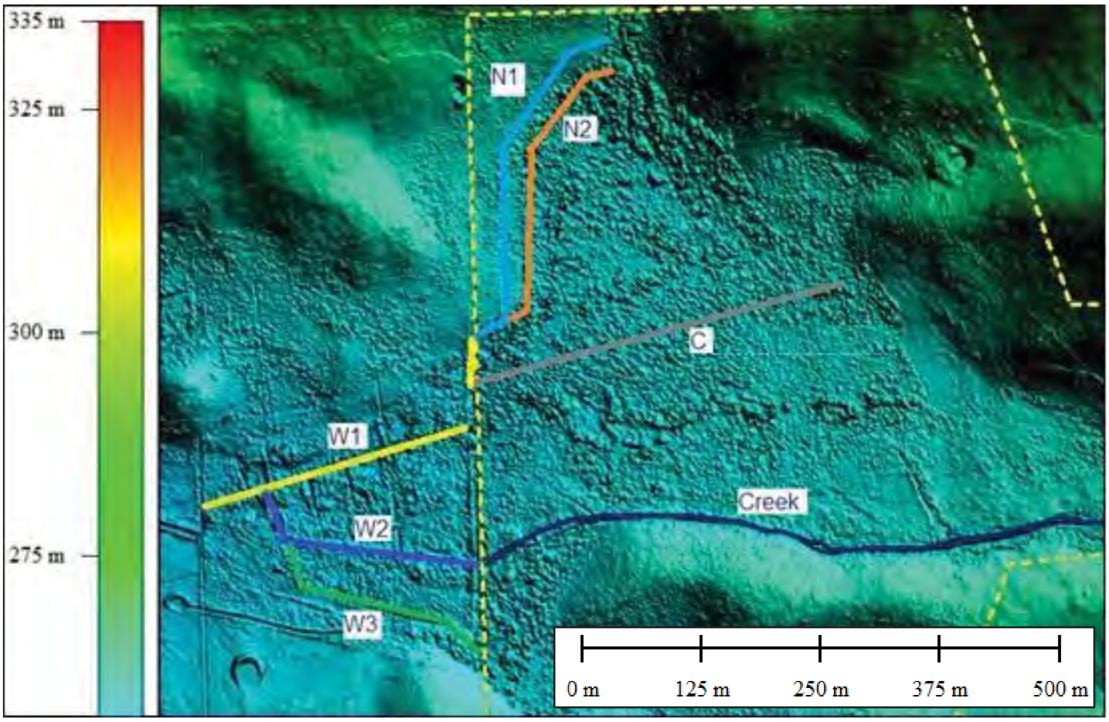


Figure 4.28 – Major drains overlaying the Digital Terrain Model for Glenshera Swamp.

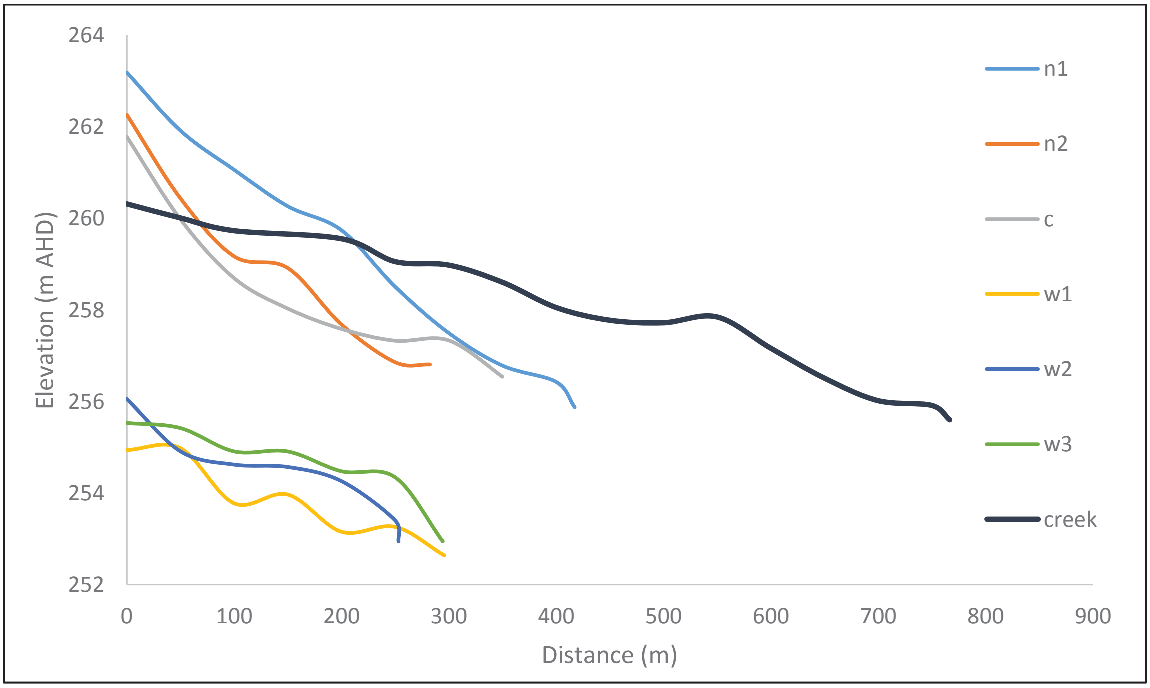


Figure 4.29 – The gradient of major drains along their length (from Figure 4.28) associated with Glenshera Swamp.

After reviewing this information, it is clear why channel W1 has become the primary conduit for drain flow away for the park, given that where it commences near the reserve boundary, it is approximately 50 cm deeper than the two alternative drains, W2 or W3. Given that all three of these drains experience around two metres of fall over a length of 300 metres; this explains their effectiveness at drawing moisture out from the peat along the western side of Glenshera Swamp. Another interesting observation is just how high up the slope the seepage zone extends based on the beginning of drains N1, N2 and C being between 3 and 5 metres higher than the level of the swamp bed; which itself gently slopes from east to west.

4.7 The impacts of artificial drainage

By combining our developing understanding from the previous sections, it is possible to begin to construct a strong conceptual basis for how the different components of the hydrological equation at Glenshera Swamp interact with the artificial drainage infrastructure on site.

The five zones indicated in Figure 4.30 form the basis for the discussion that follows in this section.

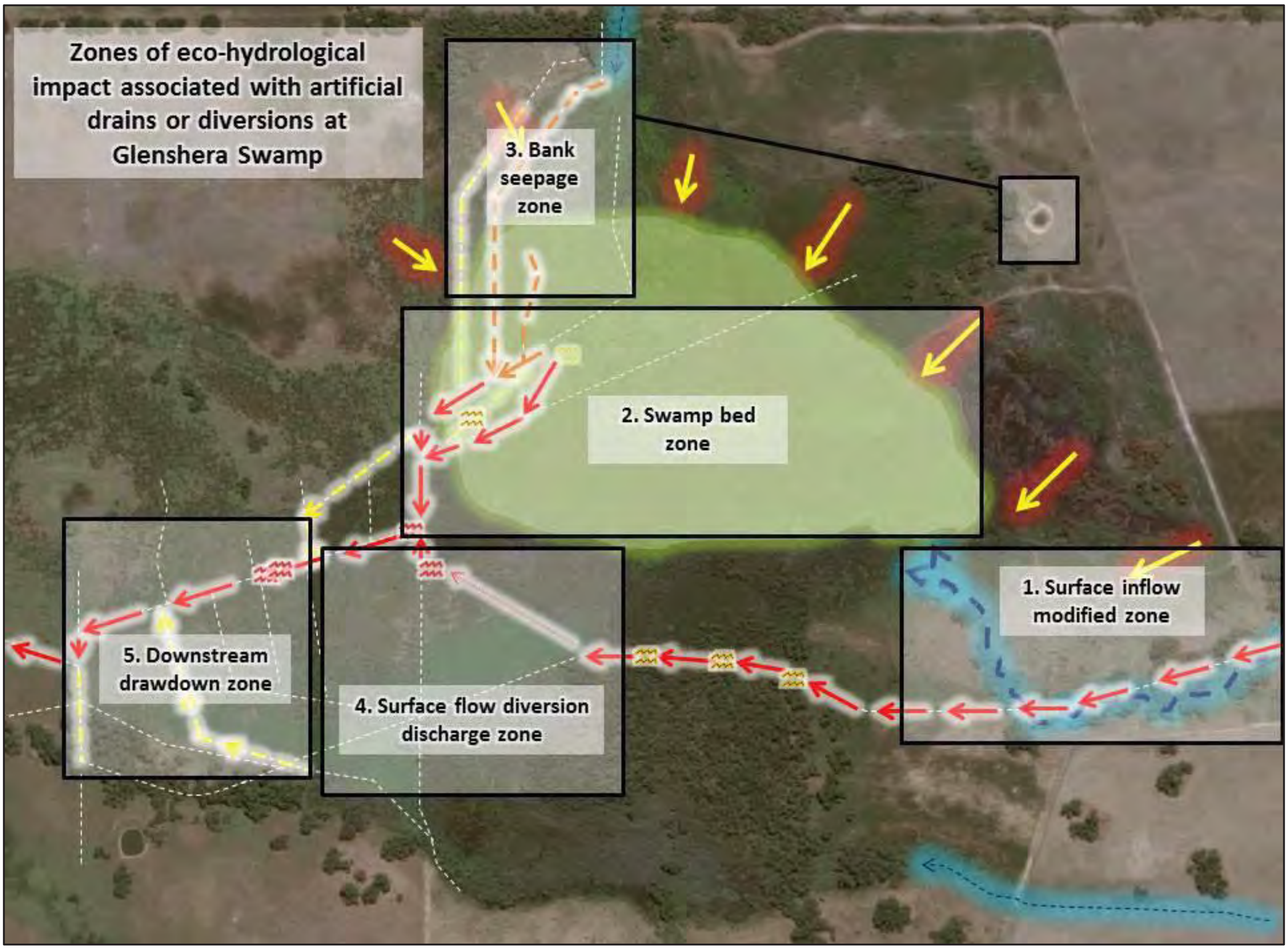


Figure 4.30 – Suggested zones where the flowing drains highlighted are having the most significant hydrological influence at Glenshera Swamp

4.7.1 ZONE 1: Main surface inflows

A key change to site hydrology occurred with the construction of the major arterial drain in the 1940s that prevents upstream surface flows from entering the swamp, bypassing around its southern edge. The impacts of this drain have been multiple, associated with:

a. Straightening of the creek

Upstream (to the east, see above right) of the diversion point marked on the map with an 'X', the natural meanders of the creek (which are still visible) have been intercepted multiple times as the deeper artificial drain was dug in a straight line along the same general alignment – also see Figure 4.31. With the drain on average 50 cm deeper than the natural channel, this serves not only to significant increase the flow velocity, but also reduces the likelihood of the adjacent floodplain inundating during flows. Later in the season as flows recede, the depth of the channel subsequently enhances the drawdown of soil stored moisture from the floodplain environment adjacent to the drain.

Figure 4.31 – Looking west towards the diversion point; from on the bank between the intercepted natural meandering creek line (left – blue line) and the deeper, straightened artificial drainage alignment (right – red arrow)

b. Cutting off flows from the terminal length of the natural creek line

For approximately 70 years, the section of natural creek line downstream (to the north-west) of the diversion point marked above with an 'X', has been starved of seasonal surface flows as a result of the depth and gradient of the artificial drain at the diversion point (Figure 4.32). The drain carries flows to the west (Figure 4.33), bypassing the bulk of the swamp.

Despite this change, fortunately the original creek alignment is still visible and lined with swamp gums (*Eucalyptus ovata*) that escaped clearance, and provides clear evidence of the original entry point for surface flows into the swamp.

Figure 4.32 – Looking east towards the point where the creek was diverted. The original meandering flowpath to the north (blue lines) has been intercepted and isolated by the westerly flowing artificial channel (red arrows).

Figure 4.33 – Looking west down the drain away from the creek diversion point.

4.7.2 ZONE 2: Swamp bed

Unlike the majority of the Case Studies provided in the Appendices in Section 8, the core area (i.e. bed) of Glenshera Swamp does not have a single fixed sill level (or specific overall target water retention height) that has been breached. Hence there is no single drainage control point that can be pinpointed and repaired or reinstated to achieve restoration. Drainage impacts are therefore diffuse across the peat bed, correlating with density of drains, as well as being significantly influenced by their depth and gradient.

Picture the peat substrate that occupies the valley floor as being the equivalent of a water-filled ‘sponge’ that gently slopes from east to west. As more vegetation is deposited and the peat profile grows with time, its water holding capacity also grows and it becomes more and more effective at restricting the movement of water through the system, which in turn maintains the perfect conditions necessary for further development of peat – in short, this is a positive feedback loop. The system relies on a hydrostatic equilibrium between **inflows** (needed to maintaining constant saturation) and **outflows** (making the system continuously leaky, or it would turn into a lake) – hence the analogy with a sponge.

When a gently sloped peat bed is deeply incised through comprehensive artificial drainage, dramatic changes can occur, both (a) in the way water moves (drawing it out, channelising it and speeding up its exit), and (b) in the physical properties of the peat itself. On the latter point, should the peat completely dehydrate, it may exhibit characteristics of irreversible drying (becoming hydrophobic), which is globally known to occur in many types of dried peat (Andriesse, 1988). Hence, once peat has been desiccated, its properties, such as its volume and moisture holding capacity, dramatically change – creating the potential for a strongly negative feedback loop to establish as the peat subsides, compacts, oxidises and further degrades, and is then often further drained (if an area is being used for agriculture) – fundamentally altering its properties.

Reversing the drainage of peat systems therefore needs to accommodate the potential impacts of these processes in seeking to restore or improve ecological function. At a useful comparison site in the South East, Pick Swamp (see Appendix 8.2), the restored wetland communities now differ from what was in place pre-development due to post-drainage peat subsidence irreversibly changing the surface elevation in the deepest parts of the swamp – resulting in more open water habitats after restoration, as shown in Figure 4.34.

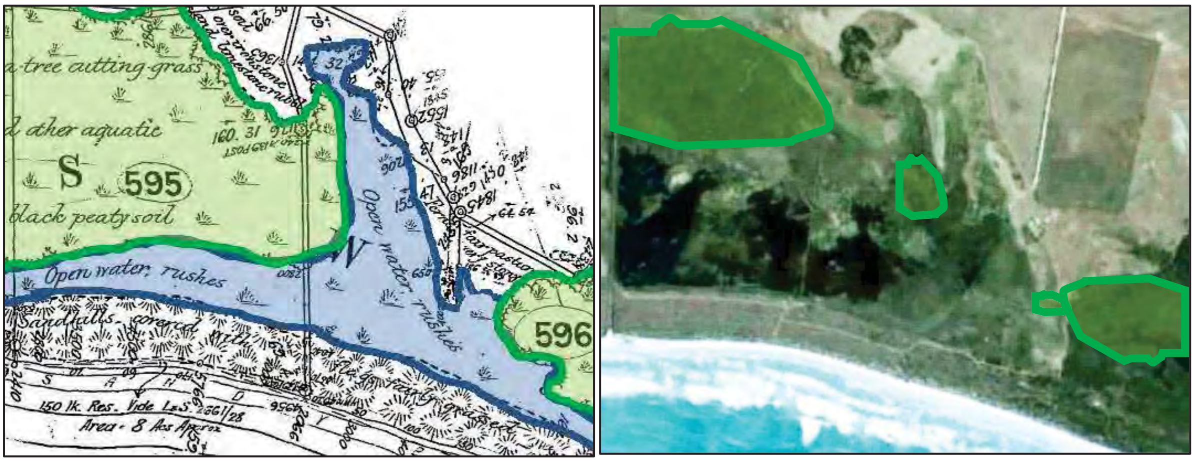


Figure 4.34 – Change in the distribution of peat fen shrubland at Pick Swamp (green area), above left in 1896 and above right, today after restoration. The subsidence of peat over 30 years of drainage and development means that open aquatic habitats now occupy a greater proportion (the balance) of the wetland area on the property.

Fortunately in that case, an extensive area of the original pen fen shrubland community (broadly comparable to Glenshera Swamp in being a constantly saturated peat bed) was still present on the property (despite being at a higher elevation) having been buffered against dehydration over the years the property was drained, by elevated groundwater discharging under pressure from rising springs. As well as being a necessary action to protect the long-term hydrology of the remnant peat fen area from peripheral drawdown, restoration has resulted in an expanded area of peripheral open aquatic habitat, which fortunately is highly desirable as a complementary conservation asset (also depleted elsewhere) in such a near-coastal environment. Additionally, because of the elevation and hydrological processes associated with the peat fen area, combined with the geomorphology of the site, the infrastructure now in place at Pick Swamp enables the site to operate as a fixed sill terminal wetland – with regulated outflows over a weir and fishway to the ocean. As desirable as this is for simplifying management, this final component in place at Pick Swamp is not an option for Glenshera Swamp, being situated within a continuously sloped valley - a vastly different geomorphological setting and landform.

With elements of this example in mind, the objective of slowing the peripheral and downstream drawdown from Glenshera Swamp should be to buffer and safeguard the elevated groundwater hydrology of the core area of existing high value habitat in Stipiturus Conservation Park – without causing any dramatic shifts in standing water elevation, but prolonging duration and expanding the zone of saturation. With this philosophy in place, there are also likely to be benefits for the downstream degraded habitats on the property to the west – which will have to be part of implementing this solution – noting that an improvement from its current state is a long-term but worthwhile proposition.

With this background in mind, the identified impacts from artificial drainage to the swamp bed have been two-fold:

a. Interception of upstream surface flows

The original destination for creek flows that were diverted in the 1940s was the south-eastern corner of the swamp bed, where the water could make its way from the top of the densely vegetated swamp to slowly pass through the system. In most winters, these surface flows would have provided a significant additional water supply for the swamp, which would ordinarily already have been saturated year-round as a result of the shallow groundwater underpinning its hydrology.

b. Drainage of groundwater from the swamp bed

The drains that run across the bed, and particularly those that capture flows from the wettest zone in the central and western portions of the swamp, are more than likely tapping into the groundwater aquifer that underpins the site – for part of the year at least. The impact of both reduced inflows and downstream drainage of this zone may have been masked to some degree by the capacity for the peat sediment profile, which is literally suspended by groundwater, to physically move. People who have walked across this zone (see Figure 4.35) will have noticed the sensation of feeling the ground wobble as a result of the footsteps of their companions nearby.

Figure 4.35 – The swamp bed, where the peat profile functions like a floating sponge.

This also means it is possible that the peat profile may have physically dropped in response to earlier drainage attempts, possibly partly explaining why a couple of the drains that were dug across the swamp bed around 1970 are now barely visible, while others around the periphery (where the peat is not as deep) remain clearly visible. Physical subsidence of the ground is a common phenomenon associated with deep-profile peat wetlands being drained. The drains in the swamp bed do not carry much discernible flow until reaching the western side of the swamp bed, where the depth of the drains (see Figure 4.36) and their gradient – hence their effectiveness – significantly increases prior to leaving the property.

Figure 4.36 – Lachlan standing in one of the deeper (1.5-2m deep), fast flowing drains near the western margin of the swamp bed. As an indicator of depth, this photograph was taken from the natural surface level.

4.7.3 ZONE 3: Bank seepage

The primary area where bank seepage appears to have been influenced by artificial drainage is in the north-western corner of the park. At this location a dense network of drains were constructed around 1970 that extend a considerable distance up slope – extending all the way to the northern property boundary.

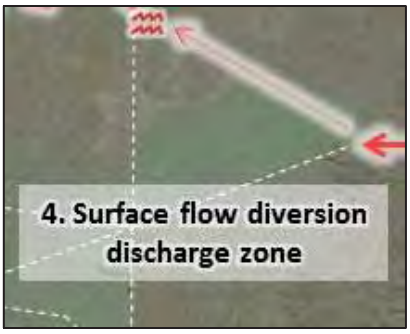
Due to the elevation of these drains, see Figure 4.37, it is clear that their primary intention was to dry out the bank to improve its capacity for grazing, but also to intercept any flows or seepage generated by a very minor natural drainage line off the neighbouring parcel of land. Based on the changes to the swamp margin in that area from the aerial photographic sequence presented in Figure 4.7, it is clear that the attempt to drain and develop this portion of the site was only partially successful.

Figure 4.37 – Looking in a northerly direction towards the property boundary (the tree line), along the highest section of the outside (westerly) drain, which was drier than the drain parallel to it, being higher up the slope.

Consistent with being a highly disturbed zone, the drains in this area were noted earlier for the presence of blackberry infestations. Habitat quality has been seriously compromised by its management history and the impact is apparent on both the present hydrology of the slope and resultant vegetation composition and structure. As a result, this north-western bank does not share the same ecological attributes as the relatively intact upslope swamp community situated around the rest of the northern and eastern swamp margin, despite evidence (see Figure 4.7) that some of those areas were also physically cleared in the past.

Additionally, it is interesting to note a length of dry up-slope drain on the north-eastern side of the swamp, which itself is downslope of the only dam within the Park. The dam, which intercepts slope runoff and seepage, is an artefact of the grazing history of the site. Given the availability of water within the swamp for wildlife, it serves no conservation purpose.

4.7.4 ZONE 4: Surface flow diversion



The consequences of the diversion of the surface inflows in the 1940s, bypassing the bulk of the swamp have been significant. As well as impacts on the areas that have been deprived of flows (Zones 1 and 2), the modification also appears to have had an impact on the downstream receiving environment of these point source flows.

Despite a channel originally visible in 1949 that was cut right through the swamp to carry to bypassing flows, a discharge zone (clearly with less slope) formed part of the way along this original alignment, inside the present boundary of the Conservation Park. This discharge zone, shown in Figure 4.38, is where the common reed *P. australis* first established in the 1960s and has increased in extent within the swamp ever since.

Figure 4.38 – Looking in a westerly direction where the higher gradient section of drain peters out into the dense, expanding stand of Phragmites australis.

When considering changes within the catchment during the period of development when the first drain was constructed, one can see how its function may have contributed to the establishment of this problematic species that is capable of capitalising on disturbance and altered hydrology. The straightened drain upstream, capable of flowing deeper, faster and further than the original creek it diverted, would have resulted in delivery of higher velocity inflows, carrying increased sediment loads and water likely to have been of poorer quality (carrying agricultural nutrients post-clearance). These attributes are likely to have favoured the establishment and subsequent expansion of *P. australis*, which now occupies an area on the western boundary of the swamp in Stipiturus CP and extends into the neighbouring private land, as shown in Figure 4.39 and Figure 4.40 – the latter using an overlay of the diagram in Section 4.5.2 – which displays the relationship between the drain discharge point location, the expanding area of *P. australis*, and the apparent deflection of flows.

Figure 4.39 – Looking north along the western boundary of Stipiturus CP, with private land to the left. The light colour of Phragmites australis foliage is visible both sides of the fence.

Figure 4.40 – the relationship between the drain discharge point location, the expanding area of Phragmites australis, and the apparent deflection of flows

The success of the expanding rhizomatous reedbed (Figure 4.41) as a sediment trap appears to have altered flow dynamics at the site. Rather than the flow continuing in a westerly direction along the original drain alignment, the main drainage discharge observed in September 2015 appeared to be deflecting north-west around the reedbed (see arrow on Zone 4 image, top-right of the previous page), before dropping into the main drain that exits Stipiturus CP in the vicinity of the main swamp bed.

Figure 4.41 – Looking south-west towards the Phragmites australis reedland (light colour) across Glenshera Swamp. The drain discharge zone begins near the patch of trees in the left the image.

4.7.5 ZONE 5: Downstream drawdown

This zone includes the network of comprehensive drains to the west of the reserve boundary, constructed in the 1960s and, on the basis of the aerial photography, probably more regularly maintained over subsequent years. This management history appears to be responsible for these drains, particularly the main east-west drain along the northern edge, having substantial gradient and capable of carrying a significant flow. After leaving the western boundary of Stipiturus CP, this was the main drain carrying all converging surface flows from the Park (irrespective of their source) when observed in September 2015.

This main drain increases in depth to the point where it is probably 1.5–2m deep at its western end. The effect of this drainage network has been to dewater the peat profile to a considerable depth in many places, strongly contributing to its degraded, weedy (particularly blackberry infested) character and preventing effective regeneration of swamp plants dependent upon a much higher degree of soil saturation. Due to proximity, this degree of drying is also likely to be having a deleterious effect, through drawdown, on the capacity of the peripheral western areas of Glenshera Swamp in the Conservation Park to maintain effective saturation after flows cease.

4.8 Summary

Despite a theoretical potential for increased runoff and aquifer recharge associated with historic terrestrial vegetation clearance in its catchment that may have resulted in increased catchment flows in the early years following development, times have changed. There is little doubt that surface water dams, channel diversion and drainage works, combined with recent climatic trends, are reducing water availability and hence seasonal soil saturation extent and duration across the entire wetland component of Stipiturus CP. The available evidence is also supported by the observations of those we have consulted with who have had a long association with the site, as well as the written perspective of Bob Bates (2015), reflecting on his early visits to the area 50 years ago (the underlined word is our correction):

> *"Drought or not, the man made water channel extending for five km held running water all year round and below that a tree lined creek with deep water holes. Away from the creek, there were seasonal water holes to fifty metres across… All along the creek were windmill driven water pumps in the main valley and also along the equally swampy side valleys. Sadly, it is very different today, with no waterholes and drainage channels which are quite dry most years by late November. By February this year they were dusty. The windmills are gone as underground water has disappeared, pumped dry after fifty years of extraction. Most of the valley heads are now planted to Tasmanian blue gum, which also suck up the sub soil moisture making large sections of the swamp dry. Today rainfall records officially show that there have been no (few) above average rainfall years across southern SA for over twenty seasons; but plenty of below average. In actual fact, well below and some average years resulting in a serious rainfall deficit which means that most of the Glenshera swamps are gone."*

Despite a few of the observations in this passage raising potential points of contention, to focus on those would be missing the point. The general picture it provides is an extremely useful reminder of the level of change witnessed over a relatively short period of time from human impacts in the area. Given the intimate relationship between water and ecology; further hydrological change will have ecological consequences, like those witnessed by long term observers of Glenshera Swamp over the past 50 years.

Against a backdrop of potential further land-use change, increased demand for water resources and predicted future declines in spring rainfall (Resilient Hills and Coasts, 2015), the artificial drainage and surface water diversion works described in detail in this section constitute a significant ongoing threat to the hydrology of the park. But unlike many of the other threats described, they can be actively managed through hydrological restoration works to buffer the site against other, future water security risks that cannot be controlled.

After an effective period of consultation with all interested parties throughout this project, it is clear that there is a developing appreciation for the risk posed by historic changes to site drainage as described. The next section of this report will focus on turning this shared understanding into suggested solutions.

5 Hydrological restoration options assessment

5.1 Setting the goal of hydrological restoration

Past drainage activities at Glenshera Swamp deliberately sought to favour agriculture over the pre-existing environmental values by endeavouring to dry out the swamp. Attempts to divert inflows, dry out the slopes, drain the bed of the swamp and increase downstream drawdown were all aimed at significantly speeding up the flow of water out of the system – irrespective of its source.

In simple terms, the goal of restoration should be the exact reverse.

Restoration goal:

- To trial and implement measures that are capable of significantly slowing down, and making better use of, water within or passing through Glenshera Swamp to preserve (and if possible enhance) its ecological values.

Measures of success:

In achieving this goal, the project should aim to:

- increase soil moisture duration across the site, in particular the year-round saturation of peat which drives ecosystem health, enabling environmental values to capitalise on smarter use of inflows;
- use methods wherever possible that cause the lowest possible disturbance impact;
- cause a positive shift in the trajectory of a set of chosen biological and/or hydrological indicators;
- enhance the site's capacity for natural regeneration and establish a new, wetter benchmark for future restoration actions to build upon; and
- also consider restoration methods capable, wherever possible, of involving interest groups and the wider community in the planning and works.

5.2 Potential hydrological management options

Several possible interventions are available which would act to increase hydrological residence time of passing flows within the swamp system. These interventions vary considerably and are explained according to their zone on the property, as introduced in the previous section:

5.2.1 ZONE 1: Main surface inflows

Reversing the impact of drainage in this portion of the property can be achieved through works that both reduce flow velocity of the stream and redirect surface flows to the swamp.

The best way to achieve both of these targets is to re-instate the natural meanders of the creek, encouraging it to follow its original course. The digital elevation data obtained for the site in October 2015 provides an excellent tool for planning this stage of potential works, as shown in Figure 5.1.

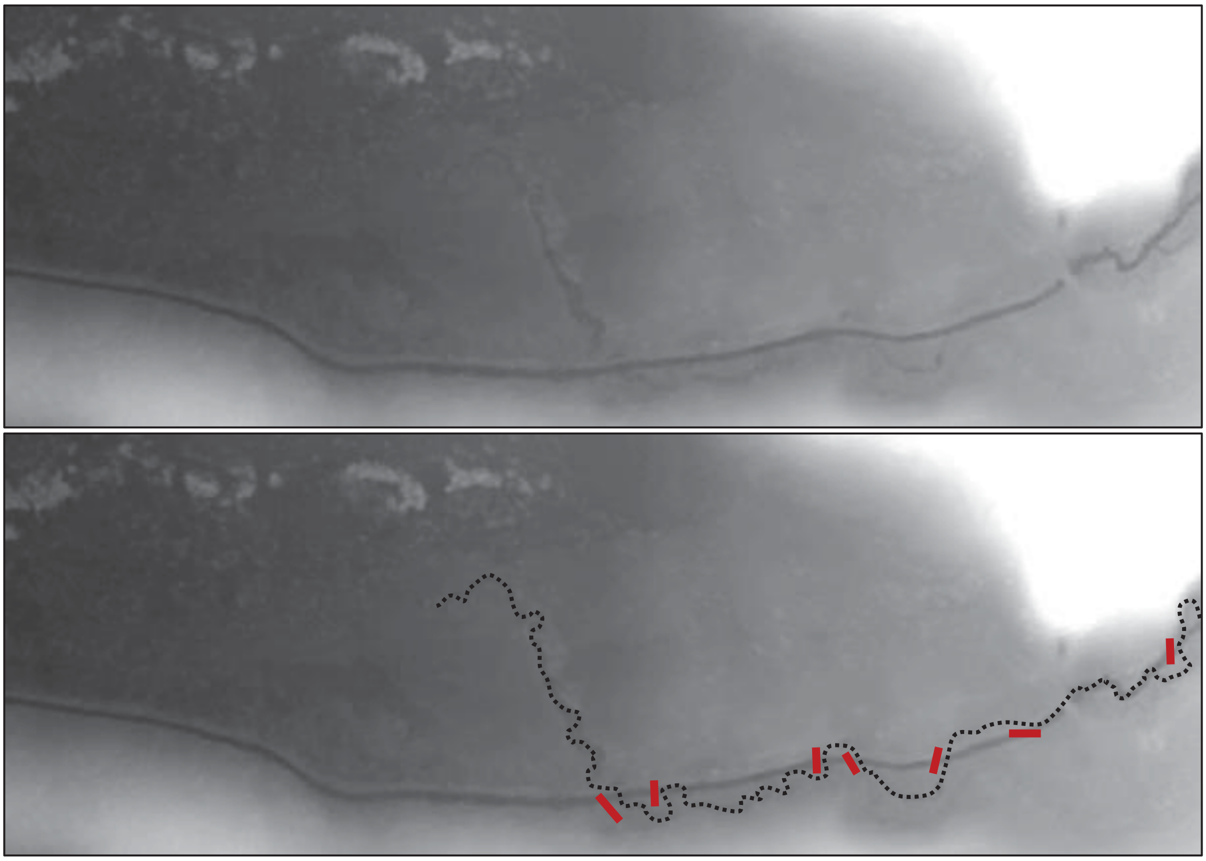


Figure 5.1 – Digital terrain model of surface inflows. The image ABOVE shows the impact of creek straightening and drainage diversion works. BELOW shows the potential flow path reinstatement.

Red bars show potential locations for the installation of earthen banks and the black dotted line shows the potential reactivated flowpath towards Glenshera Swamp, situated in the top left of each image.

We are fortunate that despite the artificial drain bisecting the original creek in a number of locations, the historical stream architecture still appears to exist, as observed on the ground. Closer analysis of the digital terrain modelling shown in Figure 5.1 reveals that in fact all original creek meanders have been retained either side of the channel.

This modelling also reveals the point at which the watercourse turned north and headed into the central region of the swamp, as opposed to continuing on a westward direction and skirting along the bottom edge of the swamp as is now the case under the channelised scenario. Again this data confirms our field observations.

Re-alignment of channelised flows back to their natural meandering state is now commonly practised globally in river restoration and, in this case, could initially be cheaply and feasibly implemented by installing a series of temporary sandbag deflection weirs – along the lines of example works presented in Section 8 – as conceptually displayed in Figure 5.2.

Figure 5.2 – Looking west towards the main diversion point; showing the potential reinstated meanders (left – blue arrows) while restricting flows down the artificial drain (right).

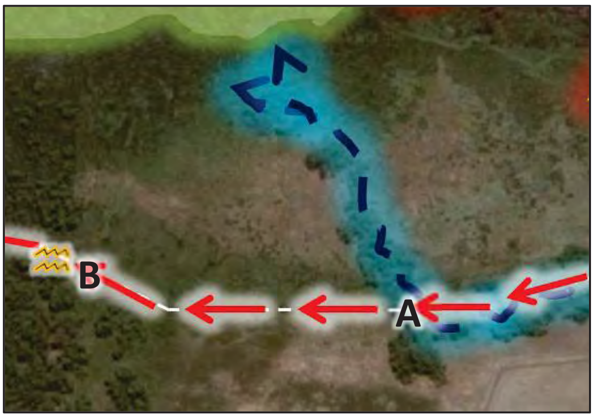
By using temporary structures, site disturbance could be kept to a minimum and during the trial phase the structures can be manipulated and tested in real time to achieve effective flow deflection under varying flow conditions. This avoids the need for high levels of initial investment in detailed hydrological modelling, which would normally be recommended before moving to permanent realignment earthworks in a single step. Hence the trial approach is a sensitive method, suitable for conservation areas, that follows the basic principle of 'try before you buy'.

All of the original creek meanders do not need to be reinstated in a single step – meaning that this work could be undertaken in stages over time. Suggested stages include:

ACTION 1: Flow redirection

The minimum works recommended to achieve successful flow redirection include:

- a diversion structure 'A' and artificial spoil bank breach at the final confluence between the drain and the creek, before it flows in a northerly direction – as shown in Figure 5.3.



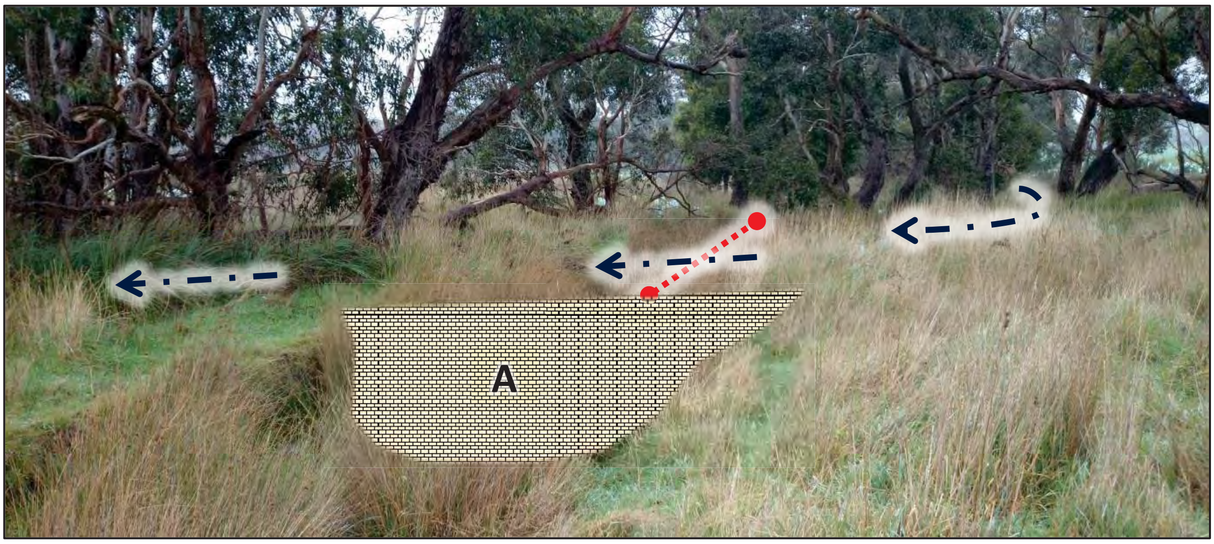


Figure 5.3 – Looking east towards the main diversion point where the creek flowpath could be reinstated (blue arrows) by blocking or regulating the westerly flowing artificial channel and breaching the spoil bank where it isolates the current flowpath from the historical flowpath.

- a block (or adjustable regulating structure) 'B' at the point further to the west on the drain where it reaches the higher sand bank vegetated by stringybark woodland – as shown in Figure 5.4. A structure at this location would prevent any surface water travelling overland, after dispersing at the terminus of the creek, from dropping back into the drain and bypassing the swamp.

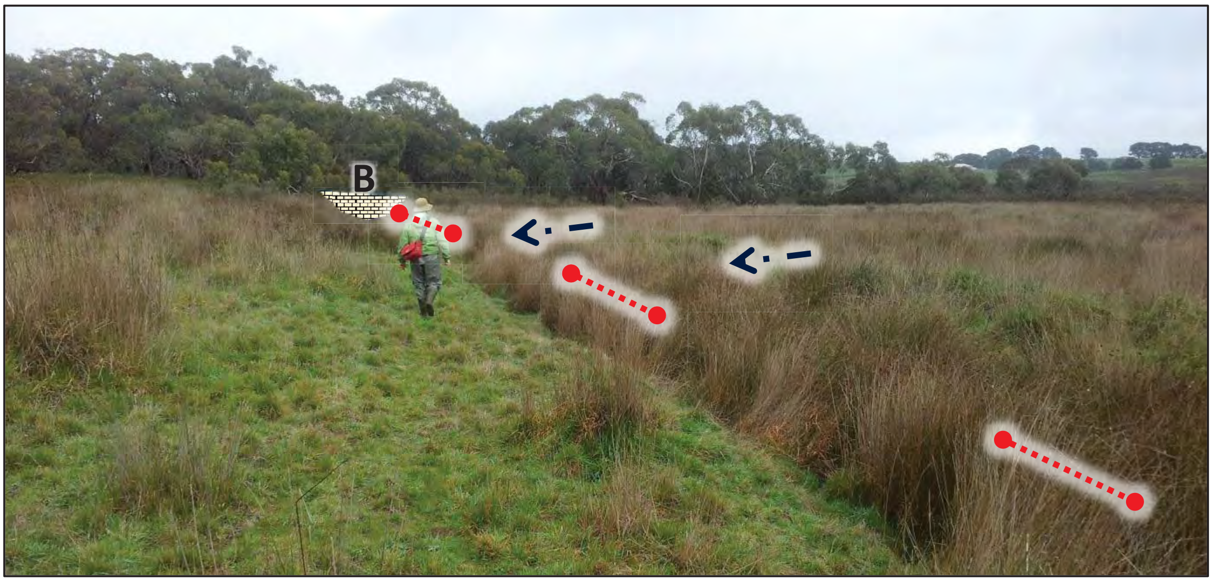


Figure 5.4 – Looking west down the drain away from the creek diversion point.

ACTION 2: Full meandering flow path reinstatement

As shown in Figure 5.1, there are a number of additional locations (at least 5 or 6), such as the one shown in Figure 5.2, where the drain could be rendered partially or fully inoperable to slow flow velocity and taking advantage of the original creek meanders.

5.2.2 ZONE 2: Swamp bed & ZONE 5: Downstream Drawdown

With the potential for increased surface water discharge entering the main swamp bed from the natural creek (from Zone 1), the key overarching priority for this zone is to the reduce the capacity for rapid loss of water from the swamp bed – both as a result of direct drainage on the western side, and as a result of drawdown caused by the deep, extensive network of drains on the private property to the west of the reserve boundary.

ACTION 3: Channel packing and regulation - measures for slowing and dispersing flow through peatland

Successful rehabilitation of comprehensively drained peat swamps has been achieved using check dams, water spreaders and chains of infiltration cells to encourage the lateral and vertical rehydration of desiccated swamp substrates (Hensen and Mahony 2010) – a concept that is particularly applicable to the downstream property where peat dehydration is most apparent.

In more sensitive areas (relevant for parts of Stipiturus CP), such methods might utilise organic materials, such as coir (coconut fibre) logs, sterilised straw bales, jute mesh, jute matting and wooden stakes to create weirs and/or pack drainage channels at regular intervals. These materials offer the advantage of being pre-made and are light weight so they can be easily carried into sites. Over time, these materials break down and become incorporated into the swamp substrate. Minor earthworks using existing spoil from on-site may also be used to achieve the same hydrological impact in less sensitive areas (potentially relevant for the downstream private property, subject to landowner consent).

In a general sense, to practically implement this strategy, sections of the swamp would be targeted in a staged approach with a likely starting point being to work on the main drainage channel leaving the swamp at the boundary of the Conservation Park, at a point where there is notable fall in gradient and working back into the park along the lowest elevation sections of the more active drains first – see Figure 5.5.

The specific design (including the number, location and precise materials) used to implement these measures can be formulated by NGT, should there be interest in pursuing this key action in the future.

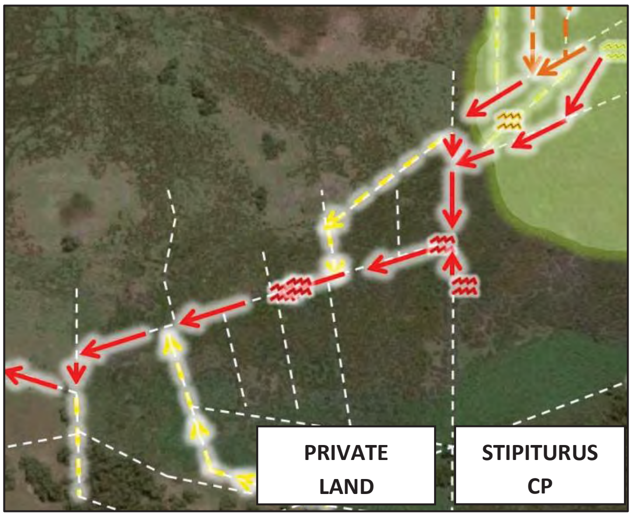


Figure 5.5 – The zone of high flow drains either side of the park boundary where channel packing and regulation is recommended to reduce outflow velocity and gradually increase peat water holding capacity.

5.2.3 ZONE 3: Bank seepage

Given the past level of disturbance in this zone, the fact that it can be managed independently (i.e. without significantly influencing) the swamp bed in any way, and the difficulties associated with trying to undertake trial measures in such a steep slope, mean that this zone would benefit from earthworks to completely backfill the drains and dam.

ACTION 4: Earthworks to physically backfill steep drains that target hillslope seepage

This activity is less urgent than some of the works proposed for other zones, due to its impact being more localised. With this in mind, the area should not be seriously targeted for swamp rehabilitation works (e.g. upslope swamp species revegetation) until the works are complete. To minimise the visual impact of these works, which will cause short-term damage to some of the remnant vegetation in the vicinity, it may be advisable to undertake the works in conjunction with a future prescribed burn. The advantage of doing the works before the burn will be in encouraging a post-fire germination response, while the benefit of delaying the works post-fire being improved visibility for the contractor. The feasibility of translocating swamp plant material (rhizomes or seed-bearing material for selected species) from sites that will be excavated or buried to freshly disturbed areas, may also be considered to hasten habitat recovery. The proposed works should <u>only</u> occur under ecological supervision to ensure that significant flora sites in the vicinity are not impacted.

Further assessment should determine how far downslope the works extend, noting that saturation may impede machinery progress. The goal should be to backfill the drains, using the existing spoil banks which run parallel to them (Figure 5.6), for as much of their length as possible. Any remaining sections of drain closer to the swamp bed that are inaccessible should be treated using the approach previously outlined for Zones 1 and 5.

ACTION 5: Earthworks to physically backfill the dam on the property

Figure 5.6 – Looking in a northerly direction up one of the hillside slope drains (white dashed line) – showing the spoil available to the right (shaded) for backfilling.

5.2.4 ZONE 4: Surface flow diversion

With the proposed redirection of the main seasonal surface inflow to the site, the opportunity exists to render the southern bypass drain inoperable along a deeper reach with considerable fall. This would prevent it potentially drawing down and capturing flows from the southern edge of the swamp. Although weed control is not the specific focus on this report, subject to the hydrological works proceeding and removing the point source discharges that appear to have facilitated the establishment *P. australis,* it is recommended that measures to control the species in Stipiturus CP are trialled and implemented.

ACTION 6: Install a series of blocks to render the bypass drain inoperable

Assuming effective diversion of flows occurs upstream, the proposed blocks – see Figure 5.7 – (at spacing intervals yet to be determined, but that would be informed by the gradient of the drain) could consist of either earthen banks or biodegradable (hessian) sand bags for ease of installation. The intention would be for the works to blend into the landscape and be consolidated by regenerating native vegetation from the adjacent banks and woodland habitat (Figure 5.8).

Figure 5.7 – The section of drain where a series of blocks would be installed

Figure 5.8 – This is the last of a series of locations along the bypass that could be blocked to render the drain inoperable – just before the drain peters out into the stand of <u>Phragmites australis</u>.

5.3 Other considerations associated with the proposed restoration works

5.3.1 Threatened flora and fauna

Given the role of contemporary hydrology in pre-determining critical habitat for both threatened flora and fauna, the capacity for changes in site hydrology to cause major changes in these habitats is a key consideration prior to undertaking any interventions. Using existing vegetation as an indicator for current hydrological regimes throughout the wetland area, we are able to forecast which areas of the swamp are likely to cross any thresholds in terms of drying or wetting in response to the proposed actions (Figure 5.9).

Unlike other restoration sites NGT has worked on, restoration outcomes at Stipiturus Conservation Park are unlikely to result in significant increases in depths of inundation. Therefore, the main consideration is how different areas of the swamp will respond in terms of increased duration of saturation. Given the predominance of inundation tolerant communities across the zones of influence (Figure 4.13), the likelihood of negative impacts is low.

Zone 1 is the area likely to experience the greatest change in terms of flow variability as this is the natural creek entry point and predominantly surface flow driven; hence more reactive to seasonal rainfall. Under this scenario, inflows would still reach the downstream channel area (zone 4) but over a more extended time period than currently occurs, as a result of slower, more diffuse flows moving through the peatland from Zone 1. The most apparent risk in this zone is that associated with pre-existing revegetation works (discussed below).

The lateral impacts of artificial drainage infrastructure typically vary according to soil type, although other factors such as depth to groundwater, slope, flow magnitude and profile roughness also determine drainage efficiency. Given that detailed information on soil horizons and flow gauging are lacking for this site, we will base our forecasts primarily on the information available i.e. general soil types and elevation considerations.

Literature based estimates (Minnesota Board of Water and Soil Resources, 2012) provide a framework for forecasting which areas of the swamp are likely to be most directly influenced as a result of modification to artificial drainage. For example, the main swamp areas (Zone 2 and 5 above) are predominantly composed of peat and the drain depths are in the order of 1 metre. Under such conditions, a setback distance of greater than 75 metres is recommended to minimise adverse hydrological impacts to adjacent wetlands. Given that these areas are laterally flat, we would expect the zone of influence to extend approximately 75 metres either side of the current drains at the site.

The contour drains on the northern slope are likely to be influencing both hillside seepage and also some surface runoff, by intercepting the drainage line identified by watershed modelling based on the DEM. By reducing the efficiency of these drains we could expect some localised downslope increases in inundation although more precise area estimates are difficult given the variable nature of the substrate and the slope (5%).

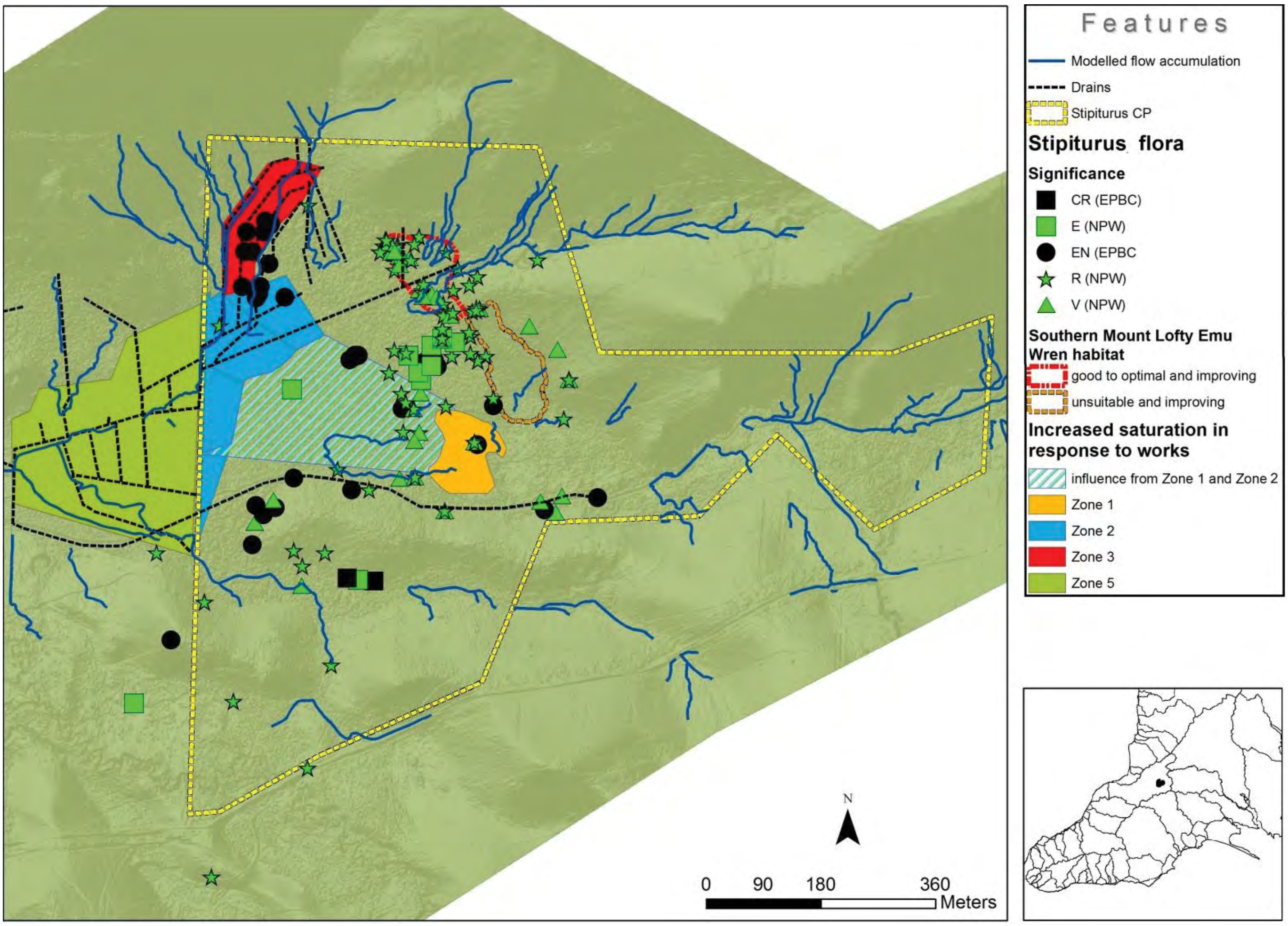


Figure 5.9 – Anticipated water regime changes in response to hydrological restoration works, showing significant flora locations and identified optimal Mount Lofty Ranges southern emu-wren habitat (see text for data origins).

NOTE: Modelled flow accumulation indicates likely points of surface runoff (or in this case possibly seepage) accumulation and does not specify or represent defined flow paths.

Aside from the identified zones of influence, a combination of deflecting inflows back into the main swamp area and reduced drainage from the northern and central areas of the swamp will result in increased residence time for flows through the bed of the wider swamp area, prolonging saturation and should cause a minor increase in water depth during flow periods. There may also be minor increases in upstream floodplain inundation associated with the slowing of water velocity within the inflow channel. Depending on the precise way water responds and moves through the site after the recommended actions are implemented, which is difficult to predict without more detailed flow studies, areas of the channel downstream of the diversion point may experience less inundation during flows as more water finds its way into the swamp proper. A potential way of maintaining aquatic habitat in that channel (e.g. habitat for the SA Rare *Triglochin alcockiae*) and preventing it from potentially continuing to drain the adjacent swamp is to implement the action proposed for Zone 4 (Action 6).

With regard to significant flora species within the park, there is an identifiable hotspot toward the eastern edge of the swamp bed (Figure 5.9). A number of species persisting in this zone of the swamp (particularly orchids) occur on mounds and hence inundation levels need to be managed so that actual inundation depth is not increased to a point whereby mounds become submerged. Given the gradual but consistent slope across the swamp, significantly increased depths of inundation throughout these areas is unlikely to occur using the restoration techniques proposed; however, continued monitoring of water levels in response to the works, which (for some key actions) can be treated as a trial and implemented in stages, is recommended.

Some of the more aquatic species such as *Ranunculus papulentus*, *Sphagnum novo-zelandicum* and *Myriophyllum amphibium* tends to occupy lower areas where water pools and the extent of inundation in these regions is likely to increase. The latter two species are restricted to peat bogs (Cooling, 2003; Murfet and Taplin, 2006) and are thus likely to benefit from activities which increase soil saturation extent and duration. Both species are adapted to these conditions and therefore should benefit. *Olearia glandulosa* is also likely to experience wetter regimes however the potential for increased inundation duration needs to be considered in terms of the precise elevation on which the species occurs. Despite historic records in the swamp bed, the majority of other significant species occur upslope of the wetland basin (in the saturated zone from hillside seepage), and are therefore unlikely to be negatively impacted by any dramatic changes to hydrology.

Areas of the swamp which are recognised as providing the most optimal habitat for the Mount Lofty Ranges southern emu-wren, and areas which are improving in terms of characters considered optimal, indicate that a majority of currently critical habitat is located in elevations above any areas likely to be significantly influenced by hydrological works (Figure 5.9).

5.3.2 Revegetation areas

A potential concern raised as a result of inflow re-instatement relates to inundation near the inflowing creek, where a significant revegetation effort is underway. Digital elevation modelling (Figure 5.10) reveals that the lowest lying areas adjacent to the inflow channel may experience an increased likelihood of inundation during high inflows.

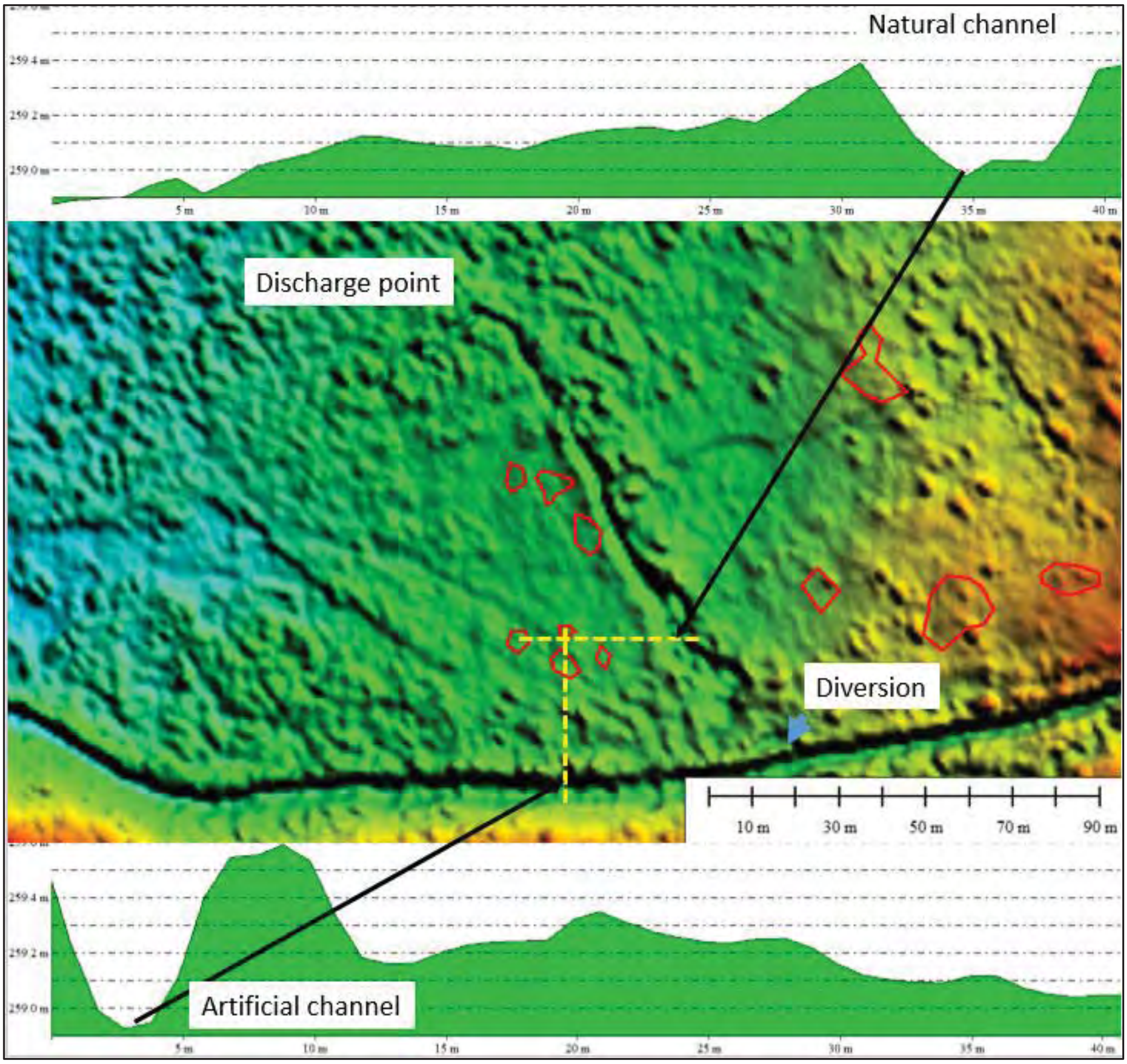


Figure 5.10 – Cross sections of channels adjacent to revegetation areas (red polygons).

While there is a possibility of a minor hydrological impact on the smaller revegetation areas to the west of the creek, the larger revegetation areas to the north and east of the creek are further upslope the zone of influence from diverted flows. These areas were in saturated soil in spring 2015 and clearly under the influence of seepage rather than creek inflows.

5.3.3 Data gaps and monitoring

In line with undertaking hydrological restoration works, a detailed monitoring program should be established to both track changes and also evaluate the forecasts (and the assumptions that underlie them) presented in this report. A network of surface water flow gauge boards, particularly in the creek upstream and drain downstream of the swamp, would be useful in determining surface inflow and outflow volumes and these could be automated using water level data-loggers which, when calibrated with rainfall data and flow measurements, could provide hourly data on flow relationships through the site.

The site also currently has a network of observation wells installed and these should be reactivated to regularly monitor water levels, if possible mirroring the frequency for the surface data-loggers to better establish and define local catchment hydrological relationships. Additional shallow well construction through the swamp and on the outer slopes of the wetland, would be important for determining influences from and relationships to groundwater, and help feed into the wider understanding of regional groundwater hydrology. This data would also help to provide a real-time cross section of saturation levels throughout the peat profile of Glenshera Swamp, a key measure for determining the impact and success of restoration works.

Assessment of vegetation changes over time will be important for evaluating the effectiveness for restoration measures to meet their objective of maintaining or improving habitat quality. Site wide vegetation monitoring should therefore be commenced in order to establish a baseline of current vegetation community positions and estimates of dominant structural species cover. This should be based on a suitably efficient method capable of revealing hydrological response trends, but also ideally able to be implemented annually at low cost. A suitable method which has been utilised at other hydrological restoration sites involves cross section transects of the swamp to record dominant species distance positions and cover, for each strata. This method is unlikely to provide sufficient resolution for threatened species and more detailed and considered monitoring would be required for these. Additional monitoring of boundaries of problem species e.g. weeds and *P. australis*, should be undertaken so that changes can detected and, if necessary, dealt with.

Bird monitoring is already well established within the park and is likely to continue and provide insights into the effectiveness of restoration. However, a critical fauna component which has received relatively little attention since the reservation of Glenshera Swamp is freshwater fish and other aquatic vertebrates. Audio recorders are a useful way of documenting frog species present and should be installed during key calling periods in order to confirm and monitor changes in species presence and, through call density metrics, surrogates for abundance.

5.3.4 Legislative considerations

Natural Resources Management Act 2004 (NRM Act) (SA)

The NRM Act is South Australian legislation responsible for the protection of the State's natural resources. A mechanism within the Act for protecting water dependent natural resources from potential harm is through a permitting system to regulate Water Affecting Activities (WAAs). WAAs are activities that have the potential to negatively impact the health and condition of water resources, other water users, and the ecosystems that depend upon those resources. Water resources may include rivers, creeks, waterholes, springs, lakes and wetlands.

Given that the permitting processes for water affecting activities under the NRM Act are designed to regulate activities that may cause damage to waterways or waterbodies, restoration work to reinstate natural hydrology of a degraded environmental asset (as a result of past works that would today be considered WAAs), does not appear to be a WAA as defined by the Act. Capturing such activities was certainly not the intention of the provision in the legislation that governs the diversion, impounding or regulation of water movement in a watercourse. However, that said, as the first proposed hydrological restoration project of this type in the AMLR region, there are advantages in participating in the formal planning process – predominantly as an information sharing and communication exercise to build a consensus for similar action at further sites in the future.

This approach was discussed at an onsite meeting in October 2015 with Martin Stokes, a water planner from DEWNR. The discussion focussed on the fact that water would not be impounded artificially in any way beyond reinstating the original swamp hydrology, with any trial works focussed on slowing (not preventing) the movement of water through the system and reinstating natural flowpaths in the process.

Should the actions proposed in the report be adopted for implementation, this permitting process should be initiated with the AMLR NRM Board. Given the nature of the proposal, it is anticipated that the time frames required for this process should not be lengthy.

Environment Protection & Biodiversity Conservation Act 1999 (EPBC Act) (Commonwealth)

The EPBC Act is Commonwealth legislation with a primary objective of providing for the protection of the environment, especially matters of national environmental significance. In the case of Stipiturus CP, matters of national environmental significance (under the EPBC Act) include a nationally threatened ecological community and several nationally threatened species. The Act provides a referral system to that is designed to protect these matters from action that could have a 'significant impact' and cause potential harm. Proponents are required to self-assess to determine their potential obligations under the Act, with additional provisions for third-party referrals also available.

Carefully planned and managed site-based recovery actions to protect and enhance habitat for threatened species and ecological communities (listed under the EPBC Act) are not typically referred by proponents given that their primary objective is to improve the conservation of matters of national environmental significance. Hence the measured (in some cases staged, trial) actions proposed within this document are not recommended for referral under the EPBC Act.

5.3.5 Impacts on the surrounding landscape and neighbours

Digital terrain modelling indicates that the wetland areas are well contained with the park boundary and upstream properties will not be impacted by surface inundation as a result of any of the proposed works. A small area of land on the south eastern boundary, in the vicinity of the proposed reinstated meandering section of the inflow tributary, may only be impacted by flooding during the most extreme flow events – given that this small area of potential floodplain is 1.4 m higher than the proposed diversion point.

Influences on catchment processes are unlikely to be discernible, and insignificant in magnitude in comparison to the dozens of instream dams which are currently in place throughout the catchment. The increased retention time and slowing of water movement is predicted to cause a reduction in peak outflows from the park; however, given the permeable nature of the substrate, the long-term impacts of these changes on overall (average annual) surface and subsurface flows, once the peat profile is re-saturated, are expected to be negligible.

As previously described, the downstream neighbour who owns the more heavily drained western portion of Glenshera Swamp has confirmed a willingness to implement restoration options (Jacqui Best, pers. comm.). The management of this parcel of land will be critical for achieving the widest potential benefit through the actions proposed.

6 Summary of recommended actions

6.1 Project communication and permit approvals

The first phase completed towards achieving hydrological works within Stipiturus Conservation Park was the peer review of the information presented in this report, validating its accuracy and applicability for reaching agreed and desirable conservation outcomes for the site. A process that commenced during the development of the report in late 2015, this review was completed after formal circulation of the draft amongst project stakeholders in early 2016, before being finalised in March 2016. Additional communication has also occurred with park neighbours, who have indicated a willingness to proceed with on-ground works implementation. Commensurate with wider project communication, applications for relevant permits (i.e. the SA NRM Act) should be initiated.

6.2 On-ground works

6.2.1 Number and location of on-ground actions

Six key actions are recommended in as being desirable to achieve a staged process of comprehensive hydrological restoration of the site. These actions are listed below and displayed in the site map over the page.

ACTION 1: Flow redirection of the natural creekline

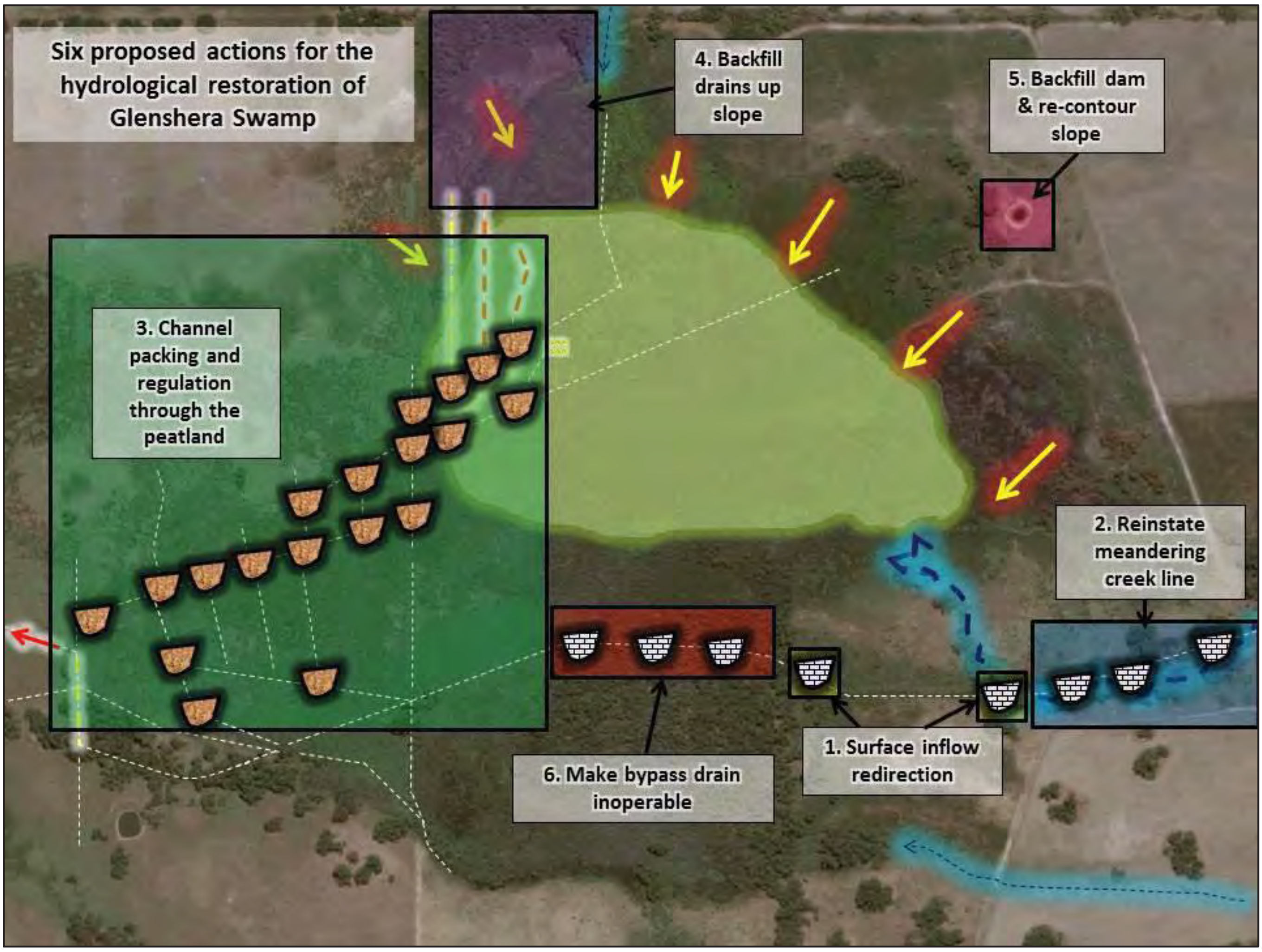
ACTION 2: Full meandering flow path reinstatement of the natural creekline

ACTION 3: Channel packing and regulation - measures for slowing and dispersing flow through the core area of peatland

ACTION 4: Earthworks to physically backfill steep drains that target hillslope seepage, undertaken under close supervision

ACTION 5: Decommission the dam to the north-east of the swamp, reinstating the original bank profile

ACTION 6: Install a series of blocks to render the bypass drain inoperable



6.2.2 Prioritisation of on-ground actions

Actions 1 and 3 are the highest priority:

- Action 1 can be implemented in the short term with limited resources.
- Action 3 will require more significant funding and further planning to successfully implement.

Actions 2 and 6:

- should follow Action 1, after the successful implementation of a trial.
- are important for completing the eventual long-term reversal of negative impacts associated with the historic creek diversion.

Actions 4 and 5:

- can be completed at any time, subject to funding.
- are independent of other tasks.

6.3 Monitoring

In line with delivering on-ground works of this nature, several indicators could be monitored to track a positive trajectory of change towards the target conservation outcomes. These typically relate to the need to demonstrate that works are having a desirable hydrological influence and that this is in turn resulting in an overall improvement in the ecological character of the site, in line with wider conservation management objectives.

Key suggested monitoring requirements that are recommended, subject to available resources, are:

- Installation of surface water level gauge boards and level loggers in both the inflow watercourse, outflow drains and across the swamp;
- Installation of water level loggers into existing observation wells and/or installation of new wells in strategic locations to capture groundwater movement and recharge information, as well as helping to quantify any future changes in peat saturation that result from the decommissioning of drains;
- Establishment of permanent cross sectional vegetation transects and undertaking of baseline monitoring to record the position of dominant species within each strata, through multiples zones of predicted hydrological influence;
- Establishment of long-term photopoints at key locations in each of the zones for works indicated in this report, where possible in conjunction with the gauge board sites mentioned in the points above.
- Review of threatened species monitoring programs to determine likelihood of detecting changes under modified hydrology, and adapting those methods as necessary;
- Identification of any permanent aquatic refuge pools within the wider catchment connected to the swamp and undertake surveys for freshwater fish;
- Establishment of audio recording stations and undertaking of seasonal recordings to establish frog species lists;
- High accuracy mapping of the boundary of the *Phragmites australis* reedland prior to and annually following restoration works and associated with any other potential control works; and,
- Continued control and monitoring of other weeds as necessary.

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8 Appendices – Wetland Restoration Case Studies

8.1 Scale Swamp, Victoria (Nature Glenelg Trust, 2014)

Scale Swamp is a 120 hectare wetland situated on private land, 15 km south of Dunkeld in western Victoria. This open, seasonal, grassy wetland of the Victorian Volcanic Plain was partly drained prior to the first aerial photograph being taken of the site in the 1940s (see Figure 8.1), and more comprehensively drained and developed for grazing over subsequent decades. The current owners have long expressed an interest in improving its degraded environmental condition, which led to the site being included as a focal area in Nature Glenelg Trust's *Wetland Restoration Program on Private Land*; a five year project focussed on hydrological reinstatement works funded by the Australian Government until June 2017.

In being situated at the top of a closed catchment (i.e. without upstream drainage lines that feed into it), where the modelled impacts of inundation could be accurately predicted using digital elevation data (see Figure 8.1), it was possible to completely block the artificial drain outlet in a single step to restore the original water regime for the site. At the same time, fencing has been reconfigured to enable grazing to be selectively used as a management tool. The works occurred before winter 2014, initiating long-term floristic regeneration (Figure 8.2) that is serving as a test case for grassy wetland natural recovery potential.

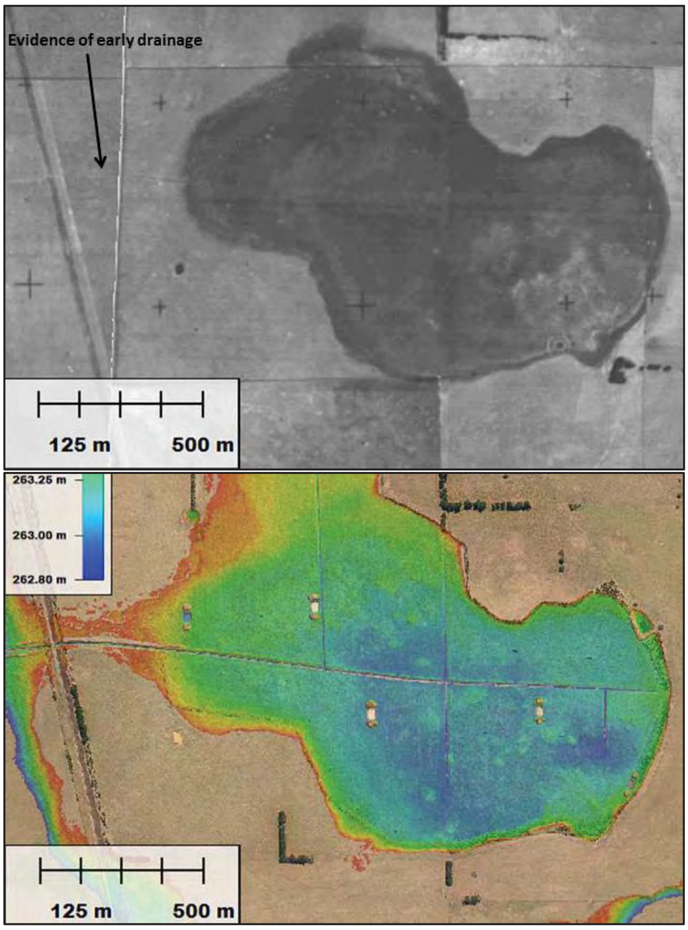

Figure 8.1 – Scale Swamp in the 1940s (above), and today (below), also showing the artificial drainage network and inundation depth model.

Figure 8.2 – looking north over the southern (deeper) section of Scale Swamp towards Dunkeld.

8.2 Pick Swamp, Piccaninnie Ponds CP, South Australia (DEWNR, 2007-09)

Pick Swamp was first identified and recommended for protection as a result of its biological values in a 1964 submission by the Field Naturalists' Society of SA to the SA Government, which led to the creation of the Piccaninnie Ponds Conservation Park. However, Pick Swamp was ultimately not included as a compromise during the landholder negotiations required to secure the new reserve. Pick Swamp remained largely intact until the early 1970s, when the property changed hands and was progressively drained and developed for agriculture.

By the time the property was first offered for resale, approximately 30 years later in 2002, the bulk of it had been modified (drained, cleared and grazed by cattle), with the exception of the now isolated Crescent Pond (a significant spring feature) and a surrounding 40 hectare area of saturated (groundwater fed) peat fen supporting Silky Tea-tree shrubland. Despite several attempts, this remnant area was never effectively drained or cleared, but was being negatively impacted by drainage of the surrounding wetland area. After a protracted negotiation process, the 230 ha property was eventually purchased by the SA Government in 2005 for restoration and inclusion in the adjacent Conservation Park. A plan (Clarke 2007) was implemented from 2007 to restore the property, through reversal of drainage and supplementary revegetation of terrestrial and wetland fringe species only, beginning a process of spectacular natural aquatic habitat recovery (Figures 8.3 – 8.6).

Figure 8.3 – Oblique image looking east over Pick Swamp before and after restoration; Jan 2003 (left) – Jan 2014 (right)

The restoration of Pick Swamp has resulted in approximately 130 hectares of land being permanently re-inundated, and the aquatic component has recovered to an excellent level of ecological functionality with minimal management intervention in the intervening eight years (Bachmann & Holland 2015). This recovery was aided by the fact that Pick Swamp was strategically selected for its restoration potential; being adjacent to an existing Conservation Park and having excellent prospects for natural regeneration. As well as hosting a wide range of different vegetation associations (Ecological Assoc. 2008), Pick Swamp has become a stronghold for the nationally threatened Australasian bittern and dwarf galaxias, and the site hosts thousands of waterbirds (DEWNR, unpubl. data; Bachmann et al. 2014; Veale & Whiterod 2014). Just five years after restoration works commenced in 2007, the site was included in the Piccaninnie Ponds Karst Wetlands Ramsar site listing at the end of 2012 – a testament to the habitat recovery potential of restored wetlands.

Figure 8.4 – May 2007 (before restoration)

Figure 8.5 – July 2007 (several weeks after restoration commenced)

Figure 8.6 – June 2012 (5 years post-restoration – note natural recovery of aquatic plants)

A further demonstration of the success of this ongoing restoration project has been the recent reintroduction of two nationally Vulnerable species, each with very specific habitat requirements, the Yarra pygmy perch (Veale et al. 2014) and the swamp greenhood (Figure 8.7) (Thompson et al. 2015).

Figure 8.7 – Swamp Greenhood (Pterostylis tenuissima)

8.3 Brady Swamp area, Grampians NP, Victoria (Nature Glenelg Trust, 2013-2015)

A series of wetlands associated with the floodplain of the Wannon River (Walker, Gooseneck, and Brady Swamps), situated approximately 12 km north east of Dunkeld in western Victoria, were partially drained from the 1950s onwards for grazing purposes (Figure 8.8). A portion of these wetlands was later acquired and incorporated into the Grampians National Park (and adjacent reserves) in the mid-1980s, managed by Parks Victoria. However, the balance of the wider wetland and floodplain area remained under private ownership, creating a degree of uncertainty surrounding reinstatement of water regime – an issue that was left unresolved for over two decades.

Many years of planning work, including modelling studies and biological investigations by a range of organisations didn't resolve the best way to design and progress wetland restoration work in this area.

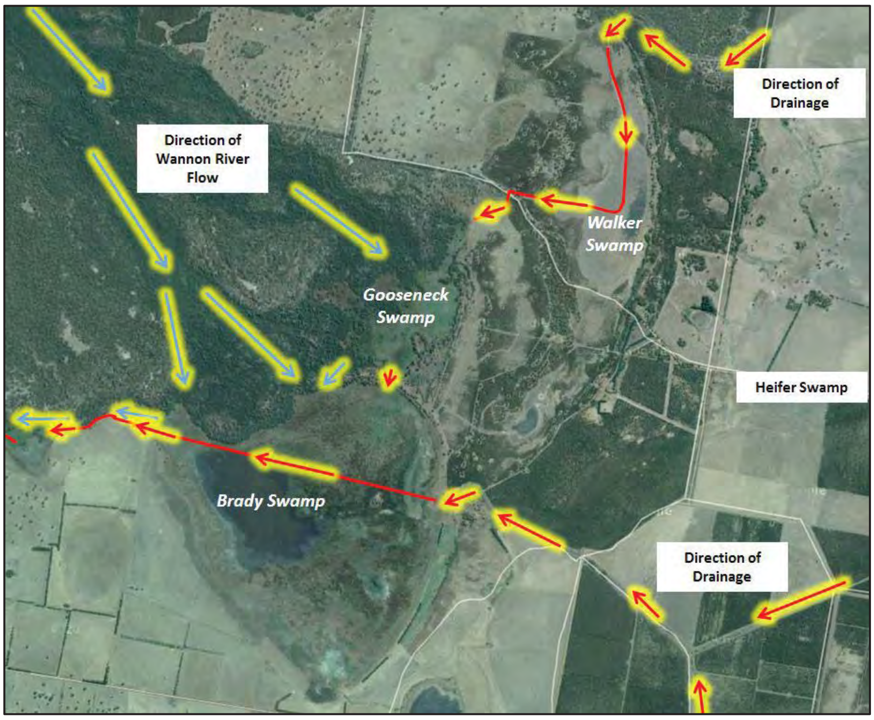

Figure 8.8 – Image from the present day: showing artificial drains (red lines/arrows) constructed to drain Walker, Gooseneck and Brady Swamps, as it operated from the 1950s–2013.

To address the impasse, at the request of the Glenelg Hopkins CMA in early 2013, NGT proposed a staged restoration trial process which was agreed to a short time later by landowners, neighbours, government agencies, and local community groups.

The restoration process began in August 2013 (grant funding provided by the Victorian Government) with the installation of the first trial sandbag weir structure to regulate the artificial drain at Gooseneck Swamp. Its immediate success in reinstating wetland levels led to similar trials being initiated at Brady Swamp and Walker Swamp (Figure 8.9) in 2014.

The success of these trials has been based on their tangible ability to demonstrate, to all parties involved, the potential wetland restoration outcome for the sites; made possible by using simple, low-cost, impermanent methods. To ensure the integrity of the trial structures, the sandbags used for this purpose are made of geotextile fabric, with a minimum field service life of approximately 5 years.

Figure 8.9 – The volunteer sandbagging crew at the artificial drainage outlet from Walker Swamp - August 2014.

The trials were critical for building community confidence and collecting real operational data (to test our scenario modelling based on digital elevation data) for informing the development of longer-term measures to increase the depth and duration of inundation. The trials ultimately led to permanent works to reinstate the breached natural earthen banks at Brady (Figure 8.10) and Gooseneck Swamps (Figure 8.11), implemented by Nature Glenelg Trust in early 2015. These works have permanently reinstated the alternative, original watercourse of the Wannon River, which now activates when the water levels in these wetlands reach their natural sill level.

Figure 8.10 – Brady Swamp drain, trial structure before (left) & after (right) 2015 permanent works

A vital aspect of the trials has been the level of community participation, not only at the sandbagging "events", but also the subsequent commitment to ecological monitoring, for helping evaluate the biological impacts of hydrological reinstatement. For example, the Hamilton Field Naturalists Club has been undertaking monthly bird monitoring counts that are helping NGT to develop a picture of the ecological value of these wetlands and their role in the wider landscape, including the detection of international migratory species.

Figure 8.11 – Gooseneck Swamp in Sept 2014: the second season of the restoration trial, just prior to the implementation of permanent restoration works

8.4 Lake St Clair CP, South Australia (DEWNR, 2009)

Figure 8.12 – Lake St Clair CP showing the location of the artificial boundary drain (red dashed line).

Lake St Clair Conservation Park is situated 20 km south east of Robe, in the South East of South Australia, and was proclaimed in 2006. An artificial channel that pre-dates the reservation of the park, to improve drainage for grazing, follows the southern half of its western boundary and discharges into the lake (Figure 8.12). This drain was having a detrimental impact on the hydrology of the remnant, freshwater wetland vegetation communities in particular, by:

- reducing depth and duration of surface inundation;
- enabling accelerated lateral seepage and discharge of the shallow groundwater aquifer that appears to strongly influence site hydrology; and,
- enabling saline water from Lake St Clair, when full, to push up into freshwater fringe habitats when under the influence of a strong southerly wind.

The impact of the drain was detectable thanks to some subtle biological clues, such as the emergence of some terrestrial species in the fresh wet heath habitat, and the expansion in the extent of more salt-tolerant species such as swamp paperbark (*Melaleuca halmaturorum*).

To minimise physical disturbance impacts in the dense vegetation communities present, restoration works involved the installation of a series of lined sandbag 'blocks' at several locations down the length of the drain in 2009 (see Figure 8.13), to prevent it from conveying flows (in either direction). The success of the works led to some blocks being permanently consolidated into earthen banks, enabling the outcomes achieved through decommissioning the drain to be perpetually secured.

Figure 8.13 – an example of a block installed on the drain in Lake St Clair CP, before (above) and during (below) winter flows in 2009.

8.5 Piccaninnie Ponds CP, South Australia (DEWNR, 2006 & 2013)

Piccaninnie Ponds Conservation Park is situated 30 km south east of Mt Gambier in South Australia. For 15-20 years after the park was proclaimed in 1969, there was considerable local interest in trying to address previous changes that had been made to the hydrology of the wetland system. Although it was protected, reserved and supporting a diverse suite of habitats and range of resident threatened species, Piccaninnie Ponds was far from intact from a hydrological perspective.

Prior to European settlement, water that discharged from the karst, rising-spring wetlands in the system flowed eastward across the State border into the Glenelg River Estuary, along a watercourse between the dunes called Freshwater Creek near what is now the township of Nelson, in far South West Victoria. This is how the system remained until 1906, when the first of several attempts to drain the wetlands of Piccaninnie Ponds directly to the sea occurred. However, rather than being the beginning of comprehensive drainage, what ensued was a turbulent nine year period during which the community, led by local fisherman in both states, lobbied governments in both South Australia and Victoria in an attempt to have the creek re-directed to the Glenelg River. It seems that the often estuarine lower reach of the Glenelg River was a hot-spot for fishing, and the locals had noticed a dramatic decline in their catch since the permanent freshwater flows from Piccaninnie Ponds were lost.

This early form of environmental activism was rewarded in 1915, when the state governments agreed to share the cost of damming the new outlet through the dunes (Figure 8.14) and constructed an alternative channel to the Glenelg River. This was necessary because the original flowpath between the dunes had been lost to drifting sand.

Figure 8.14 – 1915: damming of Freshwater Creek at the 1906 artificial outlet location to the sea

It was not long before the new flowpath caused controversy however, with landowners at the western end of the system complaining that the water level was now higher than prior to 1906, and was impacting on the viability of their grazing enterprises. By 1917, with water levels high and the dunes still unstable, another suspected act of sabotage led to a new outlet being cut near the state border, as shown in Figure 8.15.

Figure 8.15 – The new 1917 artificial outlet of Freshwater Creek. Note the stranded aquatic plants in the foreground, indicating a rapid water level drop as the cutting eroded to sea level.

The difficulties encountered in such an unstable coastal environment, and problems in getting interstate co-operation to meet the costs, then led both governments to abandon any further plans for flowpath restoration, enabling the ad hoc drainage and development of portions of the wetland system to commence by private owners or lessees.

At the time the park was proclaimed in 1969, a new main artificial outlet was draining the ponds directly to the sea. Both the South East Association of Field Naturalists and local ranger staff took an active interest in the hydrology of the area, by advocating for the restoration of flows to the Glenelg River. However, the final filed correspondence on the matter from the 1980s shows that scientific officers based in Adelaide refused to support the proposals on the grounds that a change to hydrology may cause disturbance to terrestrial vegetation in the park. The concept was shelved, until revived from a series of steps undertaken to achieve hydrological restoration from 2002 (for more detail see Bachmann et al, 2015).

The first of these steps, the stage 1 weir and fishway constructed in 2006 at Piccaninnie Ponds (Figure 8.16) halted a long-term (several decades long) drying trend in the Park, by regulating outflows on the artificial outlet for the first time.

Figure 8.16 – Stage 1 weir and fishway under construction in 2006.

It also has the effect of increasing inundation in a small area immediately upstream of the structure, under the direct influence of the weir pool it created, as shown in Figure 8.17.

Figure 8.17 – The upstream inundation impact and habitat change caused by the stage 1 weir, showing habitat change 2006–2012.

The stage 2 weir and fishway upgrade completed in 2013 (Figure 8.18) resulted in the structure height being lifted to increase future management flexibility, including providing the future ability to completely block outflows, should the option of re-instating the original flow path one day become a reality.

Figure 8.18 – The lifted and redesigned stage 2 weir and fishway on the main artificial outlet at Piccaninnie Ponds – upon completion in 2013.

The stage 2 upgrade was completed at the same time as providing a new flow path to physically reconnect the isolated eastern and western basins at Piccaninnie Ponds. These wetlands had been separated for several decades by a combination of lower water levels, sand drift and, to a lesser extent, the impact of the Piccaninnie Ponds Road. An aerial photographic view of the new flow path is shown in Figure 8.19.

These works within the original Conservation Park, have occurred in in a complementary way with those that have occurred in the neighbouring, newly reserved area at Pick Swamp (earlier case study - *Appendix 8.2*), each contributing to the wider vision for restoration of this wetland complex.

Figure 8.19 – Aerial imagery showing the reconstructed flow path and culvert location under the Piccaninnie Ponds Road. Construction occurred in 2013.

The main Piccaninnie Ponds (western wetland) are in the top left of each image, while Hammerhead Pond (eastern wetland) is in the bottom right corner of each image. Also note the increase in open water habitat to the south of the main Ponds, associated with the installation of the Stage 1 and Stage 2 weir structures.

TOP – Before works image: January 2003.

BOTTOM – Post-construction/restoration image: January 2014.

8.6 Long Swamp, Discovery Bay CP, Victoria (Nature Glenelg Trust, 2014-15)

Long Swamp is a 15 km long coastal freshwater wetland complex situated in Discovery Bay Coastal Park, approximately 50 km north-west from Portland in south-western Victoria. The wetland system supports a diverse suite of nationally threatened species and is currently undergoing a Ramsar nomination process. Despite its size, reserved status and impressive biodiversity values, including recognition on the Directory of Important Wetlands in Australia, the local community in Nelson had expressed concern for over a decade about the impact that two artificial outlets to the ocean were having on wetland condition. The outlets were cut during an era when the swamp was grazed, many decades before being dedicated as a conservation reserve in the 1970s.

While the wetland originally discharged into the ocean via Oxbow Lake and the Glenelg River mouth at Nelson, these changes to hydrology caused an interruption of flows, contributing to a long-term drying trend within the wetland complex. This situation highlights a dilemma with altered wetlands in protected areas where, unlike modified wetlands on cleared farmland, rapid native vegetation change can mask the degree and extent of modification that has occurred or may be underway. As a relatively flat, extensive, coastal freshwater wetland ecosystem becomes drier, open aquatic habitats are replaced by herblands and reedlands, reedlands are replaced by sedgelands, and sedgelands are ultimately invaded by encroaching shrublands. The wetland margin is invaded and sometimes totally displaced by true terrestrial species, such as coastal wattle and coastal bearded heath, as all the communities move ‘downslope’. As a result of this gradual process of change, which has accelerated since the exclusion of grazing, the site has been the subject of some long-running community debate about water management; because in its modern, modified condition, and despite strong observational data about physical changes underway, it continued to support a wide range of valuable wetland habitats and a host of associated threatened species.

Figure 8.20 – Shrub (Leptospermum lanigerum) encroachment into sedgeland underway in Long Swamp.

In 2012, NGT became actively involved in Long Swamp, working closely with Parks Victoria, the Nelson Coast Care Group, and the Glenelg Hopkins CMA; initially to undertake a scientific review of the aquatic ecological values that might be impacted by the ecological shifts anecdotally observed to be underway. This early work identified that the more remote artificial outlet to the sea (White Sands) had in fact naturally closed, with a dune forming in front of the former channel several years earlier during the Millennium Drought (c. 2005).

The ecological benefits observed from the natural closure of the artificial outlet at White Sands included the recreation of an area of aquatic habitat immediately upstream of the former outlet that is now home to a diverse native freshwater fish community, including two nationally threatened fish species, the Yarra pygmy perch (*Nannoperca obscura*) and dwarf galaxias (*Galaxiella pusilla*). This work and other investigations led to the planning of a restoration trial aimed at regulating or possibly blocking the second and final artificial outlet at Nobles Rocks.

Overall objectives of this restoration project are to increase the availability, diversity and connectivity of aquatic habitats throughout Long Swamp, in order to benefit a wide range of wetland dependant species. As well as undertaking basic monitoring across a broad range of taxonomic groups (birds, vegetation, frogs), the project has a particular emphasis on native freshwater fish populations (being a key conservation asset that is most sensitive to hydrological change) as a primary indicator of project success.

The restoration trial has progressed in three stages over the past two years, enabling NGT to progressively record and measure the impacts of hydrological restoration in real time, and provide the information necessary for determining a future permanent solution (see Figure 8.21).

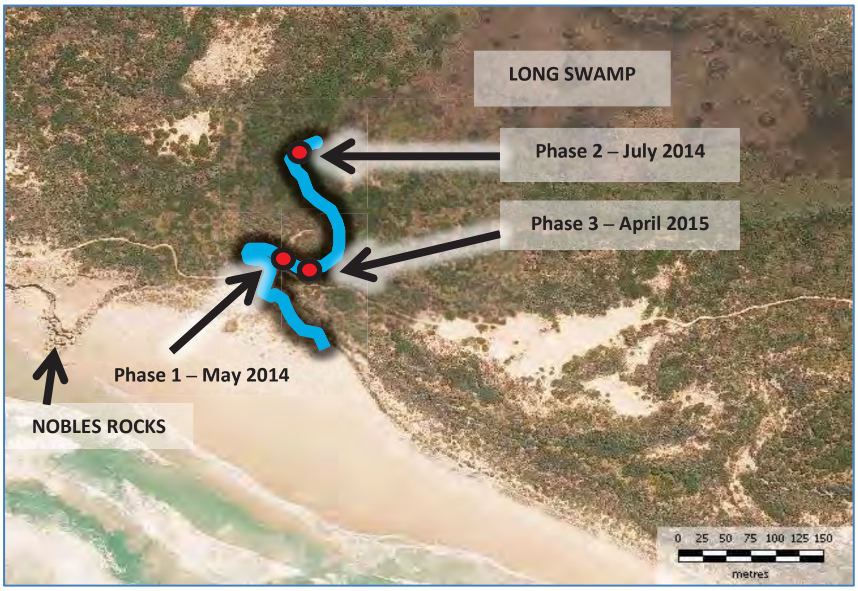

Figure 8.21 – Aerial view of Nobles Rocks artificial outlet, detailing the location of the three trial sandbag structures.

A series of gauge boards with water depth data loggers were also placed at key locations in the outlet channel and upstream into Long Swamp proper, to monitor the change in water levels throughout each stage of restoration and into the future.

The first two stages of the restoration trial in May and July 2014 involved 56 volunteers from the community working together to construct low-level temporary sandbag structures, initially at the most accessible and technically feasible sections of drain under flowing conditions. Tackling the project in stages enabled us to learn sufficient information about the hydrological conditions at the site in 2014, before commencing the third and final stage of the trial in March 2015. On the 27th April 2015, the main structure was completed, following two days of preparation and nine days of sandbagging (using about 6,600 sandbags), which were put in place with the dedicated help of over 30 volunteers (see Figures 8.22 & 8.23). To achieve our target operating height, the structure was raised by a further 30 cm (an additional 400 sandbags) in August 2015.

Figure 8.22 – NGT staff members celebrate the completion of the third and final sandbag structure with some of the many dedicated volunteers from the local community.

Figure 8.23 – View of the Phase 3 Restoration Trial Structure location; LEFT – prior to construction in March 2015, and RIGHT – in June 2015

Water levels in the swamp immediately upstream of the final structure increased, in the deepest portion of Long Swamp, from 34 cm (in April 2015) to 116 cm (in early September 2015). Further upstream, in a shallower area more representative of the impact on Long Swamp in the adjacent wider area, levels increased from being dry in April 2015, 14 cm deep in May, through to 43 cm deep in early September 2015, as shown in Figure 8.24. This is a zone where the shrub invasion is typical of the drying trend being observed in Long Swamp, and hence will be an important long-term monitoring location.

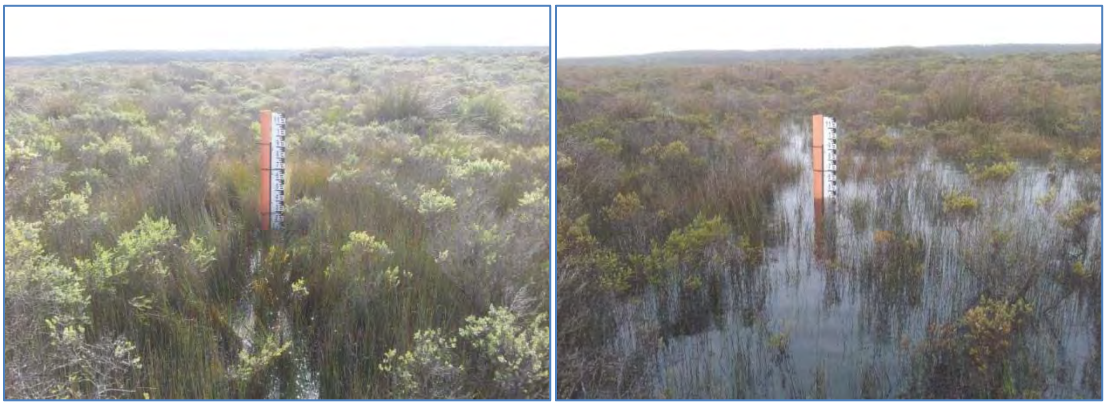

Figure 8.24 – LEFT: Further inland in the swamp after the Phase 3 structure was complete, shown here in May 2015. Depth – 14 cm; RIGHT: 4 months later in September 2015. Depth – 43 cm.

To evaluate the response of habitat to short and longer-term hydrological change, we also undertook longer-term landscape change analysis through GIS-based interpretation of aerial photography. This information indicates that prior to the trial, both aquatic and semi-aquatic vegetation types have undergone a reduction in extent over time, primarily as a result of fringing shrub invasion caused by the underlying change in hydrological regime (Figures 8.25 and 8.26). Through the restoration trial, we have currently recovered approximately 60 hectares of total surface water at Nobles Rocks, not including larger gains across downstream habitats as a result of groundwater mounding, sub-surface seepage and redirected surface flows that have also been observed.

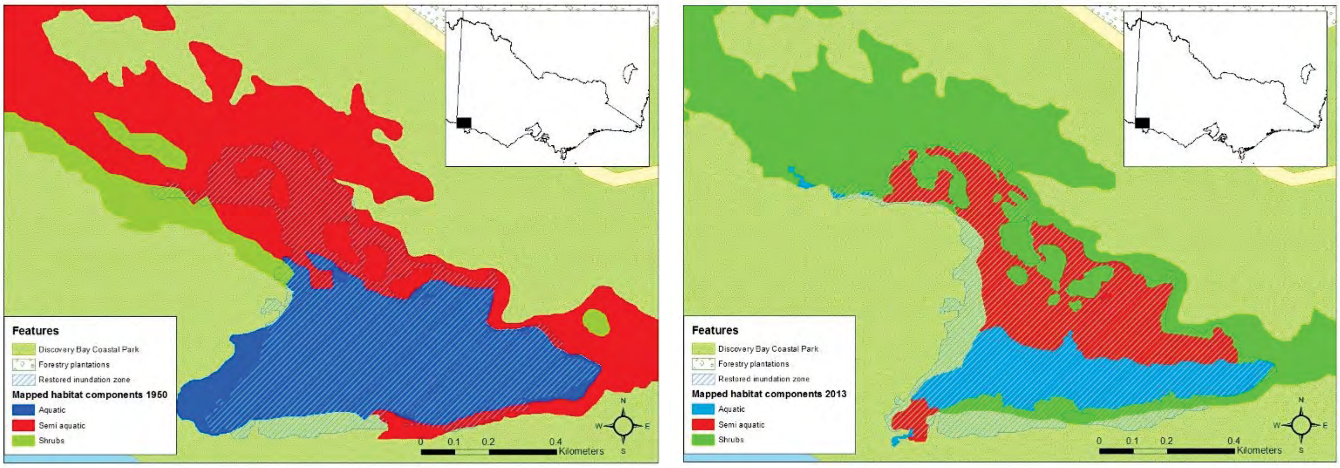

Figure 8.25 – Comparison between habitats in 1950 (left) and 2013 (right) as derived from aerial imagery with shading showing the restored wetland zone (the post-2015 anticipated new extent of aquatic habitat).

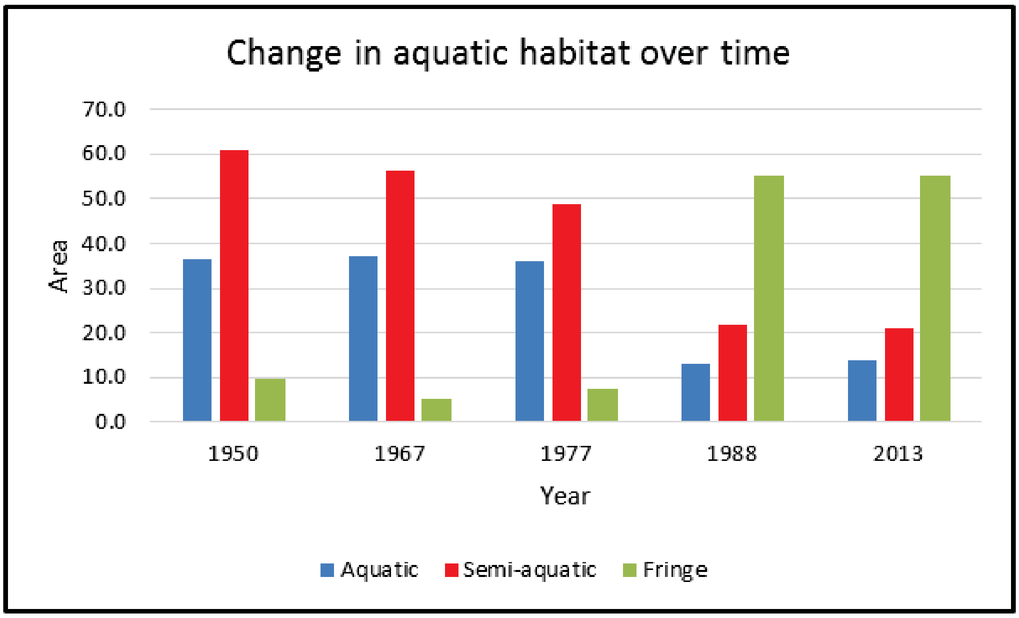

Figure 8.26 – Change in the area (hectares) of different habitat types (aquatic, semi-aquatic and fringing) recorded for Long Swamp at different intervals over the past 60 years.

The body of deeper fresh water first observed and mapped at Nobles Rocks in 1850 has reformed (see Figure 8.27). As anticipated, parts of this newly inundated area have undergone an obvious immediate shift; from supporting a terrestrialising plant community to true aquatic flora. An example of this (aquatic reed beds) is shown in Figure 8.28.

Photo: Marcel Hoog Antink

Figure 8.27 – Oblique view over Long Swamp, in the area of restored wetland habitat inland from Nobles Rocks, as its appearance has changed during the implementation of the trial.

Figure 8.28 – Floating aquatic reed beds of <u>Triglochin procerum</u> favoured by the Yarra pygmy perch are rapidly reforming in the restored areas of deeper water (50-70 cm deep) in the swamp inland of Nobles Rocks.

Meaningful community participation has been one of the most critical ingredients in the success of this project so far, leading to a strong sense of shared achievement for all involved. Monitoring will continue to guide the next steps of the project, with the ultimate aim of informing a consensus view (among those with shared interest in the project) for eventually converting the trial structure to a permanent solution.