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Reimagining the future of the wallan wallan wetlands –

How historic information and modern tools can guide the restoration of burrung buluk

DISCUSSION PAPER 3 – October 2022

Introduction

Nature Glenelg Trust (NGT) is an independent, charitable, not-for-profit, non-government organisation operating in south-eastern Australia. While we work across a wide range of biodiversity issues, major priorities include wetland restoration and management, and threatened species research and recovery.

This discussion paper is the third in a series produced by NGT to investigate the *wallan wallan* wetlands. These wetlands are providing an excellent test case for exploring how planning processes might (a) freshly assess large in-stream or floodplain wetland features embedded within the zone designated for future urban growth around Melbourne, and (b) consider new approaches for better achieving urban floodplain and waterway protection and restoration, as part of Victoria's commitment to healthy waterways and Integrated Water Management (IWM).

The previous discussion papers can be viewed via these links:

- **Discussion Paper 1:** Restoration Vision for the *wallan wallan* Wetlands, including Herne Swamp, as the centrepiece of the *wallan wallan* Regional Park. March 2019.
- **Discussion Paper 2:** Achieving Integrated Water Management of the *wallan wallan* Wetlands – Recognising gaps, understanding systemic obstacles to adoption, and identifying solutions. July 2020.

To review all past news stories by NGT related to urban wetland restoration, please click this link.

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Executive Summary

Situated south of Wallan within Melbourne's northern growth corridor, *burrung buluk* (Hanna Swamp) is a highly modified in-stream seasonal wetland feature that provides a new, rare opportunity to achieve strategic and lasting catchment, community and environmental benefits in the context of urban development. These benefits include flood buffering, water quality improvement, infiltration, liveability, urban cooling, meeting Traditional Owner aspirations, landscape amenity, open space and recreation, and opportunities for urban residents to connect with nature.

In order to adequately understand current condition, changes experienced, and potential for restoration of a wetland, it is necessary to collate and compare information from multiple fields including hydrology, soil science, geology, geomorphology, history and historical geography.

As a result of our analysis of these materials, combined with an understanding of wetland eco-hydrology, we can share a number of observations:

- *burrung buluk* is clearly identified as an in-stream wetland of Strathaird Creek on the earliest (mid 1800s) maps of the Wallan district, as shown below.

Inset of the 1854 wallan wallan Parish Plan, showing burrung buluk, and the approximate location of its inlet via Strathaird Creek from the north, and outlet towards Meade and Herne Swamps to the east.

- Despite the artificial diversion of Strathaird Creek over 100 years ago, *burrung buluk* continued to receive sufficient water to remain a semi-functional wetland.
- Aerial photographs show that the first artificial drain was cut into the bed of *burrung buluk* in the early 1970s, before comprehensive drainage occurred in approximately 2004.
- Regular inundation and/or saturation of *burrung buluk* until recently helps explain persistence of native wetland flora in the less cultivated parts of the wetland basin today.

The following table, which is subject to further amendment and refinement as more information becomes available, broadly summarises all the changes outlined in this discussion paper.

Period	**Description**	**Notes of likely impact on *burrung buluk***
Pre-1830s	Pre-European colonisation	The wetland in its original condition, and part of the traditional cultural landscape of the Wurundjeri Woi Wurrung people.
From 1830s	European colonisation: Sheep grazing introduced and period of continuous farming commences	Native wetland flora impacted as sheep preferentially graze the most palatable species. Introduction of weeds, deliberate (in the form of introduced pastures) or inadvertent, would compete with native flora. Exclusion of Traditional land management (cultural burning).
From c. 1900	Strathaird Creek diversion drain likely constructed prior to 1913, reducing the catchment of *burrung buluk*	The frequency and magnitude of flows entering and/or passing through *burrung buluk* are significantly impacted. Despite this, the local immediate catchment for the wetland continues to see it persist, albeit with a modified hydrological regime.
From c. 1960s	Investment occurs in soil conservation measures along Strathaird Creek / drain	While these measures appear to have had a significant impact on the way the Strathaird Creek diversion drain functions, it has no impact on *burrung buluk*, continuing to divert flows away from the wetland.
From c. 1970	Construction of larger dams into the bed of *burrung buluk*	A new impact on hydrology as voids draw water below the natural surface level of the wetland – i.e. the potential for internal drainage or soil dewatering within the wetland.
From c. 1973	First single artificial drain cut across the bed of *burrung buluk*	The wetland is artificially drained for the first time. Despite this significant change, there is evidence that the wetland continued to inundate during wetter periods, and that the original drain may not have been wholly effective (i.e. it was possibly not maintained).
From c. 2004	Comprehensive drainage network constructed, including deepening of artificial drainage outlet below wetland bed level	The wetland itself is comprehensively drained (in a herringbone pattern), allowing intensification in land use and soil cultivation, which continues to the present time.
From c. 2010	Centre-pivot irrigation commences south of *burrung buluk*	A possible inadvertent side-effect of the artificial irrigation of the land south of *burrung buluk* is an increase in soil saturation and seepage to the southern part of the wetland.

Determining the future water regime for *burrung buluk*, informed by its history of change, physical form and potential water sources, is the first and most important consideration on its path to recovery. This is intimately linked to questions about the current condition of the site and its restoration potential, and what future vision, in terms of ecological values and hydrological function, is ultimately adopted for the wetland.

If a vision is adopted that provides flexibility to meet a broad range of waterway policy targets, then burrung buluk could be used to test new concepts in Integrated Water Management.

Subject to landholder consent, a restoration trial for *burrung buluk* is also feasible and would be inexpensive to implement, providing an excellent opportunity to test ideas and learn about the wetland ahead of urbanisation. Should this occur, a wide range of environmental values will subsequently return – some quickly and some gradually.

Some further observations, relevant to the restoration and remediation potential of *burrung buluk* and its catchment, include the following:

- Because of the inherent variability of wetland values and the ongoing impacts of past land management, observations at a single point in time cannot and do not provide an adequate assessment of current or potential future ecological values or hydrological function.
- As a measure of that high degree of variability and being a shallow wetland, *burrung buluk* would have completely dried out regularly, almost every year. Equally, any catchment rainfall

events (seasonal or episodic) would inundate a restored *burrung buluk*, meaning that it is capable of functioning as a seasonal wetland again.
- Reinstatement of a more natural hydrological regime across the entire natural footprint of *burrung buluk* is most consistent with state policy on waterways and wetlands, and would create a desirable ecological state as seasonal wetlands support a wide diversity of species.
- The experience of Nature Glenelg Trust's team with similar wetlands demonstrates that native wetland flora and fauna can readily re-colonise a drained wetland after restoration of the hydrological regime. Ecological condition would steadily improve over time through natural processes, which could be accelerated by species enrichment planting.
- In an urban setting, water availability for a restored *burrung buluk* is unlikely to be a limiting factor. Prior treatment of any urban runoff to remove excess nutrients is also an important consideration if the goals for a reinstated *burrung buluk* are primarily ecological.

In conclusion, it is worth noting that in-stream wetlands (especially large ones) are very important natural equalisation basins for catchment management purposes, attenuating flows during floods by delaying the time it takes for water to reach downstream. Even in its drained state, *burrung buluk* briefly demonstrated this potential catchment function after heavy rainfall in mid-October 2022 – as shown below – before being rapidly emptied by the artificial agricultural drains which are still in place across the wetland basin.

The view of burrung buluk (Hanna Swamp) looking south-east across the wetland towards Spring Hill from Old Sydney Road on the 14th October 2022. Photo: Claudia James.

The drainage of, or diversion of flows around, in-stream wetlands like *burrung buluk* increases the speed and magnitude of flows reaching downstream waterways. This is a key consideration in the Merri Creek catchment, which has well documented downstream flooding risks.

Hence an agreed multi-objective restoration vision for *burrung buluk* could achieve a wide range of IWM outcomes; including retention, infiltration and attenuation of catchment and stormwater runoff, as well as recovery and expansion of residual wetland flora and fauna. If we collectively get this right, then a wetland feature that for millennia formed a part of the traditional cultural landscape of the Wurundjeri Woi Wurrung people, could be once again be reinstated as an in-stream wetland, managed and preserved in perpetuity. In doing so, and beyond its practical purpose for water management, *burrung buluk* would also provide an inspiring area of open space – a natural centrepiece with its own unique story of renewal, a place for reconciliation, contemplation and environmental education for all members of the future Wallan community.

PART 1: Building a new foundation of knowledge: seeing the *wallan wallan* landscape through fresh eyes

This discussion paper will take you on a journey through time and also the science of wetland eco-hydrology, to illustrate the range of reference materials and tools that are available, and could be used to inform modern planning and decision making for our wetlands, floodplains and waterways – if we are prepared to take the time to more deeply understand them.

The focal feature explored in detail within this discussion paper is *burrung buluk* (Hanna Swamp), a *wallan wallan* wetland that is especially topical and relevant at the present time. This feature straddles two Precinct Structure Plan (PSP) areas of Melbourne's northern growth corridor, which are designated for future urban development and are currently progressing through the Victorian Government's planning processes.

In mid-October 2022, heavy rainfall and flooding across much of Victoria is reminding us again of the need to plan for Australia's climatic extremes – in the words of poet Dorothy Mackellar, this is the land of "droughts and flooding rains". It is a natural history well understood and experienced for millennia by First Nations people, embedded in the cultural knowledge passed down by their ancestors. Hence, at the time of writing, the *wallan wallan* wetlands, Herne Swamp, Meade Swamp and *burrung buluk,* despite being artificially drained for decades, are once again temporarily inundated, as shown over the page. Despite the massive changes that have occurred since the 1830s, the landscape is giving us a glimpse into the past, as well as illuminating the possibility of a different future for the in-stream floodplain wetlands of the upper Merri Creek and its tributaries.

In this discussion paper we seek to confirm the original natural character and extent of *burrung buluk*, and investigate its connection to local waterways. We do so by highlighting the type of information that is not typically assembled, shared or presented for consideration, as a result of the way the planning system currently operates. This is despite former and current wetlands, waterways and floodplains being prioritised in local and state planning policy. Such information is capable of supporting more sophisticated discussion and planning decisions relevant to those wetlands that occur across planning boundaries, were modified by prior land use, and retain rehabilitation potential. Well informed planning also has the potential to achieve outstanding complementary outcomes for the environment, water management and liveability. This issue has lasting implications because the pattern of urban development that is being shaped by current planning processes will likely persist for centuries; hence better informed and considered decision-making is clearly in the public interest.

Although this discussion paper will primarily explore the story of *burrung buluk*, the same principles and logic presented here, can be applied to any wetland or floodplain feature in Melbourne's urban growth corridor. It is about developing a new, collective, agreed vision for a modified waterway or wetland, which requires a shared base of knowledge and understanding. We genuinely hope that the material presented here - which we emphasise is also open to future refinement as new information becomes available - might establish a new foundation.

Nature Glenelg Trust is committed to making complex environmental science more accessible and available to decision makers and the general public, for community and environmental benefit. In this spirit of constructive dialogue, feedback or questions in relation to this discussion paper are most welcome.

You can contact Nature Glenelg Trust by emailing info@natureglenelg.org.au.

Looking in a south-easterly direction over Herne Swamp from Green Hill on the 14th October 2022.
Despite comprehensive artificial drainage of the wetland, Herne Swamp is temporarily inundated across much of its former footprint, as a result of heavy rainfall in the catchment. Some of the former wetland is now reclaimed land (part of the Wallara Waters suburban development, shown in the central foreground). Photo: Rob Eldridge.

Looking in a south-westerly direction over burrung buluk (Hanna Swamp) from Green Hill on the 14th October 2022.
As a result of heavy rainfall, the wetland is temporarily inundated across much of its former footprint, despite the impact of the artificial agricultural drains which are cut below the wetland bed level and can be seen discharging here via the single outlet drain in the foreground. Photo: Rob Eldridge.

PART 2: The importance of a multi-faceted approach to defining wetland eco-hydrology

At Nature Glenelg Trust, our interest in wetland restoration requires a wider ecological and bio-physical understanding of the landscape than is typical of regular environmental science training. Beyond the simple observation and measurement of flora and fauna at a point in time, using scientific methods and accessing peer-reviewed literature from a single field, we have found that it is generally necessary to seek out and integrate knowledge from a much wider range of related endeavours; seeking information from scientific fields like hydrology, soil science, geology and geomorphology, as well as related fields of social science like history and historical geography.

Being able to take the 'blinkers' off and integrate, interpret and triangulate data from various fields, enriches our understanding of a site and places modern observed conditions into an appropriate historic context. It provides an opportunity to genuinely become better informed across multiple related disciplines. Through this process, past regional and local developments that may have modified, simplified or constrained a wetland's ecological function (as it subsequently responds over decades) can be identified, and a likely earlier natural state explored.

Even intact wetlands are inherently dynamic in nature, so at modified wetland sites it is even more important to be able to describe, overlay and disentangle additional factors such as land management history, and changes to drainage, inundation patterns and climate, via a deep search of the available reference material – both new and old, and in its variety of forms. This includes modern data, scientific papers, GIS layers and the aerial photographic record which collectively can often take us back to the 1940s. To explore earlier times, noting that Victoria was comprehensively colonised in the 100 years prior, older unpublished material like early maps, survey diagrams, government records, newspaper articles and journal entries, where they exist, are incredibly important. As well as simply defining current condition, these and other information sources help to describe the trajectory of change that a site has experienced, and assist with formulating plans for, and describing, future restoration or rehabilitation potential.

After refining this approach to investigating wetland eco-hydrology in an especially intensive way over the past 10 years, Nature Glenelg Trust has established a reputation for undertaking considered, well-informed background research and utilising that investigative work to inform and guide subsequent remediation, rehabilitation or restoration action at many sites. Adaptive management is a key attribute of our approach, as we have found that we learn most about eco-hydrology through implementation and observation. Water is an especially forgiving medium to work with, for reasons articulated later in this discussion paper.

However, it has become apparent that the methods we have adopted, adapted and developed over time, are not commonly employed, and as a result NGT is regularly sought out for our skills in wetland eco-hydrology; by government agencies, community groups, industry and private landholders. We adopt an inquisitorial approach to determining wetland history and eco-hydrology, where we remain open to discuss, assess and incorporate new information as it emerges to enrich our understanding of a site. Our goal is to determine the truth about the history and management of a site, as best as it can now be ascertained.

This information, when drawn together into a reconstructed timeline of change, paints a picture of how wetlands, like *burrung buluk*, once functioned in the landscape – including their role in supporting culture, biodiversity and hydrological systems. Understanding the past can offer a great number of insights, both inspiring and better informing options for the future.

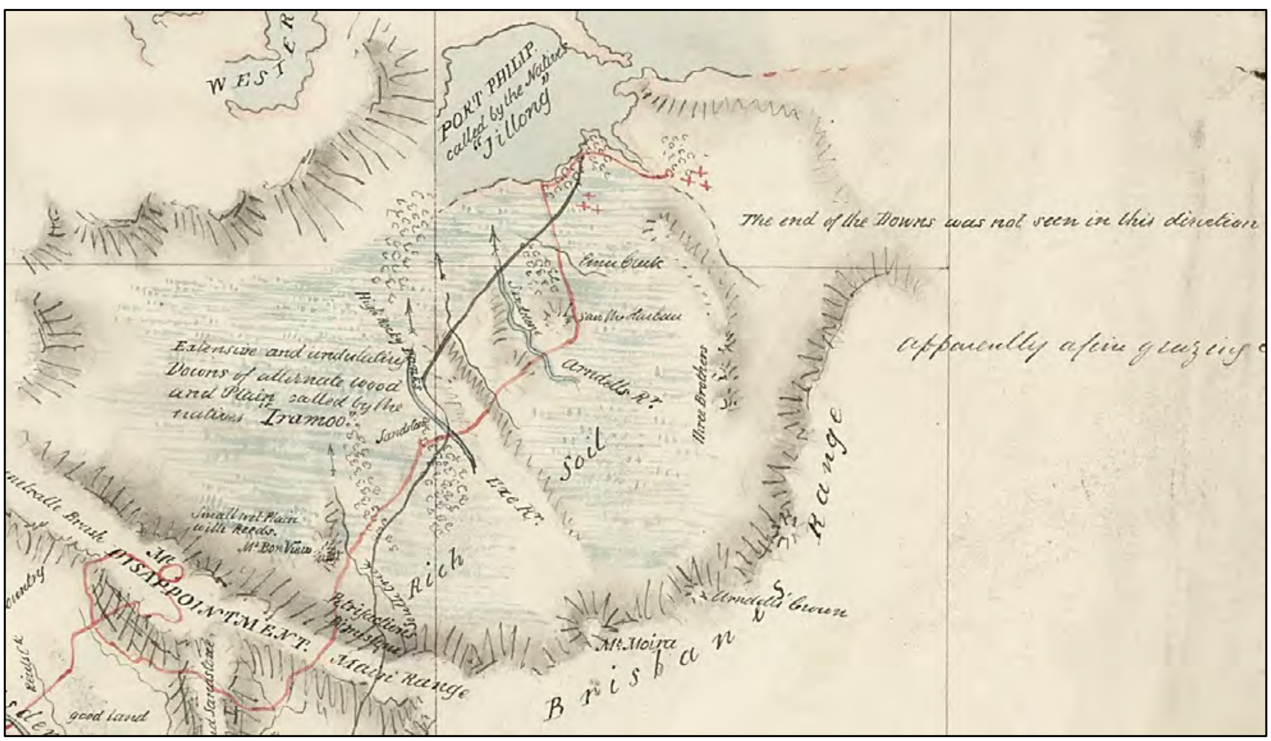
PART 3: A broad timeline of physical changes impacting *burrung buluk* (Hanna Swamp)

European colonisation

Despite the prior establishment of a land-based settlement within present-day Victoria at Portland (and the earlier presence of sealers along the coast), the unregulated, rapid expansion of pastoral grazing by squatters largely radiated inland from Port Phillip Bay after a permanent colonial settlement was commenced there in 1834.

We have not come across any specific references to *burrung buluk* prior to European colonisation in 1834. Despite being present on the land for tens of thousands of years, unfortunately the passing on of cultural knowledge by many First Nations people across Victoria was intentionally interrupted by the activities and policies of the colonists, with ongoing cultural impacts. This formed part of the deliberate, systematic process of land occupation and dispossession, accompanied by a parallel wave of frontier conflict and violence.

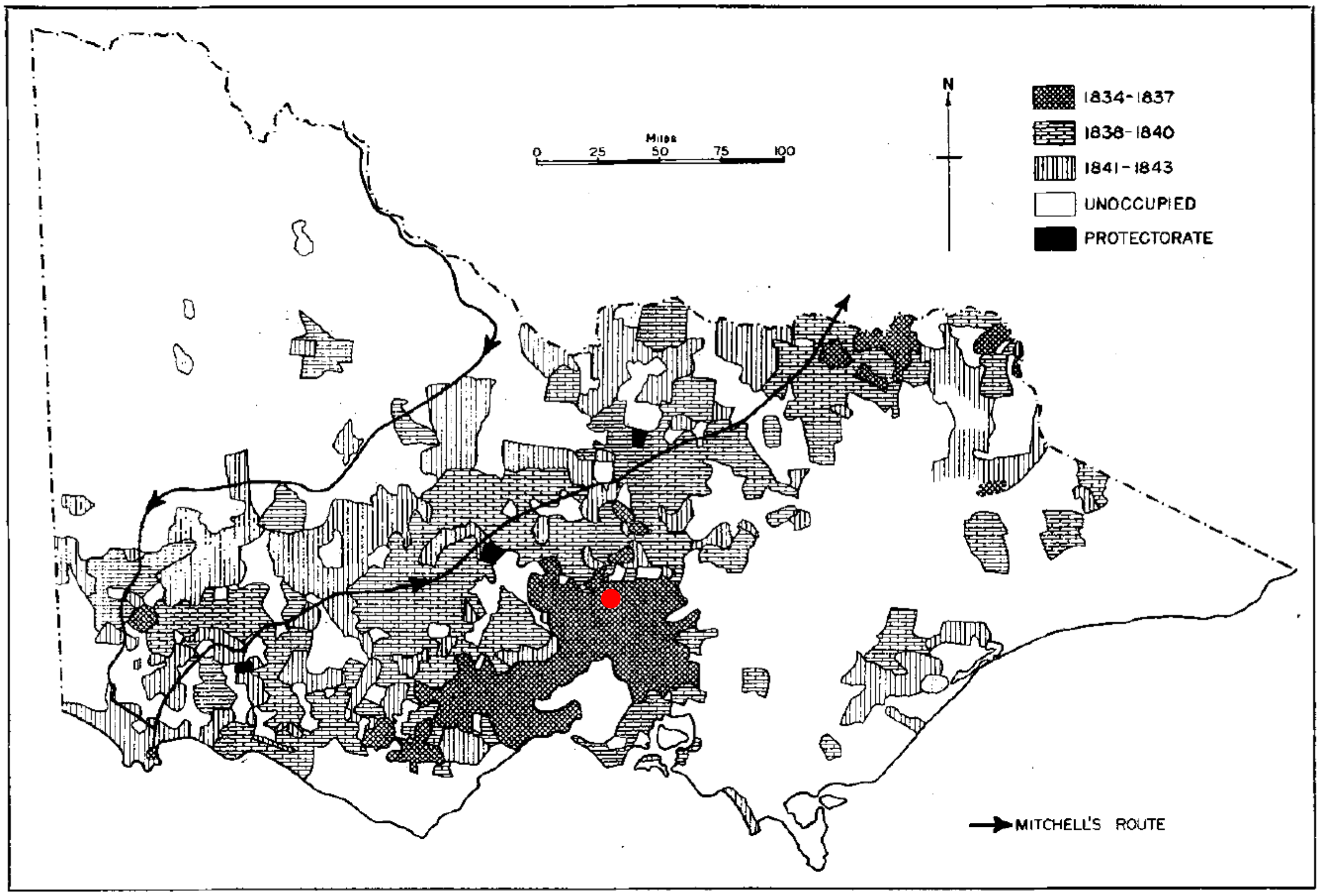
A handful of general accounts of the land and landscape around Melbourne prior to 1834 by European explorers do exist, and they are suggestive of a grassy landscape occupied and actively managed by Aboriginal people. The grassy 'downs' around present-day Melbourne observed by Hume and Hovell in their overland journey in 1824/25 (see below) and the grassy plains of western Victoria observed by Major Mitchell in 1836, were clearly environments deliberately shaped and maintained by the traditional cultural use of fire.



Inset of the map of Hume and Hovell's 1824-25 overland journey. Note that north is down. The annotation north of Melbourne reads "Extensive and undulating downs of alternative wood and plain, called by the natives 'Iramoo'". The annotation west of Melbourne reads "The end of the downs was not seen in this direction".[1]

[1] From: H. Hume's sketch of a tour performed by W. H. Hovell and himself from Lake George to Port Phillip, Bass's Straits, at their own expense in the years 1824 and 1825 through the request of Sir Thomas Brisbane. Accessed online from the State Library of NSW. File number: FL3692398.

It is therefore no accident that that initial expansion of sheep grazing across present-day Victoria corresponded with Hume and Hovell's account, later complemented by the account of Mitchell's journey, as shown below. Clearly, what they documented in their accounts drove a speculative rush by squatters to forcibly occupy land across the territories of several First Nations groups deemed most suitable for grazing by livestock.



Pastoral expansion in the Port Phillip District of NSW (present-day Victoria) from 1834-1843, from Powell (1969)[2]. The red dot ● is the approximate location of burrung buluk.

This pattern of pastoral expansion, combined with the fact that *burrung buluk* was situated within a plain of grassland and grassy woodlands near Melbourne, along the main overland transport route between Melbourne and Sydney, means that it was likely grazed by sheep from the earliest years of European colonisation in the 1830s – as marked and indicated above.

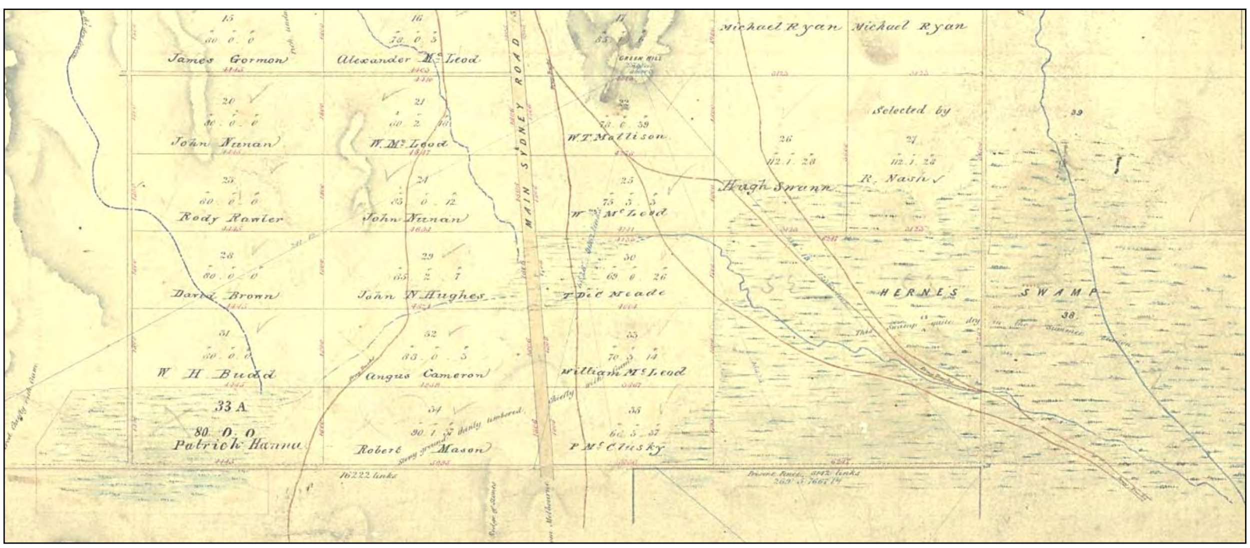
The proximity of this area to Melbourne and the transport route to Sydney also explains why the wetland is mapped in some very early Parish Plans, indicating the approximate time when land was resumed by government from pastoral use, then subdivided and sold for closer settlement. *burrung buluk* straddles two Parishes, hence it was partly or fully mapped on multiples occasions in the early decades after colonisation.

[2] Powell, J. M. (1969). The Squatting Occupation of Victoria, 1834-60. *Australian Geographical Studies*, 7(1), 9–27.

burrung buluk is clearly identified as a wetland on all of the earliest maps

The earliest maps of the Parishes of Merriang (which covers the southern portion of *burrung buluk*) and wallan wallan (which covers the northern portion of *burrung buluk*) indicate that *burrung buluk* was clearly identifiable to the surveyors at the time as a wetland, as shown below.

1840 – Inset of the Merriang Parish Plan, broadly showing the location of burrung buluk (left) and Herne Swamp (right)



1854 – Portion of the wallan wallan Parish Plan, showing burrung buluk (left) and Herne Swamp (right)

Inset of the 1854 wallan wallan Parish Plan, showing burrung buluk, and the approximate location of its inlet via Strathaird Creek from the north, and outlet towards Meade and Herne Swamps to the east.

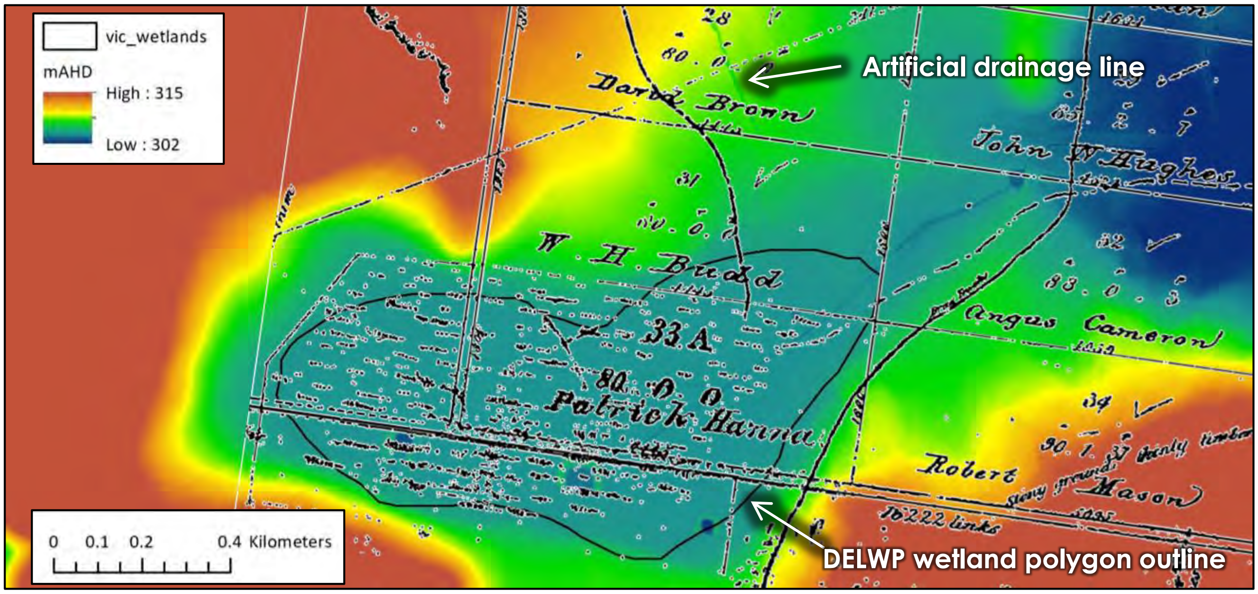
A feature of early survey maps is that the broad dimensions of wetlands were often shown, based on their appearance at the time – which would indicate to both government and prospective land purchasers something of the productive capability of the land, as well as the likely presence and availability of water. The location and existence of waterways or flow paths was also usually noted, and general, broad descriptions of the native vegetation were sometimes included. Given that the native vegetation growing on the land was typically grazed as it was found, these annotations were important indicators of land capability.

burrung buluk is clearly identified as an in-stream wetland of Strathaird Creek on all of the earliest maps

It is also very important to note that the surveyors were tasked with mapping the land as they found it. They had no reason to deliberately misrepresent the general location of wetlands or waterways. With this in mind, it is immediately clear from the 1854 map that *burrung buluk* was an instream wetland of Strathaird Creek.

The proximity of the inlet and the outlet (which were not directly connected) is readily explained by the shape of the wetland depression between them, which will be explored later in detail. Today, we also have the benefit of modern technology to look for evidence to support the observations of the surveyor almost 170 years ago.

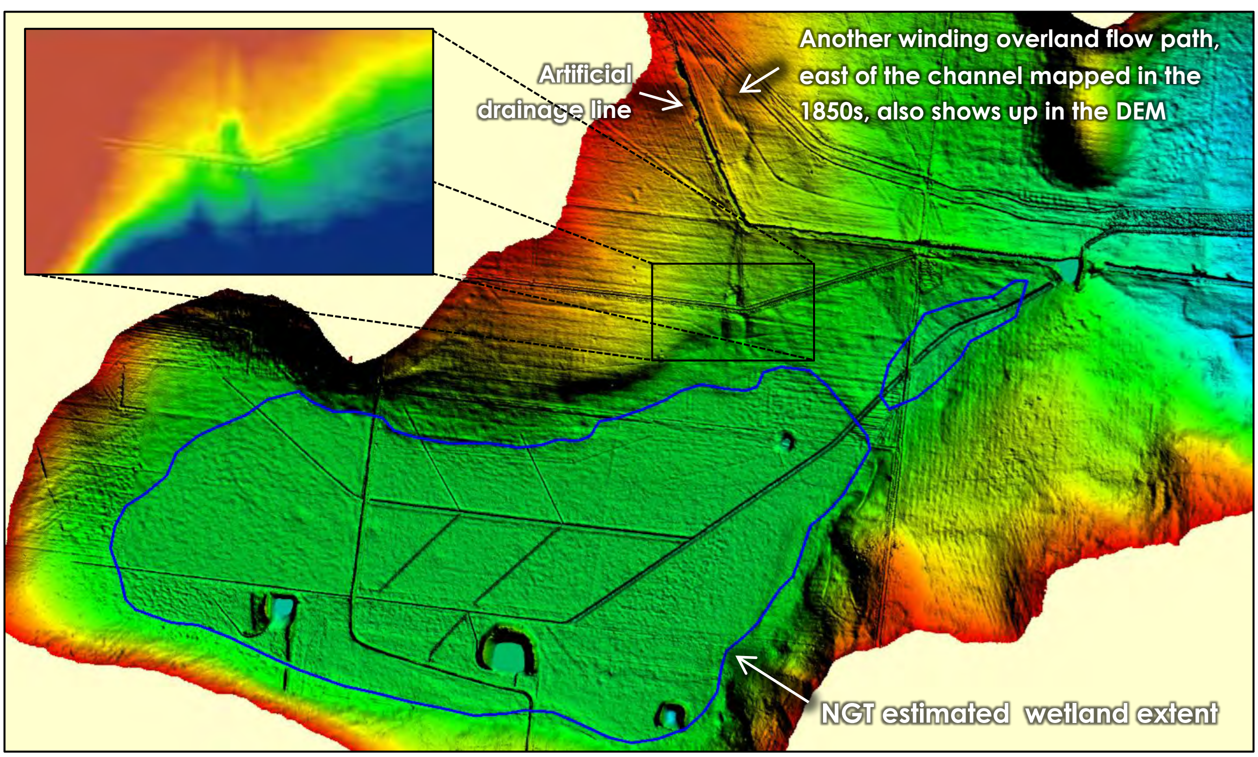
With this in mind, we have taken a closer look at the LiDAR (Light Detection and Ranging) data, in the form of a Digital Elevation Model (DEM), to identify the location of the original waterway. As shown below, we can overlay the 1854 map with this modern information source to assist our search for evidence. At first glance, given the general flatness of the terrain, it is difficult to see the evidence for the original flow path, which is not as apparent as the modern artificial drains that are more deeply incised into the land surface.



Transparent inset of the 1854 wallan wallan Parish Plan, showing burrung buluk, overlaid above the DEM, with the DELWP wetland layer also shown (solid line) to indicate the modern mapped boundary of the wetland.

The Strathaird Creek inlet into *burrung buluk* is clearly identifiable in the modern Digital Elevation Model (DEM) of terrain around the swamp

However, adjusting the sensitivity of the DEM and using hill-shading to identify steeper changes in terrain, allows a fuller picture to emerge.

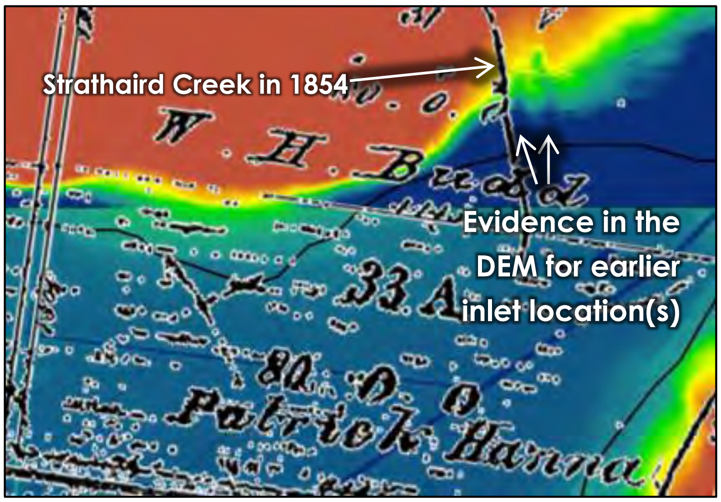


DEM, with inset, showing the location of the former inlet(s) into the northern edge of burrung buluk. The NGT estimate of the original cease-to-flow full supply level of the swamp is marked in blue.

In addition to the natural inlet to the swamp being clearly visible, another winding overland flow path, east of the channels mapped in the 1850s, also shows up in the DEM. It is not entirely clear if this is an ancient flow path for Strathaird Creek, whether it is an alternative flow path that developed after European colonisation but is now stranded, or if indeed it is a more spatially accurate representation of the same flow path that was first mapped by the surveyors.

The Strathaird Creek inlet into *burrung buluk*, still evident in the DEM, corresponds with the location of the waterway on the 1850s maps

Either way, the minor erosion scours at the northern edge of *burrung buluk*, align almost exactly with the location of the flow path inlet mapped in 1854, as shown below.



Overlay of the 1854 map combined with the DEM, showing the former location of the Strathaird Creek inlet(s) into burrung buluk, in close proximity to the location marked on the 1854 map.

This first detailed Parish Plan map was revisited a short time later, when the Geological Survey Office sent a surveyor out to map the geological features of the *wallan wallan* area in 1857, later published in 1862.

Inset from Geological Survey of Victoria map published in 1862, based on 1857 field data, showing Strathaird Creek, flowing into burrung buluk (left), and Taylor's Creek, flowing into Meade Swamp (right), along with the overflow from burrung buluk. On this map, green shaded areas are marked as "Alluvial flat, swampy in winter".

It is noteworthy to see on this map that the flow path connecting *burrung buluk* and Meade Swamp is shown as a broad alluvial flat rather than a narrow channel, which also potentially explains the dashed line drawn on the 1854 plan being in a lighter-blue colour than for the other waterways on that map. This suggests that original flows out of the wetland were a broad sheet flow across natural surface rather than via a defined stream within an incised channel.

Australian waterways, including Strathaird Creek, have dramatically changed since European colonisation

This representation is consistent with what we now understand was the original shape and form of many of Australia's minor waterways prior to European colonisation and the widespread introduction of vast numbers of hard-hooved grazing animals. In many cases, overstocking led to the land being rapidly stripped bare of deep-rooted perennial vegetation and compacted the soil, altering the character of our soils and exposing them to widespread erosion. In some parts of Victoria, this process was noted to have commenced as early as the mid-late 1840s, as per the following 1853 account by John Robertson from the Wannon region of western Victoria, in the La Trobe letters[3]:

> *"One day all the creeks and little watercourses were covered with a large tussocky grass, with other grasses and plants, to the middle of every watercourse… now that the only soil is getting trodden hard with stock… the strong tussocky grasses die before it. The clay is left perfectly bare in summer. The strong clay cracks; the winter rain washes out the clay; now mostly every little gully has a deep rut; when rain falls it runs off the hard ground, rushes down these ruts, runs into the larger creeks, and is carrying earth, trees, and all before it. Over Wannon country is now as difficult a ride as if it were fenced. Ruts, seven, eight, and ten feet deep, and as wide, are found for miles, where two years ago it was covered with tussocky grass like a land marsh."*

Many larger waterways that today are deeply incised channels and which we think of and call 'creeks', were once a 'chain of ponds', connected by gentle, ill-defined, vegetated overland flow paths. Indeed, if you look at the oldest maps across Victoria, you will regularly see the notation 'chain of ponds'. Further, many minor waterway features in steeper terrain that we recognise as creeks today, were originally nothing more than gentle vegetated depressions in gullies.

An example of the transformational process of gully erosion in Victoria is shown below, where dispersive subsoils are washed away, causing the ongoing undermining and collapse of both topsoil and freshly exposed subsoil at the head cut. The process gradually works its way upstream, as the energy of flowing water over what becomes a more severe elevation change over time, drives further undermining, collapse and erosion.

This illustrates how a gently sloped gully, with a barely discernible waterway that might only flow seasonally, can become a deeply incised, massively eroded 'creek-line', the likes of which are now seen across much of Victoria with erodible soils and subsoils. We need to remind ourselves that even where such creek-lines are now fenced off and stabilised, they are not at all representative of original conditions and should not be interpreted as such.

Example of gully erosion (Agriculture Victoria)

[3] Letters from Victorian Pioneers to La Trobe, Lieutenant-Governor of the Colony of Victoria.

The deeply eroded and incised upper section of Strathaird Creek above *burrung buluk* is shown to the right. This is evidence of a process of gully erosion that commenced long ago, and provides some insights into both the land management history of the catchment and landscape surrounding *burrung buluk*, as well as the nature of the highly dispersive (sodic) subsoils that are present.

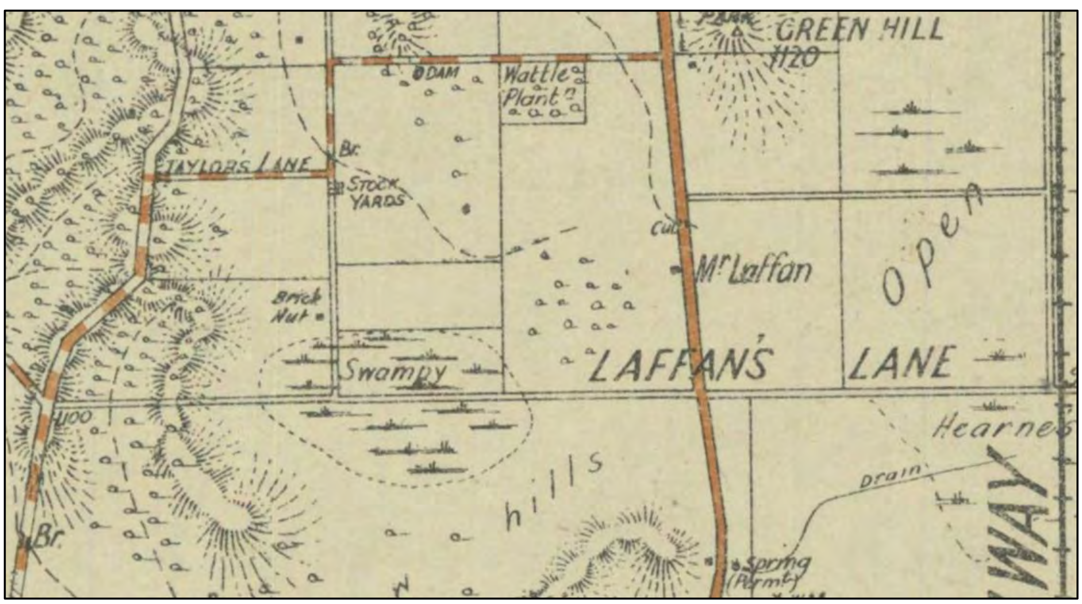
Right: Example of severe, long-term gully erosion in Strathaird Creek (from Alluvium 2021[4])

With this in mind, it is noteworthy that the original alignment of Strathaird Creek, which is in precisely the same location on maps from both 1854 and 1857 is, in places, barely detectable on the DEM today. This is instructive about the sequence of events and the history of this catchment. It does not mean the waterway was not there, it simply means that the waterway had a shallower, vegetated form and functioned very differently to its modern equivalent.

In summary, when the 1850s maps shared in this discussion paper were drawn, it was a time when waterways in the Australian landscape were vastly different to their appearance today, and were on the cusp of great change. Areas with dispersive, sodic soils or subsoils, like the Wallan area, were especially susceptible and this helps to explain some of the later changes that become apparent as we follow the history of the site forward.

Strathaird Creek was likely diverted away from *burrung buluk* before 1913

In a map published in 1913, shown below, we see the first evidence for the diversion of Strathaird Creek flows away from *burrung buluk.*



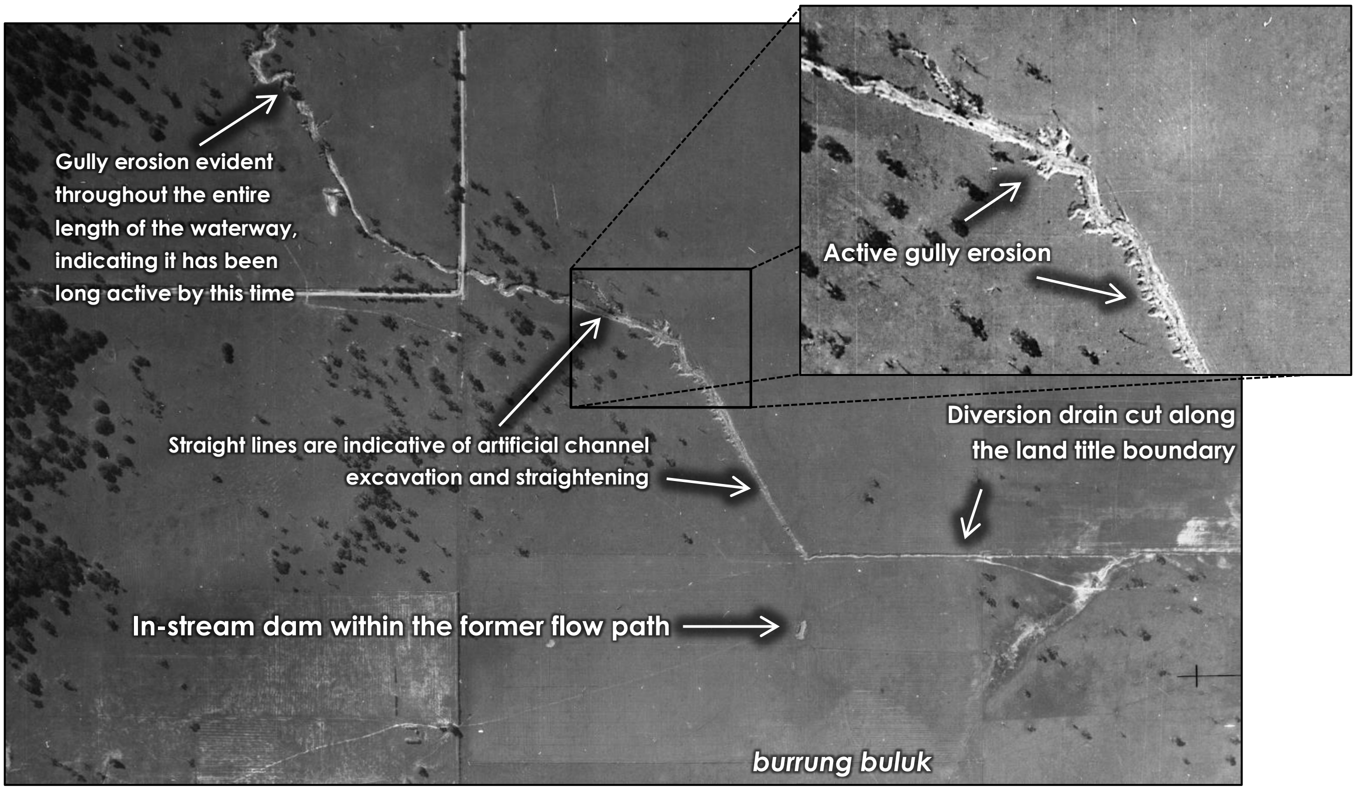
Inset from "Sketchmap of Wallan and Donnybrook Districts", 1913. For the first time, Strathaird Creek is shown diverted away from burrung buluk, toward the culvert where Taylor's Creek is directed under the main road.

[4] Alluvium (2021). Wallan-Beveridge Pre-planning Waterways Assessment 2020 (Stage 1 to 4 – Desktop, field and modelling assessments). Report Prepared for Melbourne Water.

We also can see that artificial drainage was taking place in the vicinity, with the draining of a permanent spring towards Herne Swamp in the bottom right corner of the image. This information appears to logically dovetail with the earliest aerial imagery available for the site in 1940, potentially helping us to date the first deliberate diversion of flows in Strathaird Creek to before 1913.

Evidence of erosion, drainage and diversions in the 1940s aerial imagery

As shown in the 1940 image below, the deliberate drainage channel to divert Strathaird Creek away from *burrung buluk* appears to have been long in place by this time.

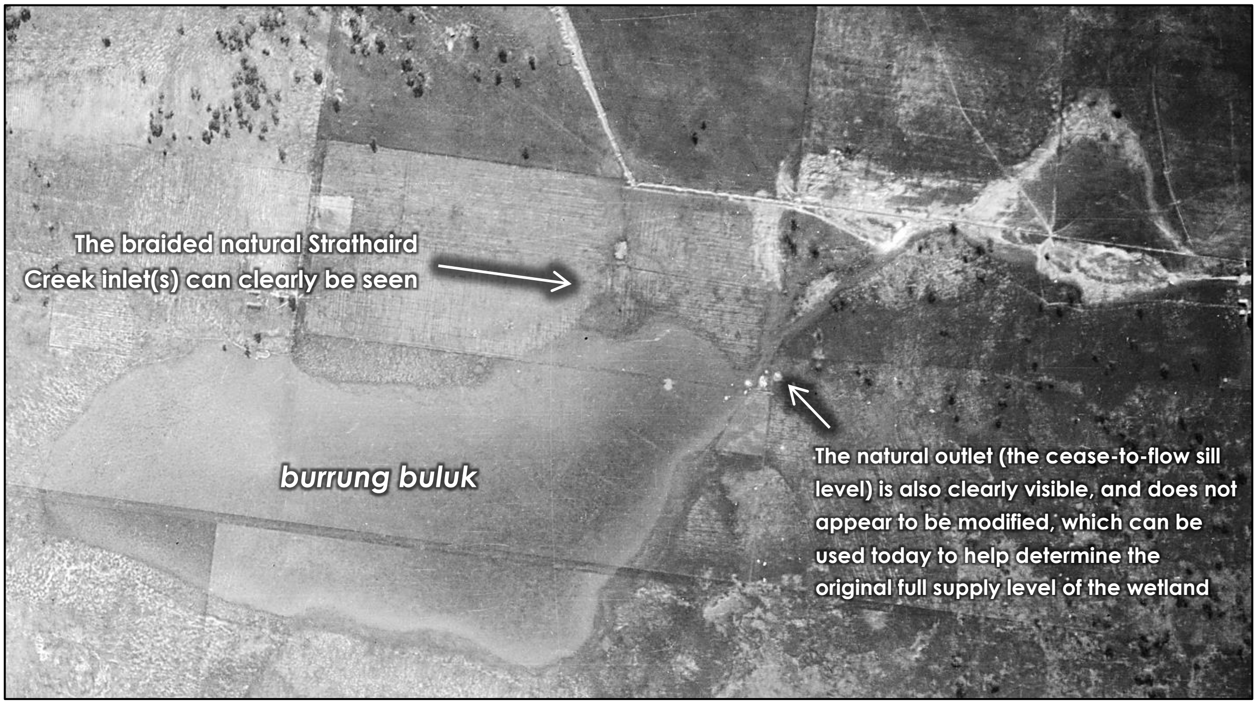


The first aerial photograph of Strathaird Creek in 1940, showing active gully erosion possibly triggered by the construction of the artificial diversion drain which exposed the dispersive, sodic subsoil to seasonal flows.

We may never know whether Strathaird Creek was already experiencing gully erosion in the late 1800s - due to overgrazing by livestock, like so many areas in Victoria - or whether this process was triggered in this location by cutting the diversion drain and exposing the dispersive subsoil to increasingly channelised, flashy and higher energy flows. Regardless of the cause, the process led to massive erosion which is evident in the 1940 image and beyond.

It is also worth noting that the key giveaway above, to indicate that the diversion drain is an artificial channel along most of its length (likely triggering or hastening the erosion process by exposing the subsoil), is the fact that the overall channel alignment seen in the image above is perfectly straight between each bend, and even follows the cadastral boundary between two land titles. Given that waterways in areas of low relief are never perfectly straight, we can state with certainty that this waterway has been straightened and channelised along most of the length shown in this image (except for the top left hand corner).

Although the diversion of Strathaird Creek had occurred by the 1940s, and despite this significantly reducing the available catchment of *burrung buluk*, it is also clear from the subsequent imagery, like the 1946 image below, that this work did not prevent the wetland from inundating.



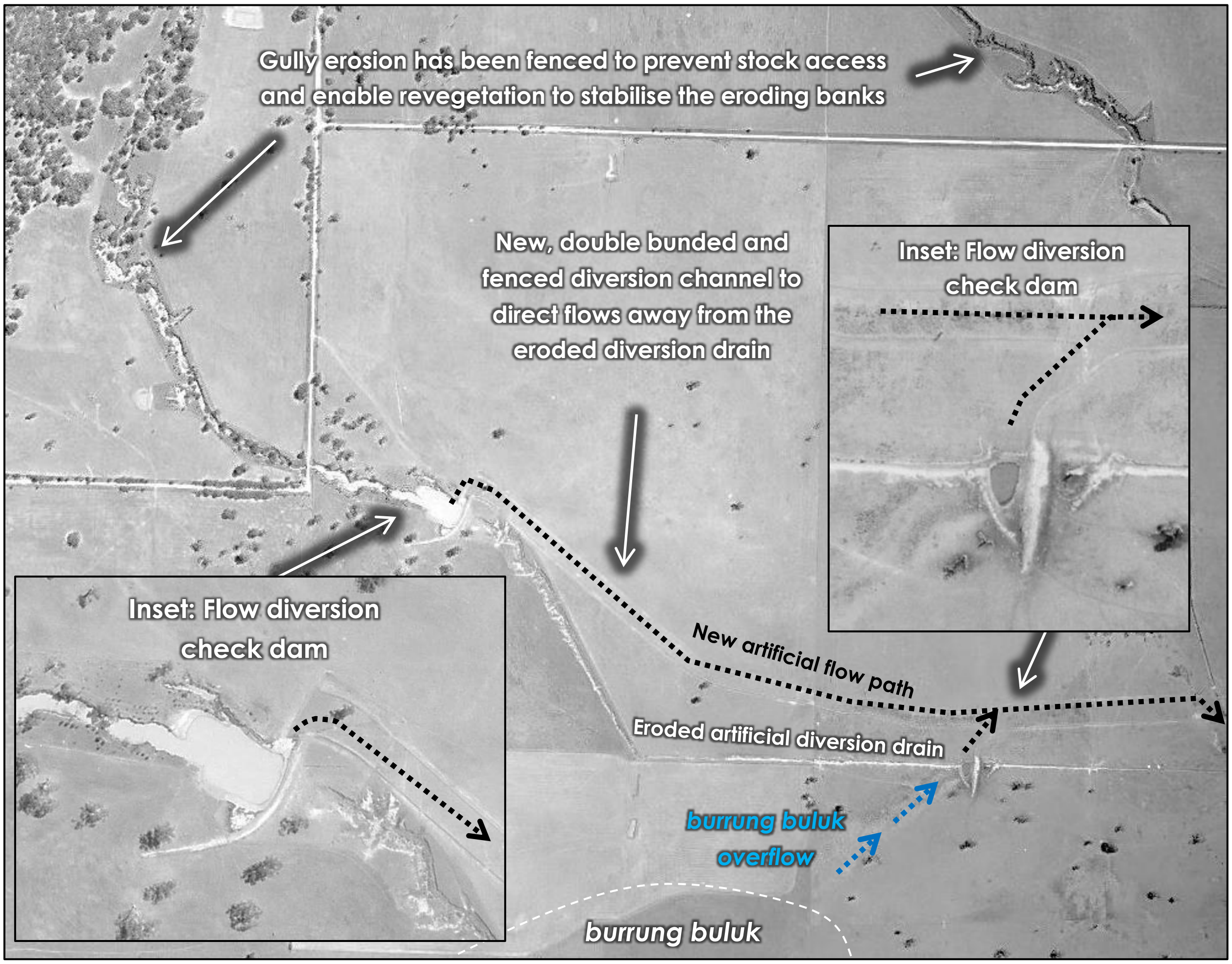
Aerial photo of burrung buluk and the Strathaird Creek diversion drain in 1946. The natural wetland extent, and the natural inlet and outlet from the wetland are still clearly visible. A significant zone of soil deposition as a result of the erosion process, spilling out either side of the diversion drain, is evident.

Vegetated seasonal wetlands that have never been drained and remain intact today are usually readily detectable in old black and white imagery, and often have a similar appearance to *burrung buluk* as shown above. Aside from the diversion of Strathaird Creek, there is no other evidence to suggest that the wetland has been hydrologically compromised by this time, as no artificial drainage outlet is apparent. Hence, an ongoing ecological response from the wetland vegetation present, whenever conditions were suitable, could be expected. This explains the difference in colour/texture that demarcates the wetland edge, visible in the image above.

Also note that the degree to which a wetland is more or less visible in the aerial imagery over time, can and does vary greatly, because it is dependent on factors like the season/time of year when the photo was taken, the amount of wetland vegetation growth and/or open water and/or bare ground present at the time. These factors are also driven by both the prevailing longer-term climatic conditions and the land management practices of that era. The wide variability in the physical appearance and vegetation composition of seasonal wetlands will be explored in more detail later in this discussion paper, but explains why wetland appearance in aerial imagery can differ markedly over time.

The soil conservation works era arrives for Strathaird Creek

By the time of the next image we have obtained, from 1968, it is clear that the soil conservation works era – by this time is in full swing across Victoria with major investment from the state government – has also reached Wallan.



March 1968 aerial photograph showing significant works underway to address the significant erosion problems associated with the original Strathaird Creek diversion drain. At this time burrung buluk is still not drained.

If you look carefully at the previous image, you will see that:

- The actively eroding upper reaches of both Strathaird Creek and Taylor's Creek have been fenced off from livestock grazing.
- The deeply eroded Strathaird Creek diversion drain has been dammed in two locations.
- Those two check dam locations have been used to divert flows into a new, double-bunded, surface floodway, directing flows away from the eroded diversion drain.
- The second of those check dams was placed to capture and divert the overflow from *burrung buluk*, suggesting that the wetland still overflowed via its natural outlet, and noting that it was not artificially drained across its bed at that time.

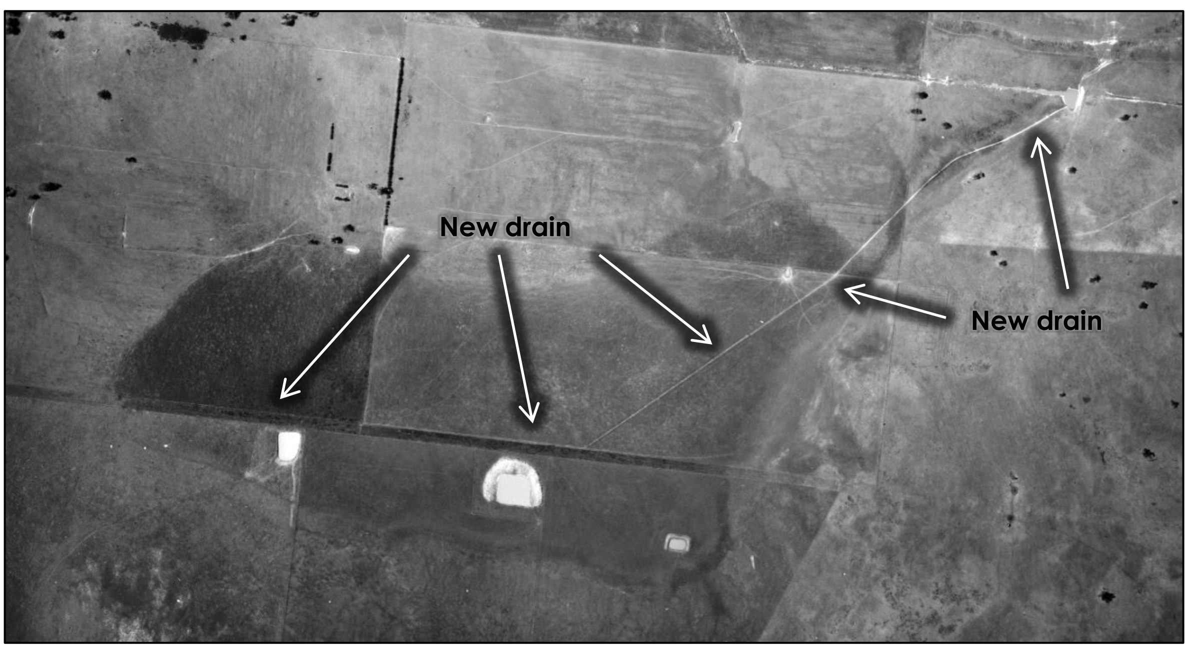
Dam construction in the southern portion of *burrung buluk*

By 1972, two larger dams have been dug into the bed of the southern portion of *burrung buluk*. The wetland has still not been artificially drained and continues to reliably inundate and/or retain saturation across much of its footprint, as indicated by the darker colour which indicates a differentiation in plant growth and composition, as shown in the image below. Despite being grazed and farmed for over 100 years, this watering regime would have continued to support the life cycles and sustain the persistence of a portion of the seasonal grassy wetland flora and a range of associated fauna within the wetland feature. This said, the changes up until this point also mean a number of differences from its original unmodified state would also be expected.

The 1972 aerial photograph shows the construction of dams in the southern portion of burrung buluk, noting that the wetland feature is still not drained.

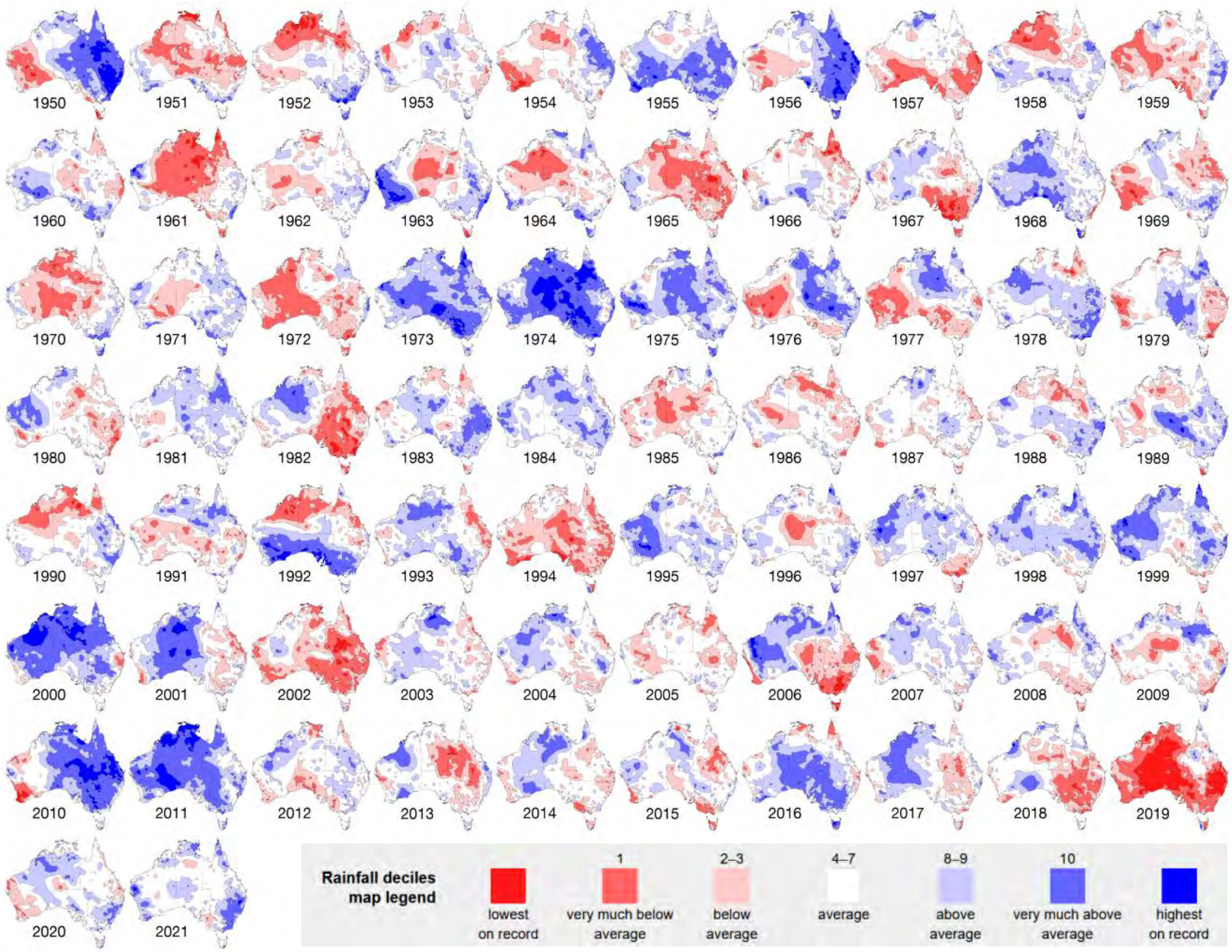
The relatively recent comprehensive artificial drainage of *burrung buluk*

Analysis of aerial photography available from the 1970s for the site indicates that the first artificial drain was cut into the bed of *burrung buluk*, near the natural outlet, sometime between 1972 and 1974, as the drain is visible for the first time in an image from August 1974. The image below shows the wetland 18 months later, in January 1976.



The January 1976 aerial photograph shows the location of the first artificial drain which was cut into the bed of burrung buluk, near the natural outlet, sometime between 1972 and August 1974.

Of note, this work was completed in the midst of Australia experiencing a triple back-to-back La Niña climatic event, which lasted from 1973-1976, as represented by the rainfall summary shown below. This wetter phase might have been a contributing factor towards the decision by the landholder to commence the artificial drainage of this shallow wetland feature for the first time.



Australian rainfall data since 1950, illustrating broad climatic trends[5].

As shown in the sequence of images over the page, the drain constructed circa 1973, does not appear to have been the subject of much maintenance and was not upgraded for 30 years. Then in 2004 or 2005, comprehensive drainage of the wetland occurred.

Hence in the final, December 2005, image over the page, we can see the herringbone pattern of artificial drainage appears across the bed of *burring buluk* for the first time, in a clear attempt to more completely and effectively dewater the wetland.

This pattern of artificial drainage remains in place in 2022, almost two decades later.

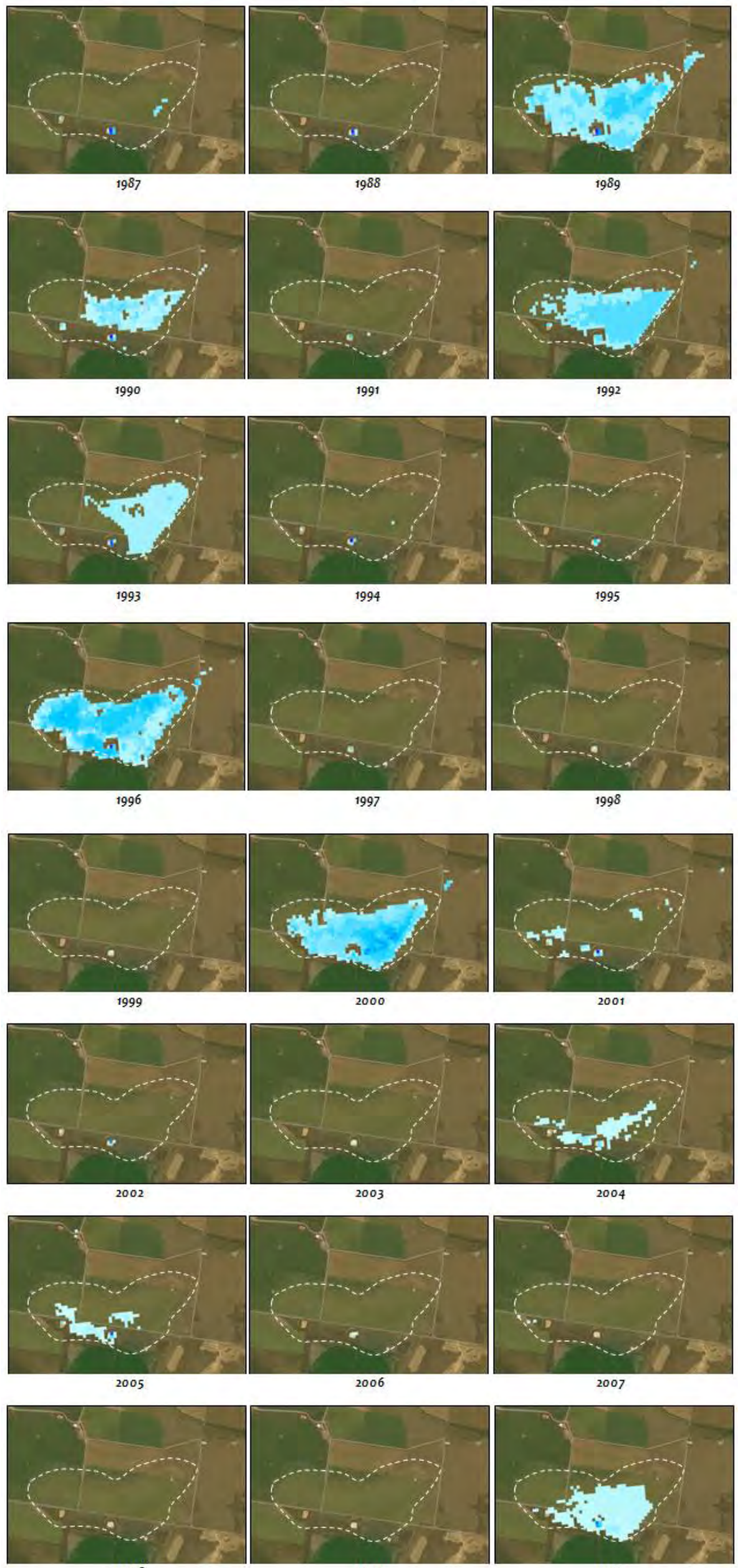
[5] From: 122 years of Australian rainfall. Bureau of Meteorology. http://www.bom.gov.au/climate/history/rainfall/

April 1989 image of burrung buluk. No changes to artificial drainage since 1974.

Jan 2004 image of burrung buluk. Again, no changes to artificial drainage since 1974.

December 2005 image of burrung buluk. We can see that a comprehensive drainage network (the herringbone drain pattern) was constructed in 2004 or 2005, along with an upgrade of the 1970s drain.

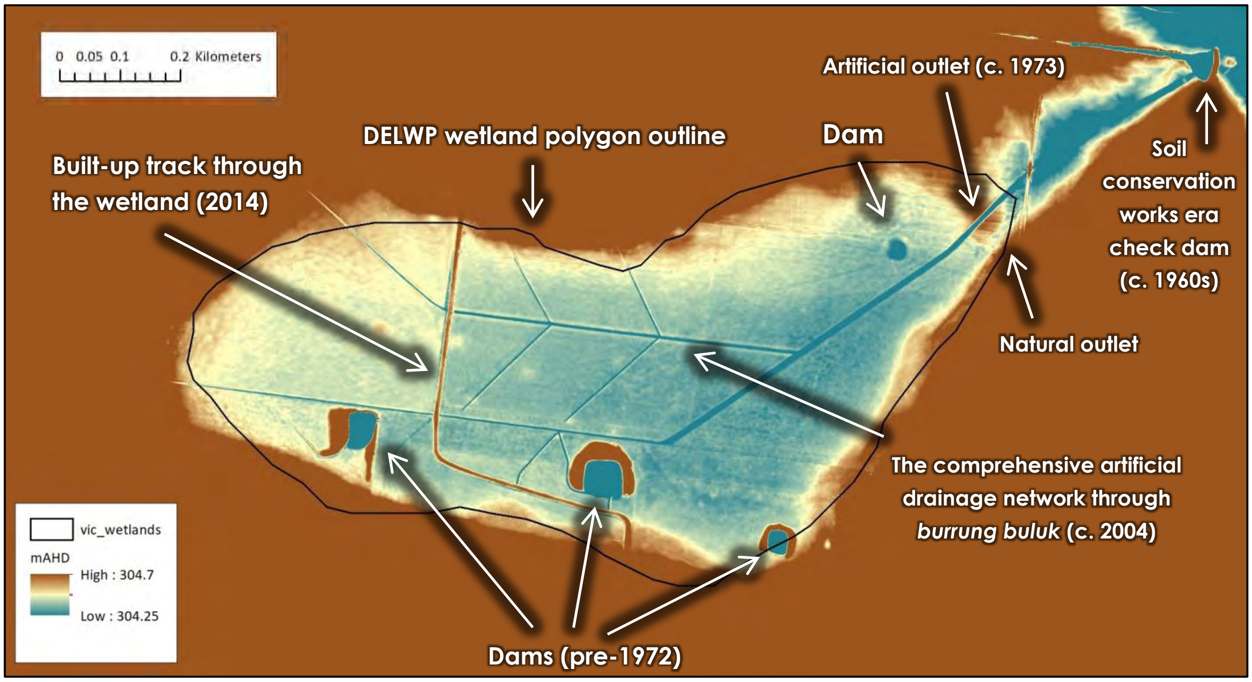
Evidence that supports the photographic evidence and the fact that *burrung buluk* was still a semi-functioning wetland until relatively recently is available in historic Landsat inundation data, called Water Observations from Space (WOfS) and shows areas of open water, as shown below.



Water Observations from Space (WOfS) for burrung buluk from 1987-2010.

WOfS data show a distinct change in the area of the wetland and the regularity of detection that corresponds with more comprehensive drainage of *burrung buluk* in 2004/05. Notwithstanding the amount of rainfall in the 2010 La Niña year, when the Millennium Drought broke over much of eastern Australia, *burring buluk* did not inundate to the same extent as it had in above average rainfall years prior to 2004.

In summary, the artificial drainage network constructed circa 1973 and comprehensively enhanced circa 2004, along with tracks and dams also present through the wetland, are now clearly visible in the DEM across *burrung buluk.*



Recent DEM showing the comprehensive artificial drainage of burrung buluk in c. 2004 and other features evident in the elevation data.

The most recent wave of development since 2004 has facilitated a parallel intensification in land use, in particular an increase in soil cultivation in parts of the wetland; this can, along with reduced depth, duration and frequency of inundation, have significant detrimental impacts on the emergence and persistence of wetland flora, and habitat use by wetland fauna, while those threats remain. The image above tells the story of all those accumulated, in some cases now substantial, changes to the hydrology of *burrung buluk* over the past 70 years, and yet the physical geomorphic form of the wetland is still clearly apparent – which means that the site could be readily remediated as a functioning wetland feature.

Despite the many changes that have occurred during the aerial photographic record (since the 1940s), the more regular inundation and/or saturation of *burrung buluk* until relatively recently (c. 2004) helps to explain the ongoing persistence of a portion of the former native grassy wetland flora in some of the less frequently cultivated parts of the wetland basin today.

Despite fundamentally altered hydrology, biological values associated with previously modified natural wetlands can show great resilience. Coupled with the fact that, as a landscape feature, *burrung buluk* still clearly exists (albeit in a dormant and artificially dehydrated state), with further land use change imminent, the future of the wetland feature in what will become a newly urbanised environment is worth serious and closer consideration.

PART 4: Exploring how wetlands like *burrung buluk* respond to hydrological change

Broad timeline of change

From the material we have reviewed in Part 3, it is clear that *burrung buluk* has undergone a series of changes that have dramatically impacted upon its hydrological regime and biological values. The following table, which is subject to further amendment and refinement as more information becomes available, broadly summarises those changes as they are currently understood.

Period	Description	Notes of likely impact on *burrung buluk*
Pre-1830s	Pre-European colonisation	Wetland in its original condition, and part of the traditional cultural landscape of the Wurundjeri Woi Wurrung people.
From 1830s	European colonisation: Sheep grazing introduced and period of continuous farming commences	Native wetland flora impacted as sheep preferentially graze the most palatable species. Introduction of weeds, deliberate (in the form of introduced pastures) or inadvertent, would compete with native flora. Exclusion of Traditional land management including cultural burning.
From c. 1900	Strathaird Creek diversion drain likely constructed prior to 1913, reducing the *burrung buluk* catchment	The frequency and magnitude of flows entering and/or passing through burrung buluk are significantly impacted. Despite this, the local immediate catchment for the wetland continues to see it persist, albeit with a modified hydrological regime.
From c. 1960s	Investment occurs in soil conservation measures along Strathaird Creek / drain	While these measures appear to have had a significant impact on the way the Strathaird Creek diversion drain functions, it has little direct impact on burrung buluk, continuing to divert flows away from the wetland.
From c. 1970	Construction of larger dams into the bed of *burrung buluk*	Impact on wetland hydrology as voids draw water below the natural surface level – i.e. the potential for internal drainage or soil dewatering within the wetland.
From c. 1973	First single artificial drain cut across the bed of *burrung buluk*	The wetland is artificially drained for the first time. Despite this significant change, there is evidence that the wetland continued to inundate during wetter periods, and that the original drain may not have been wholly effective (i.e. it was possibly not maintained over time).
From c. 2004	Comprehensive drainage network constructed, including deepening of artificial drainage outlet below wetland bed level	The wetland itself is comprehensively drained (in a herringbone pattern), allowing intensification in land use and soil cultivation, which continues to the present time.
From c. 2010	Centre-pivot irrigation commences south of *burrung buluk*	A possible inadvertent side-effect of the artificial irrigation of the land south of burrung buluk is an increase in soil saturation and seepage to the southern part of the wetland.

The net effect of these changes is that current conditions at *burrung buluk* do not resemble anything close to the original hydrological regime. Yet, how is it that the wetland still retains residual elements of native grassy and herbaceous wetland flora that have been found in recent years within the wetland feature?

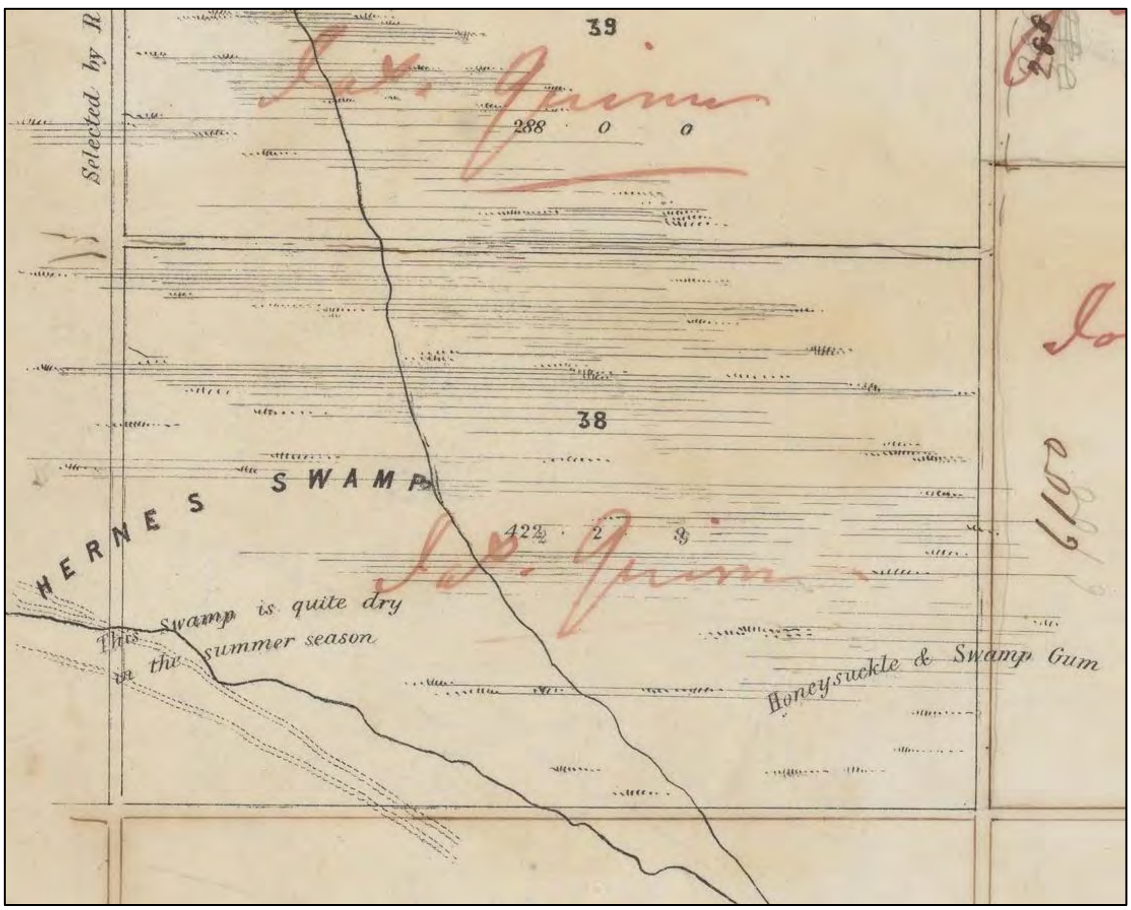
These have been discovered:

- in reasonable condition within southern portion of the wetland,
- in poorer condition within relictual patches of the northern portion of the wetland (prior to subsequent approval for clearance in recent years), and
- within artificial drainage lines.

The answer lies in the biology itself of wetland plants, which requires a parallel understanding of the natural variability of wetland hydrology. This is because for <u>any</u> wetland, ecology is determined and driven by the hydrological regime[6].

Understanding how plants and animals respond to natural variability in wetlands

Wetlands are highly dynamic and variable ecosystems. We know that *burrung buluk* and the other *wallan wallan* wetlands, indeed grassy wetlands generally, are excellent examples of the variability of wetland hydrology. For example, even before any changes to drainage had occurred, the earliest maps show that nearby Herne Swamp (an in-stream floodplain wetland located downstream, with a larger catchment) was capable of complete seasonal drying, as shown below.



An example of the notations on an 1855 plan stating that, prior to its artificial drainage, Herne Swamp could be "quite dry in the summer season"

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[6] A water regime is the prevailing pattern of inundation (frequency, depth, extent, duration) over time, including its variability. It is a range of conditions, not a single state.

The natural wet and dry seasonal variability of Herne Swamp was also recorded in the 1870s Melbourne newspapers, when the new North East Railway Line (which bisects Herne Swamp) was being constructed and opened.

For example:

- ***Thursday 13th July 1871 (Argus)*** "The heavy embankment across that dreary stretch of country known as Herne's Swamp is finished. The bridges in this embankment as originally designed are now considered not sufficiently large to carry off the water, and they are to be enlarged. Very great difficulty is here experienced in getting a good foundation for the bridges, it having been found necessary to pile to a great depth."
- ***Monday 6th November 1871 (Age)*** "From the 22nd to the 26th mile the line crosses a remarkable flat at the head of the Merri Creek, known as Herne's Swamp. This is crossed on an embankment of about four feet in height."
- ***Sunday 13th April 1872 (Leader)*** "…the railway commences to enter Herne's Swamp, a tract of country some three miles across, in the middle, of which the Merri Creek takes its rise. No great difficulty was encountered in laying the permanent way, except in the base of one culvert, where it was necessary to drive piles in order to obtain a foundation. This large marsh which in winter is almost under-water, but in summer is clothed with a rich verdure, seems to be of volcanic origin. Indeed, surrounded as it is with an amphitheatre of hills, which almost deserve to be termed mountains with little islands of bluestone boulders, Herne's Swamp somewhat resembles the crater of a huge volcano. After stopping in the middle of the marsh to give the engine water the train starts again and 29 miles from Melbourne the site of the station at Wallan is reached."

These descriptions imply that prior to artificial drainage Herne Swamp resembled a well-vegetated marsh, reverting to a lush grassy character over the summer months, which is entirely consistent with other similar undrained wetlands which are seasonally wet, and support a diverse grass and herbaceous layer as the water recedes. The map from 1855 suggests that the wetland margin also had woodland elements, with silver banksias ('Honeysuckle' – a formerly common species of the grassy woodlands of the Victorian Volcanic Plain which is now largely lost from those environments) and gums also a feature on its eastern side.

Strathaird Creek did not 'pass through' *burrung buluk,* the swamp was literally part of the creek

A key difference between Herne Swamp and *burrung buluk* however is as follows.

The natural waterways of Herne Swamp (Merri and Taylor's Creeks) appear to have gently meandered their way right through this wetland, prior to their later deepening, straightening and channelisation to facilitate improved agricultural use of the swamp[7].

In contrast, the digital elevation model (DEM, based on LiDAR) now shows very clearly that *burrung buluk*, whilst an in-stream feature of Strathaird Creek, did not have any form of incised natural channel passing through it. That is, the wetland had to fill to a shallow depth across its extent before Strathaird Creek flows would spill over the natural outlet sill and continue downstream.

In short, *burrung buluk* itself formed part of the creek.

[7] See: http://natureglenelg.org.au/wp-content/uploads/2019/03/Public-Release-NGT-Discussion-Paper-Herne-Swamp-11th-March-2019.pdf

***burrung buluk* would have dried out completely, almost every year**

Yet given that *burrung buluk* is relatively shallow, with a modest original catchment including Strathaird Creek (which did not generate permanent base flows), it would also have experienced seasonal drying almost every year. The exception might be those years with episodic thunderstorm rainfall events, which of course would have been capable of occasional, temporary refilling of these wetlands at any time of the year.

The role of the Strathaird Creek catchment in more regularly filling *burrung buluk* after rainfall events needs to be better explored and understood, and could be determined if monitoring of flows and flow volumes currently passing down the artificial bypass drain were undertaken. Although this catchment is modest in size, it is capable of generating significant runoff after rainfall events. In summary, as a result of the influence of episodic rainfall events and dry spells also commonly experienced in the Wallan area, *burrung buluk* would have been capable of either being dry, or alternatively inundated variably to any degree, at essentially any time of the year.

Recent episodic catchment rainfall events demonstrate restoration potential of *burrung buluk*, despite past artificial drainage and diversion works still being in place

The ability for nearby Herne Swamp to temporarily re-flood even in the absence of restoration works (as a result of inflows overwhelming the capacity of the agricultural drains through the swamp and Merri Creek downstream) at any time of the year after episodic catchment rainfall, illustrates the potential of the *wallan wallan* wetlands. Below is an example from autumn 2020, but this occurs every time the local catchment experiences heavy rainfall (including the recent event referred to and shown in Part 1, from October 2022).

Looking south (towards Melbourne) over Herne Swamp after heavy rainfall on the 4th April 2020. Note the North-East Rail line bisecting the wetland, where (prior to artificial drainage) steam locomotives once used to stop to refill with water. Drone image courtesy of The North Central Review (with marking up of artificial drains by Mark Bachmann)[8].

Note that:

- As a result of the diversions in place from Strathaird Creek, the Herne Swamp image above now includes some water which historically was either retained in, or if already full would have passed through, *burrung buluk*.

[8] Image from: https://natureglenelg.org.au/it-hasnt-been-restored-yet-so-how-do-we-explain-the-temporary-return-of-herne-swamp/

- Herne Swamp also receives catchment inflows from Taylor's Creek, Wallan Creek and Merri Creek.

A more recent example event, when 103.4 mm of rain fell over 12th-14th October 2022 (figures from the nearest weather station at Kilmore Gap[9]) also resulted in the temporary inundation of *burrung buluk*, despite being cut off from the bulk of its original Strathaird Creek catchment. The image below was taken on the morning on the 14th October from Green Hill at Wallan.

burrung buluk (Hanna Swamp) on the 14th October 2022. Photo: Rob Eldridge.

Examples of wet and dry cycles in wetlands

If we accept that this high degree of variability was the natural hydrological regime for the *wallan wallan* wetlands, including *burrung buluk*, then the flora and fauna values that did occur, or might still persist as residual elements in these wetlands, can be viewed, interpreted and understood through a more appropriate and sophisticated lens.

This inherent variability is perhaps best illustrated first by looking at images of a couple of unmodified wetlands over time, remembering that with the exception of some wetland types that are permanently wet, inundated or saturated to a similar degree on an ongoing basis (like peatlands or lakes), the vast majority of wetlands in Australia experience more variable seasonal, ephemeral or episodic water regimes.

This means that the water depth, area and duration of inundation can change dramatically within a single season, let alone on a year to year basis, or over time in response to longer term climatic trends. Change and variability within wetlands is the norm, as shown below.

Dry and wet phases of a wetland with variable hydrology. Images: Damien Cook, Wetland Revival Trust.

[9] Data from the Bureau of Meteorology website: http://www.bom.gov.au/climate/dwo/IDCJDW3038.latest.shtml


Dry and wet phases of a wetland with variable hydrology. Images: Damien Cook, Wetland Revival Trust.


Dry and wet phases of a seasonal herbaceous wetland. Images: Damien Cook, Wetland Revival Trust.




Dry and wet phases of an in-stream floodplain wetland within the Grampians National Park, a site where a previously modified hydrological regime has been restored by NGT. Images: Mark Bachmann.

The limitations of once-off assessments that seek to describe wetland character

This variability makes the description of the biological values or hydrological function of any wetland extremely difficult to accurately pinpoint at a single moment in time, based on observations from a single site visit, or even multiple visits over a single season.

All of the information generated by professional consultants engaged by various parties to visit *burrung buluk* and describe its values, needs to be viewed, interpreted and understood within this context.

In the past, such assessments have not been particularly helpful for describing the variability of wetlands or their trajectory of change over time. This is crucial because almost no wetland (including those that are considered 'intact') remains in a steady state, and additionally, many wetlands (including those dominated by native wetland flora) have experienced past impacts that continue to influence to their hydrological regime and hence current ecological attributes.

This is not a criticism of the consultants who are responding to the brief they have been given by their client(s), to work within and respond to the demands of our current development system. It is actually a much broader challenge for the development assessment and approvals system because it is fundamentally more suited to the assessment of ecosystems whose dominant environmental values are less variable over short time frames, like terrestrial ecological communities such as shrublands, woodlands or forests.

This inherent variability in wetlands highlights a major limitation in effectively assessing and recognising the current or indeed potential future values of ecosystems where the expression of those dominant values is linked to and driven by a variable hydrological regime.

Seasonal changes and variability in wetlands explained

A good way to visualise this variability is to think about where plants grow within the elevation gradient (i.e. up and down the slope, edge or bank) across a wetland, and how they and associated fauna respond to changing conditions over time.

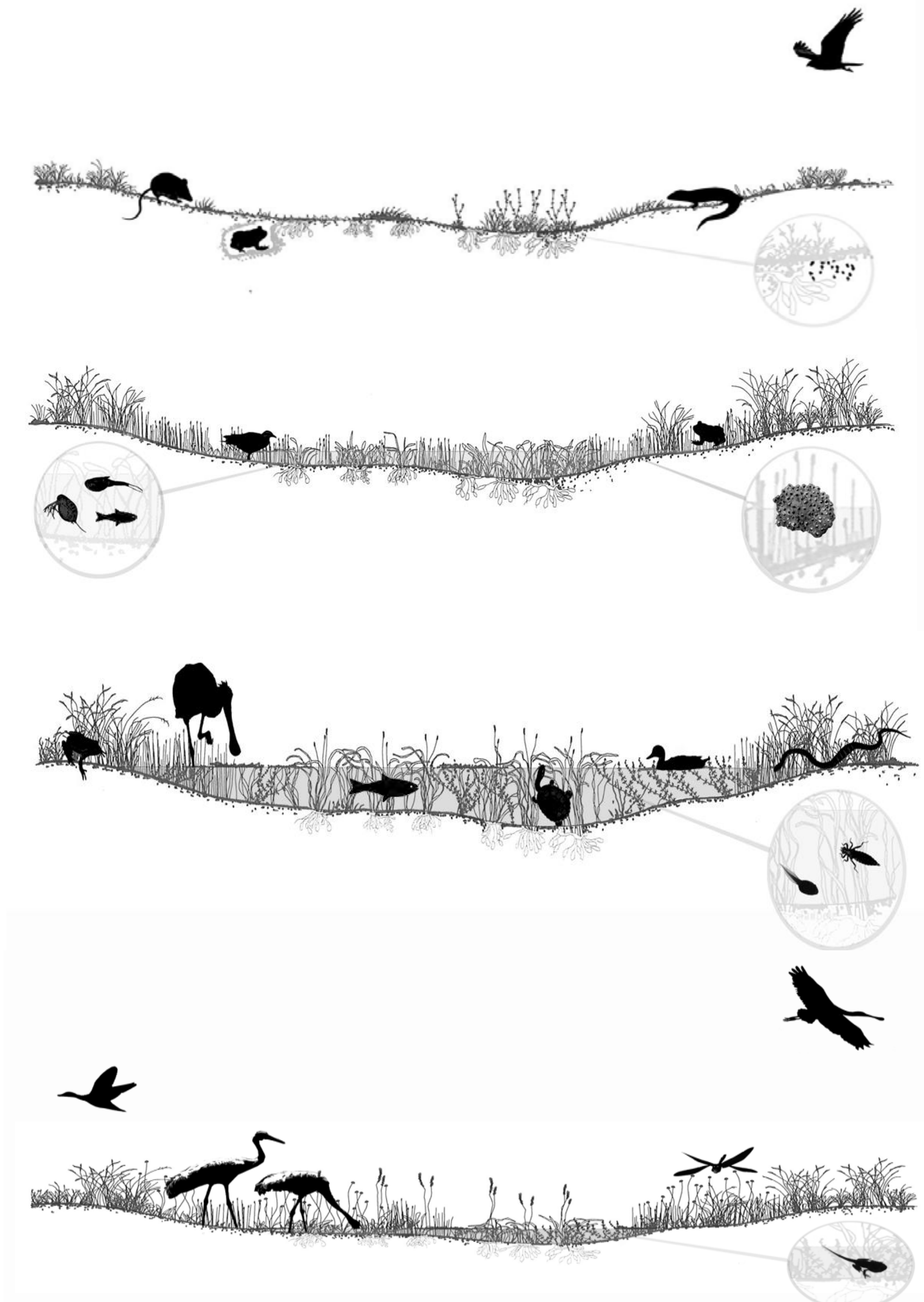
Within an intact wetland, this process can look like the following sequence. In short, a wide range of species of plants and animals, many with totally different hydrological requirements, all occupying parts of the same space, but using it variably to meet their specific biological needs over time.

Dry phase
(which could be prolonged for years [e.g. naturally via drought], or decades [e.g. artificially via drainage or diversions])

Filling phase
(which is typically winter/spring but can happen in any season)

Full phase
(which could be a different level every time the wetland fills)

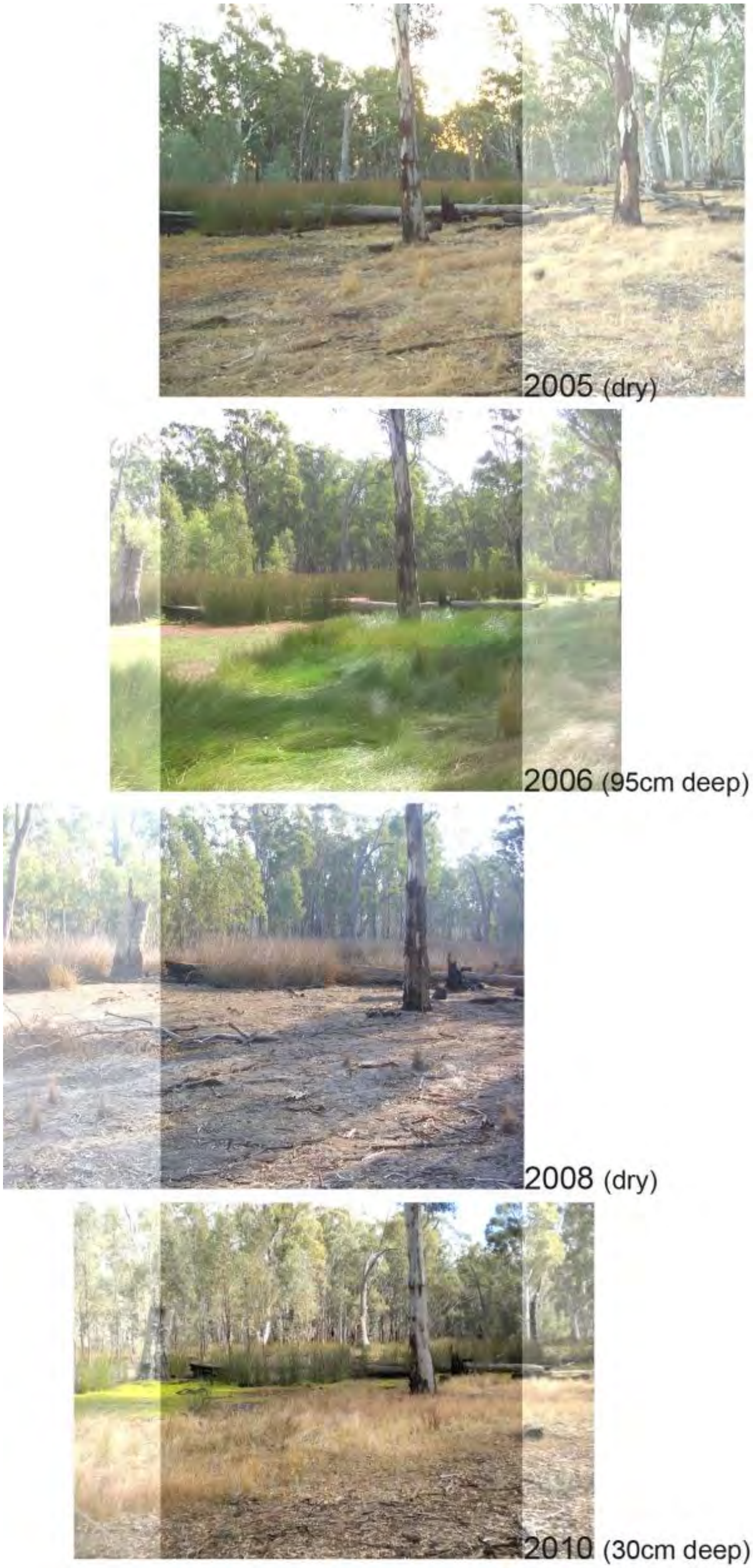
Drying phase
(which can be fast or slow subject to climatic conditions)



The typical wetting and drying cycle of a seasonal herbaceous wetland.
Courtesy of Damien Cook, Wetland Revival Trust. Notes in brackets by Mark Bachmann.

The next image sequence shows how inherently variable the inundation level can be at an individual wetland in response to climatic conditions, and how this influences wetland ecology, including the distribution of wetland flora – in this case over a period of five years.

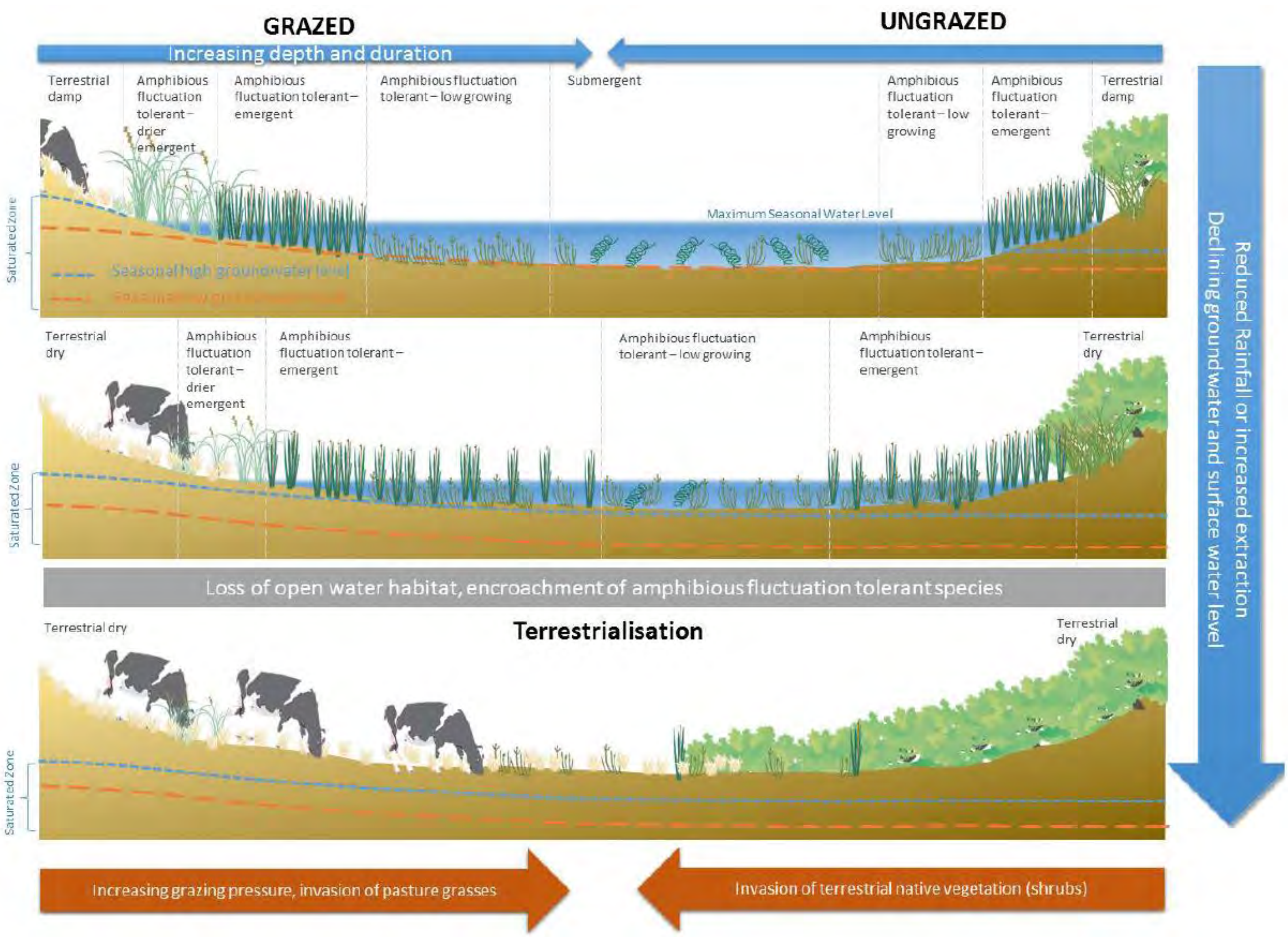
Fluctuations in wetland depth are not likely to be quite as broad at *burrung buluk*, which is more likely to typical experience between 0-50 cm of inundation at the deepest point, perhaps surcharging temporarily up to approximately 70 cm deep during flow events; hence this example is for illustrative purposes rather than as a direct comparison.



A photo point which illustrates the variability of wetland hydrology, and hence ecology. Courtesy of Damien Cook, Wetland Revival Trust.

The added complexity of human-induced modifications to wetlands

In wetlands modified by farming practices like grazing, drainage, or both, an already naturally complicated formula of moving variables becomes even more complex as a result of human intervention, as represented by the left hand side of the conceptual cross-section diagram below.



Conceptual model of changes in wetland plant functional group zonation because of declining water availability (from Deane et al. 2015)[10].

It is important to note a few key issues when considering this information, which are covered in the following sections.

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10 Deane, D., C. Harding, J. Brookes, S. Gehrig, D. Turner, J. Nicol, K. Clarke, M. Clark, K. Aldridge, B. Ostendorf, and M. Lewis. 2015. Developing ecological response models and determining water requirements for wetlands in the South-East of South Australia: Synthesis Report. Goyder Institute for Water Research Technical Report Series No. 15/24, Adelaide, South Australia.

Terrestrialisation, in its various forms, is reversible

The terrestrialisation process within a modified wetland is reversible if past hydrological changes can be reversed (including remediation of physical changes), and this forms the basis of much of the eco-hydrological restoration and/or rehabilitation work undertaken by Nature Glenelg Trust over the past 10 years.

Examples of both scenarios, ungrazed and grazed, are shown below.

May 2015 ***September 2015*** ***October 2017***

An ungrazed, reserved wetland managed by Parks Victoria:
The extremely rapid reversal of terrestrialisation (in this case, wet heath shrub invasion) through NGT's hydrological restoration of Long Swamp, Discovery Bay Coastal Park[11].

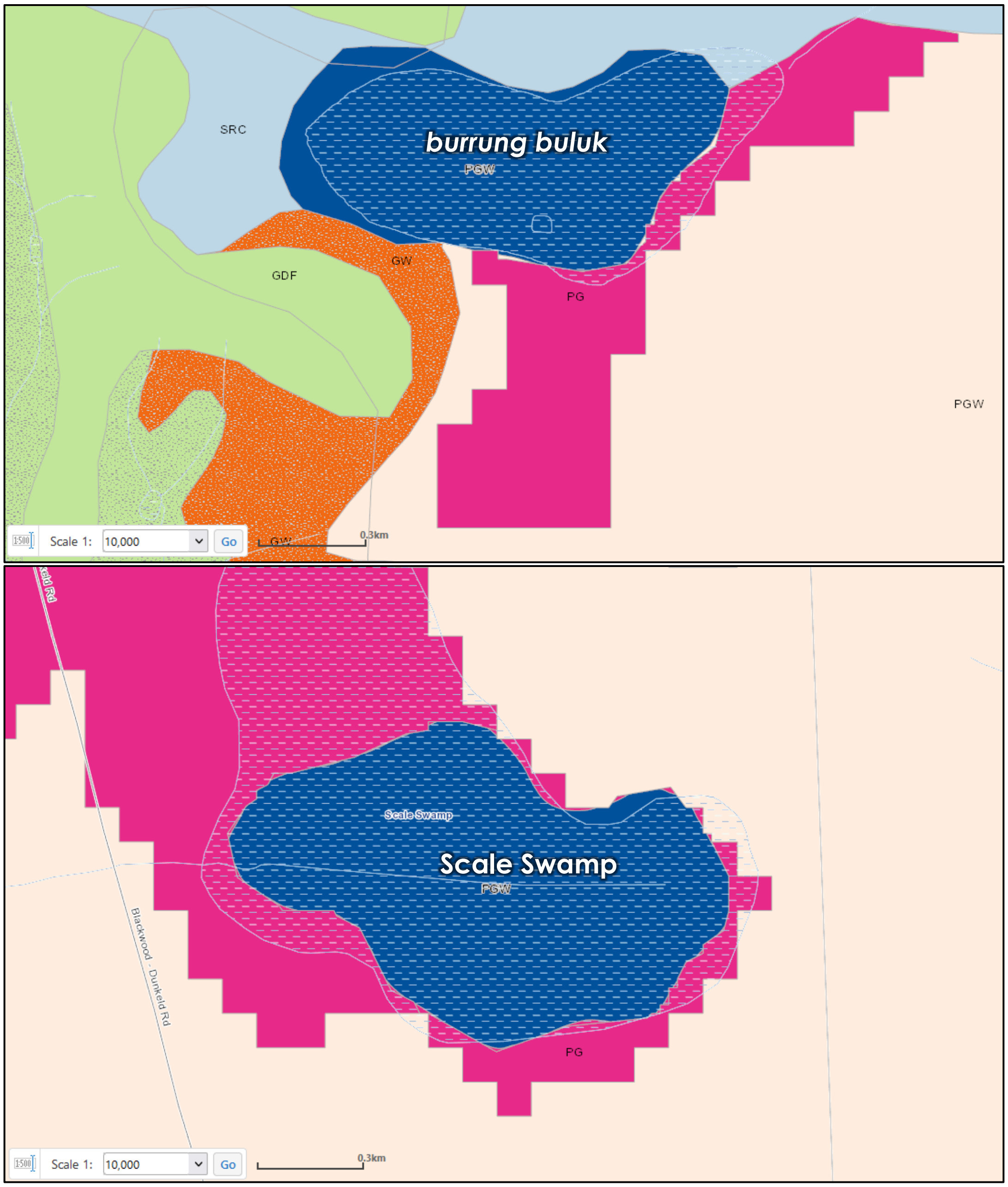
The appearance and condition of Scale Swamp, immediately before and after restoration: a previously grazed and farmed, privately owned seasonal wetland on the Victorian Volcanic Plain (VVP).

[11] From: Bachmann, M.R. (2020) The role of historical sources in the restoration of Long Swamp, Discovery Bay, Victoria. *Ecological Restoration & Management* Vol 21 No. 1. Pages 14-25.

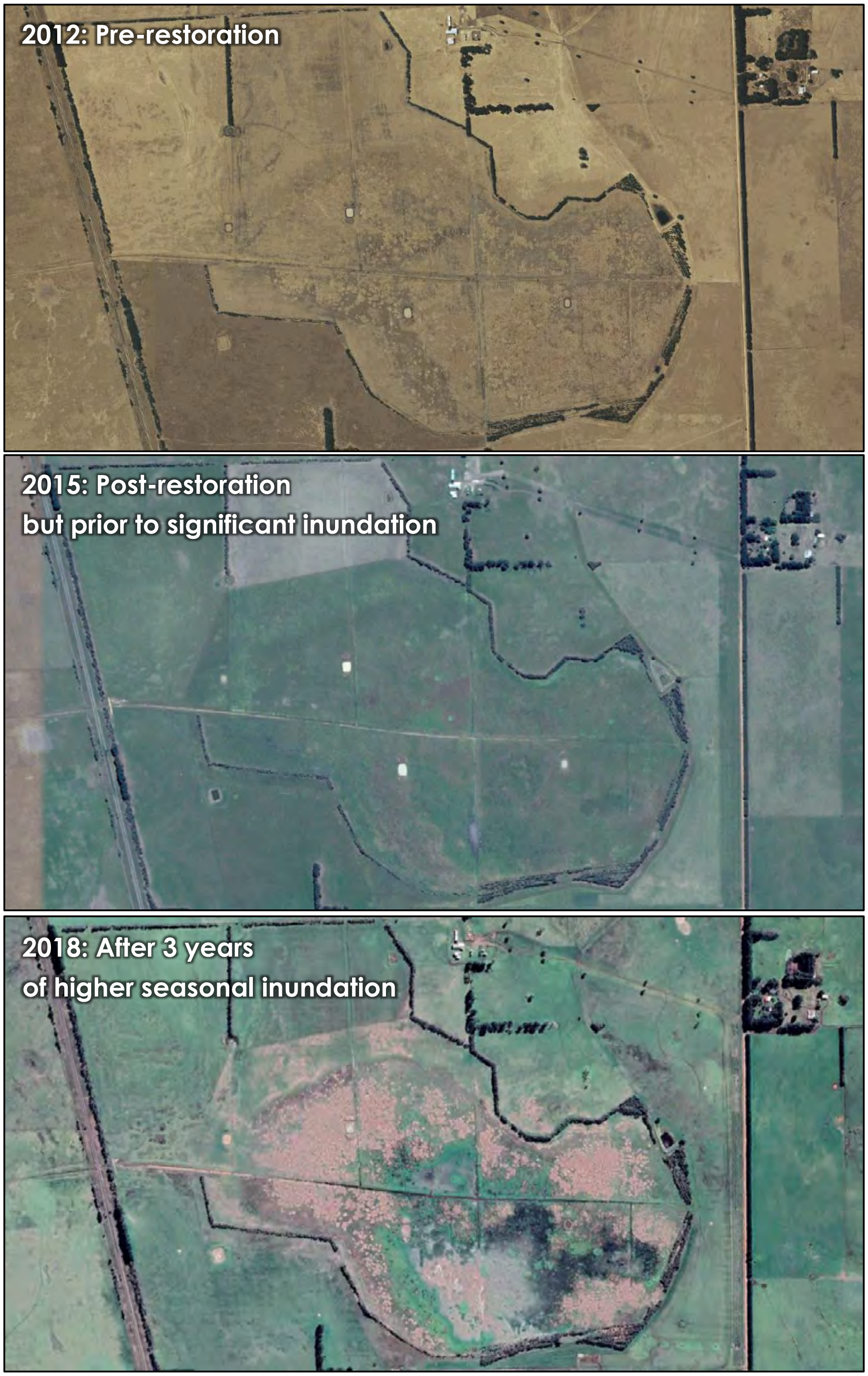
Case Study 1: Scale Swamp

Scale Swamp is a particularly useful comparative example for *burrung buluk*, because it has similar inundation depths, is also a seasonally inundated grassy wetland of the VVP, is surrounded by highly modified farmland, has a small localised catchment, and prior to hydrological restoration was drained, tilled, sown with pasture and farmed for many decades.

See the sequence of images below for background.



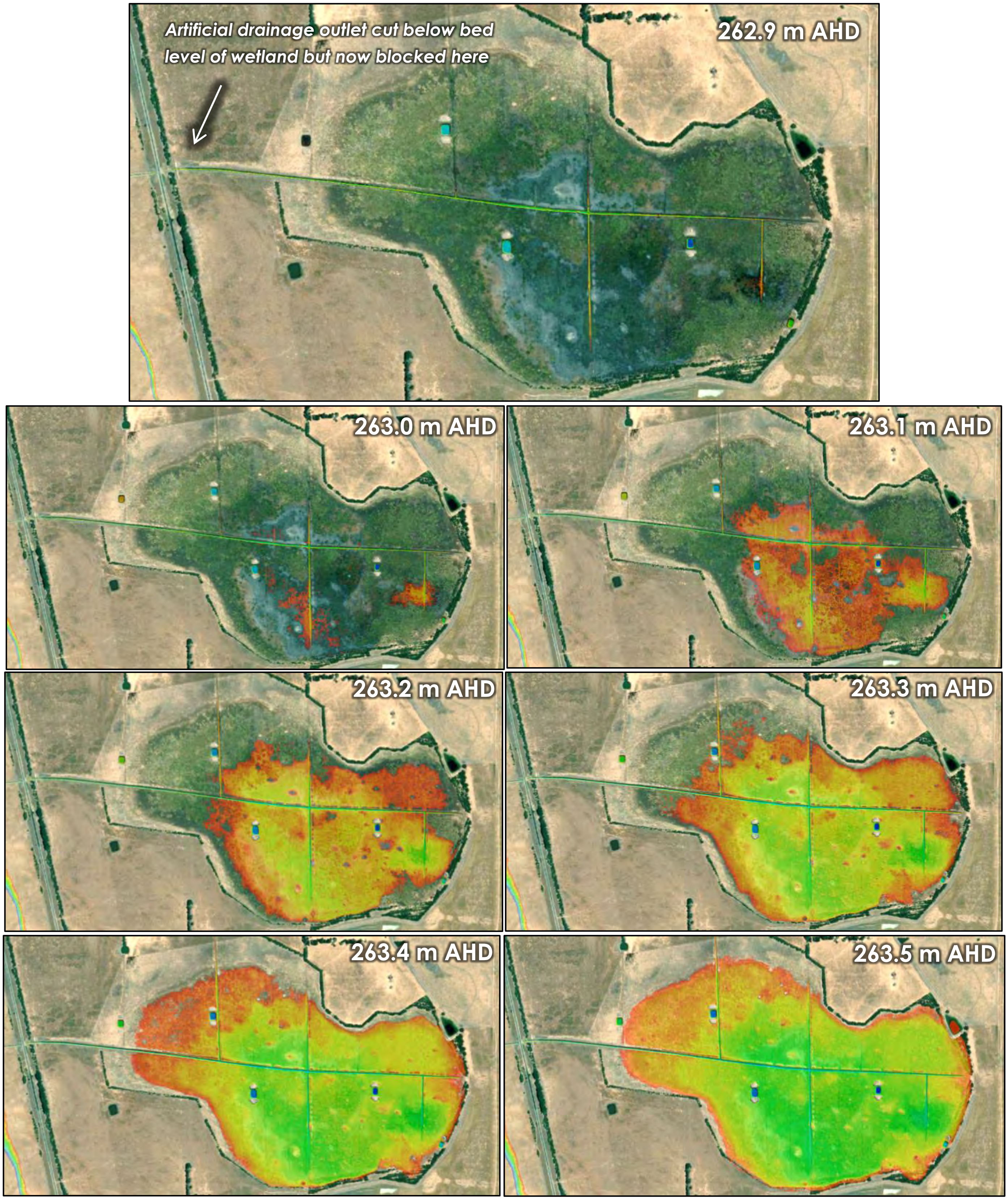
Pre-1750 EVC mapping by DELWP for burrung buluk (above) and Scale Swamp (below), both originally similar sized shallow grassy freshwater wetlands of the Victorian Volcanic Plain.
Blue is Plains Grassy Wetland, pink is Plains Grassland and beige is Plains Grassy Woodland.



Scale Swamp: recent hydrological restoration of a previously drained grassy wetland in the VVP.

As previously illustrated for *burrung buluk*, we can also use the DEM as a retrospective tool to show what actually did happen at Scale Swamp as a result of the hydrological restoration works.

The first image below shows the most recent aerial view we have of the site, which was taken in the past year or two. Note the wetland vegetation re-establishment process and how the colour signature and zonation of vegetation in the swamp, reflecting both vegetation type and/or saturation levels, neatly matches the different water depth zones. This is another example of how ecology follows, and is determined by, hydrology.



Using modern GIS tools and the DEM, we can illustrate the process of how Scale Swamp now re-fills from empty in 10 cm increments, as a result of hydrological restoration. Approx. depth guide: red/orange - up to 10 cm; yellow - up to 20 cm; light green - up to 30 cm; dark green and blue - over 40 cm.

Despite apparently limited native seedbank diversity being present prior to restoration and doubts expressed about its ability to recover (Casanova 2012[12]), inundation has effectively displaced (via drowning) the bulk of introduced pasture species (which require aerobic (drier) soil conditions) and their seed throughout the wetland, which has given the competitive advantage to native wetland flora, and has allowed those residual native species to recover, reproduce and dramatically expand in extent. Casanova and Casanova (2016)[13] noted that:

> "*one of the sites used in Casanova's (2012) study has had its hydrology restored (Scale Swamp near Penshurst), and some native flora has re-established. Monitoring of this site should continue, as it is likely to provide valuable information on the recovery trajectory of sites disturbed by cropping.*"

Surveys of wetland flora in the two years immediately after restoration resulted in the emergence and detection of nine native species that were not recorded in the earlier seedbank study. Detailed monitoring is scheduled to occur at this site again in the near future, which will make an interesting comparison to this initial flora response. For a visual indication of what unfolded on the ground at Scale Swamp over the first five years, these images show the process of conversion from introduced pastures to a functional wetland.

Photo-point 1: Initial rapid death and displacement of introduced pastures occurred in Scale Swamp in winter 2014. This image was taken in November 2014, the first year when sustained shallow inundation occurred after hydrological restoration, in an area previously dominated by introduced Phalaris.

Photo-point 1: Post-restoration recovery of native wetland habitat at Scale Swamp, 5 years later – after hydrological restoration, fencing and destocking – in November 2019.

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[12] Casanova MT (2012) Does cereal crop agriculture in dry swamps damage aquatic plant communities? *Aquatic Botany* **103**, 54–59. doi:10.1016/j.aquabot.2012.06.002

[13] Casanova M.T. and Casanova A.J. (2016). Current and Future Risks of Cropping Wetlands in Victoria: Technical Report. Department of Environment, Land, Water and Planning, East Melbourne.

Photo-point 2: Initial rapid death and displacement of introduced pastures occurred in Scale Swamp in winter 2014. This image was taken in November 2014, the first year of sustained shallow inundation after hydrological restoration, in an area previously dominated by introduced Phalaris.

Photo-point 2: Post-restoration recovery of native wetland habitat 5 years later in November 2019. The initial response was dominated by hardier and more common native wetland plants at Scale Swamp, as the ecosystem adjusts to the new hydrological regime after reinstatement of water levels and destocking.

Prior to restoration, the locations shown here in the photo-points were dominated by Phalaris, an introduced pasture species that is tolerant of damp soil but not prolonged inundation, and is often sown into the heavy soils of drained swamps in an attempt to increase site productivity for livestock grazing.

Beyond flora, the return of sustained inundation each winter and spring has also seen the recovery of the food-web in the wetland, and has attracted a wide range of associated fauna to utilise the wetland. This will be covered in a subsequent section of this paper.

Residual values will often persist, if any level of soil saturation within the former wetland occurs

While the process of terrestrialisation may never be permanently reversed for many grazed and drained wetlands in a farmland context due to land-use change, residual wetland values can still emerge during wetter climatic phases, even at long-modified sites. Anything from an increase soil in saturation to temporary inundation of a former wetland, will often trigger the natural post-drought emergence response of those species.

In the case of plants, some species can persist in the form of a dormant seedbank, tubers or rhizomes, but without full restoration of the hydrological regime, it will be those hardier wetland species most tolerant of fluctuating wet/dry conditions that will primarily emerge and persist.

Case Study 2: Cunningham Swamp

Cunningham Swamp is another useful comparative seasonal wetland, because in its present eco-hydrological state, it sits somewhere on the continuum between Scale Swamp and *burrung buluk*. Like *burrung* buluk, Cunningham Swamp also happens to be a modified wetland at the present urban fringe (at Point Cook, south-west of Melbourne) that has been designated for future urban growth. As shown right, DELWP 1750 EVC mapping considers that this is also an area which originally consisted of plains grassy wetland (blue) surrounded by plains grassland (pink).

Despite a long history of drainage and other hydrological modifications, as the aerial images below show, even modified wetlands that have not yet been hydrologically restored are capable of a degree of partial natural reversion during wetter phases and/or if drains are not maintained.

2006 ***2021***

The stark difference in the appearance of Cunningham Swamp over a 15 year period, between the Millennium Drought and a later wetter climatic phase. Note urban encroachment from the north over this time.

On the ground, the stark difference in the appearance between the dry phase and wet phase at Cunningham Swamp – despite still being artificially drained and farmed for decades – illustrates the complexity of assigning a notional 'value' to a modified wetland at a single point in time, when it can be reasonably assumed that residual values (in the form of a dormant seedbank, tubers or rhizomes) will still occur at the site.

Dry Phase

Wet Phase

Example of the change in vegetation cover within Cunningham Swamp between dry and wet phases.

As previously explained, many species associated with seasonal wetlands are especially tolerant of a wide range of hydrological conditions, so it is not surprising to learn that residual values of this type have also persisted in the southern portion of *burrung buluk*, when and where conditions temporarily enable these species to be expressed. Locating these persistent species, however, does not indicate that this part of the wetland is experiencing anything close to its original hydrological regime.

As outlined throughout this discussion paper, all of *burrung buluk* – precisely like the example also provided here for Cunningham Swamp – is currently artificially drier than it was historically and does not resemble the much wetter hydrological regime (in terms of depth and duration of inundation) which could be returned. The proven persistence of these species is, however, an excellent indicator of the future restoration potential that still exists in these long modified wetland features.

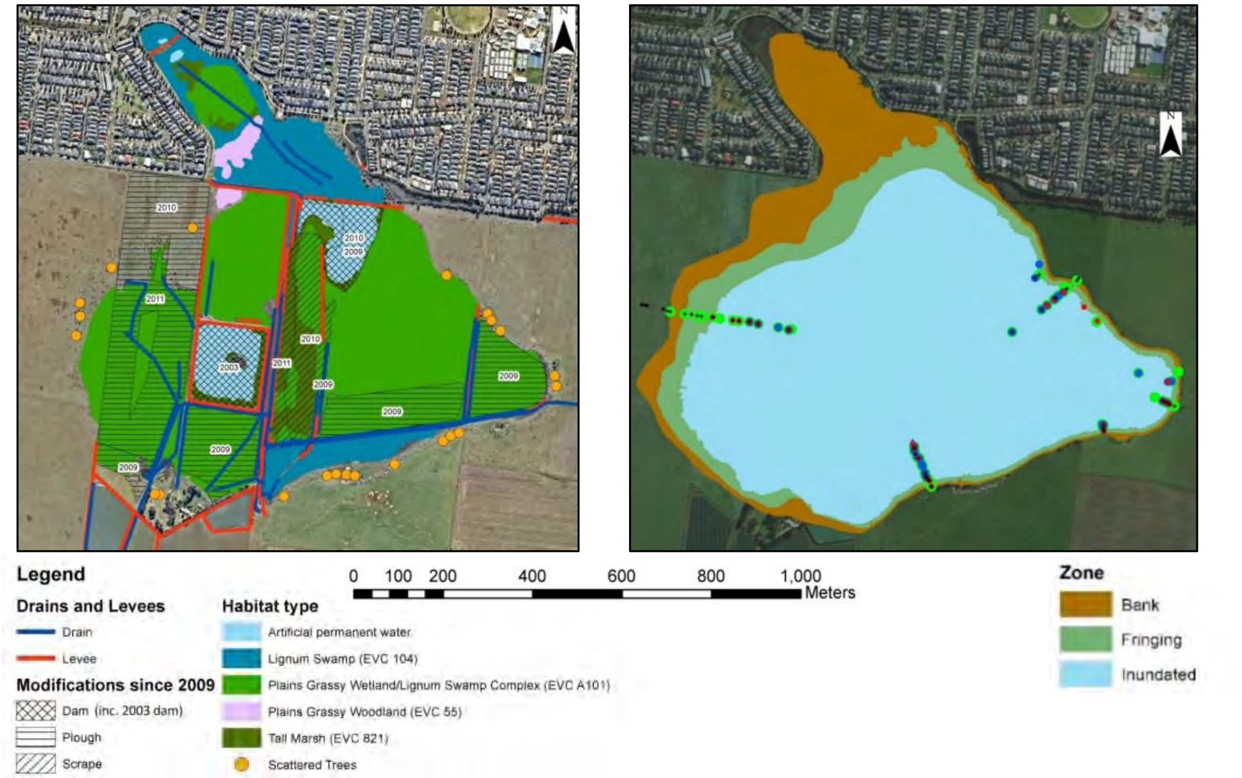
Wetland flora can move up and down slope and recolonise newly inundated ground

The capacity of these residual wetland plants to naturally re-colonise and trigger wider recovery within a wetland we find is regularly questioned, but at NGT we have direct practical experience of implementing these projects and witnessing this process unfold dozens of times.

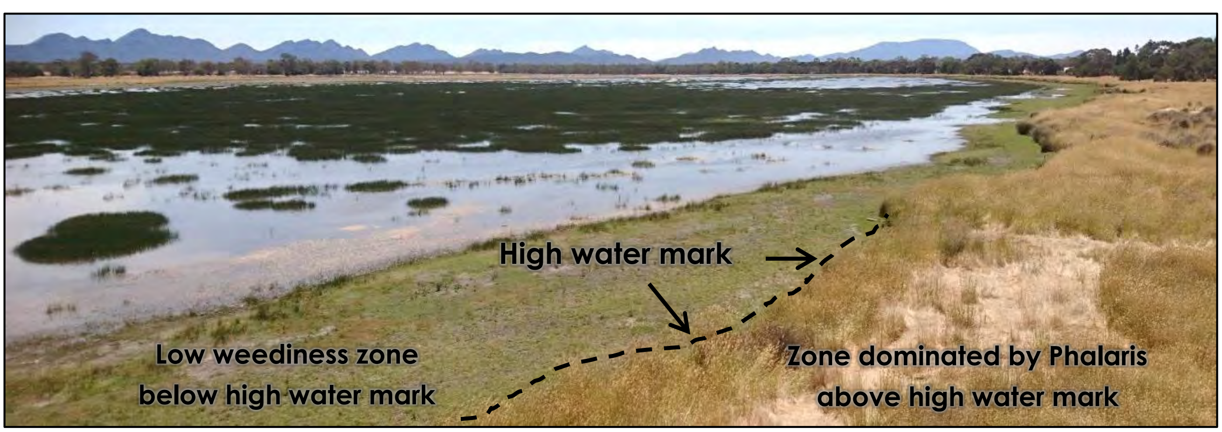
The ability for wetland plants to migrate up and down slope in quick time is an adaption that is required by these plants to cope with the high degree of natural variability of the water regimes of wetlands generally. This process explains how and why residual, albeit hardier, species of wetland flora have been found growing in the bed of the excavated artificial drainage channels in the northern portion of *burrung buluk*. This is an example of where these species have migrated downslope, to grow in a wetter environment more suited to their eco-hydrological requirements.

By lifting the water back out of the drainage channels and allowing it to inundate the land, immediately reducing competition from introduced terrestrial species, which will be drowned, the possibility clearly exists for the immediate movement and expansion of the range of residual wetland flora still present within the entire *burrung buluk* wetland feature. The images from the Scale Swamp example illustrate just how rapidly this process can occur.

At the Cunningham Swamp case study site, the current complex distribution of habitats and their relationship to past physical disturbance and modifications is shown below left, next to a map that shows the broad wetland zones which could be reinstated via remediation works to remove artificial drains, dams and embankments, coupled with restoration of the hydrological regime[14].



The most challenging zone for wetland management after restoration is usually the well-watered zone above high water mark, which does not get wet enough, for long enough, to kill or displace the terrestrial pasture or other introduced species. The example below shows how this phenomenon is expressed at Walker Swamp, a high-profile wetland restoration site (and NGT Reserve) in the southern Grampians district, western Victoria.



Walker Swamp: as water levels recede, high water mark is a readily observable line of floristic demarcation.

In an urban environment, this zone above high water mark can be managed through planting with native wetland edge species, or using slashing to control any undesirable weedy biomass.

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14 Both maps are from: Kerr G. D, Farrington L, Tuck J, Bachmann M (2021). Assessing the restoration potential of Cunningham Swamp (Point Cook, Victoria). September 2021. Nature Glenelg Trust, Warrnambool, Victoria.

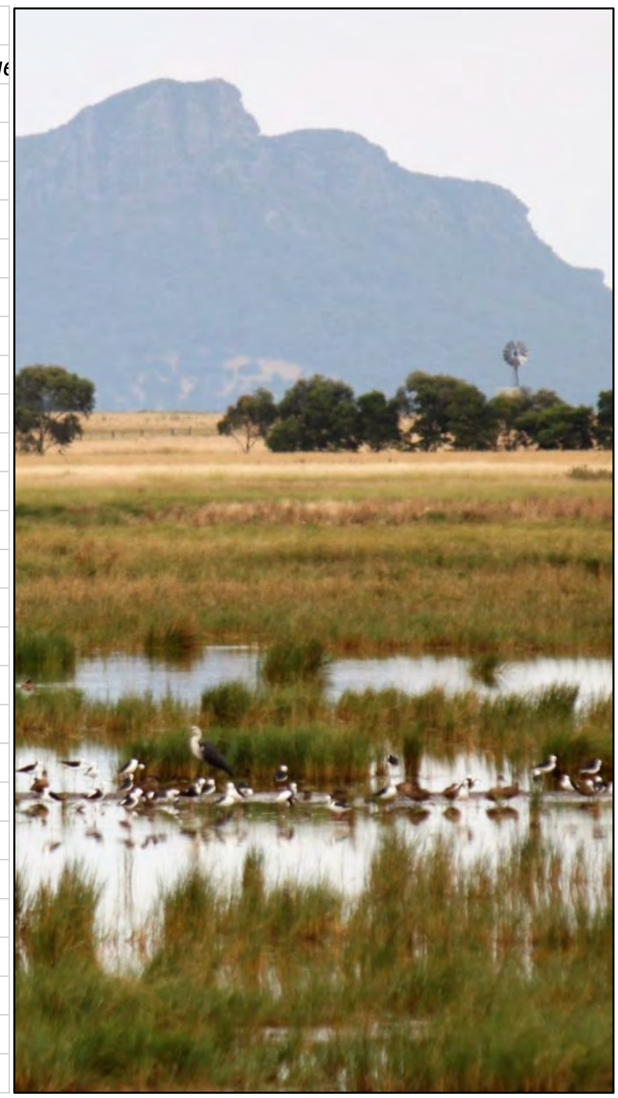
Wetland fauna will also quickly return

Wetland fauna are even more mobile and responsive than wetland flora. Once a shallow wetland is re-inundated, the macro-invertebrates re-appear and waterbirds will immediately find the site, quite often before the plants have even had a chance to respond. Any physical connection to other waterways allows the water itself to provide a migration pathway for aquatic species, and frogs and turtles are known to recolonise wetlands by migrating over land. All of these fauna species have co-evolved with native flora and can also assist with their recovery, noting that waterbirds are known to move wetland flora around the landscape in their scats or attached to their feet or feathers.

Seasonally inundated wetlands are especially productive environments for fauna – indeed more productive and ecologically diverse than permanently inundated lakes or waterbodies – because of the carbon cycle and nutrients that are unlocked each time the wet and dry cycle occurs.

As a comparative example relevant to *burrung buluk*, the most recent comprehensive bird survey conducted at Scale Swamp (that we currently have the data for), was approximately four years ago by Dr Rod Bird of the Hamilton Field Naturalists Club and Dr Greg Kerr of Nature Glenelg Trust. This resulted in the detection of 26 native bird species (and 1 non-native species) which are listed below.

Common Name	Scientific Name
Australasian Grebe	*Tachybaptus novaehollandiae*
Australian Shelduck	*Tadorna tadornoides*
Australian White Ibis	*Threskiornis moluccus*
Black Swan	*Cygnus atratus*
Black-winged Stilt	*Himantopus leucocephalus*
Brolga	*Antigone rubicunda*
Brown Falcon	*Falco berigora*
Brown Songlark	*Cincloramphus cruralis*
Chestnut Teal	*Anas castanea*
Eurasian Skylark	*Alauda arvensis*
Grey Teal	*Anas gracilis*
Hoary-headed Grebe	*Poliocephalus poliocephalus*
Latham's Snipe	*Gallinago hardwickii*
Magpie-lark	*Grallina cyanoleuca*
Masked Lapwing	*Vanellus miles*
Purple Swamphen	*Porphyrio porphyrio*
Red Wattlebird	*Anthochaera carunculata*
Red-kneed Dotterel	*Erythrogonys cinctus*
Royal Spoonbill	*Platalea regia*
Sharp-tailed Sandpiper	*Calidris acuminata*
Straw-necked Ibis	*Threskiornis spinicollis*
Stubble Quail	*Coturnix pectoralis*
Whistling Kite	*Haliastur sphenurus*
White-faced Heron	*Egretta novaehollandiae*
White-necked Heron	*Ardea pacifica*
Yellow-billed Spoonbill	*Platalea flavipes*
Yellow-faced Honeyeater	*Caligavis chrysops*



Of note, Brolga are now regularly sighted at Scale Swamp, as are flocks of other species.

A portion of a flock of 16 Brolga recorded at Scale Swamp in January 2018. Photo: Lachlan Farrington, NGT.

Royal Spoonbill flock (left) and some of a group of 450 Sharp-tailed sandpipers recorded at Scale Swamp a few years after hydrological restoration. Photos: Lachlan Farrington, NGT.

As grant funding programs do not typically invest in follow-up monitoring and data collection, providing a more complete picture of the full suite of ecological outcomes that have flowed so far from the hydrological restoration of Scale Swamp is not yet possible. At this point, however, in the absence of that more complete picture, and while clearly the site has not yet reverted to a "reference" or "pristine" state, we are satisfied that the project has been a complete success. The goal for Scale Swamp was to set it on a trajectory of assisted environmental recovery, a process which is clearly underway and remains ongoing. The site will continue to ecologically improve and recover over the years and decades ahead.

A visual summary of the past 75 years to illustrate the changing trajectory of Scale Swamp is shown below.

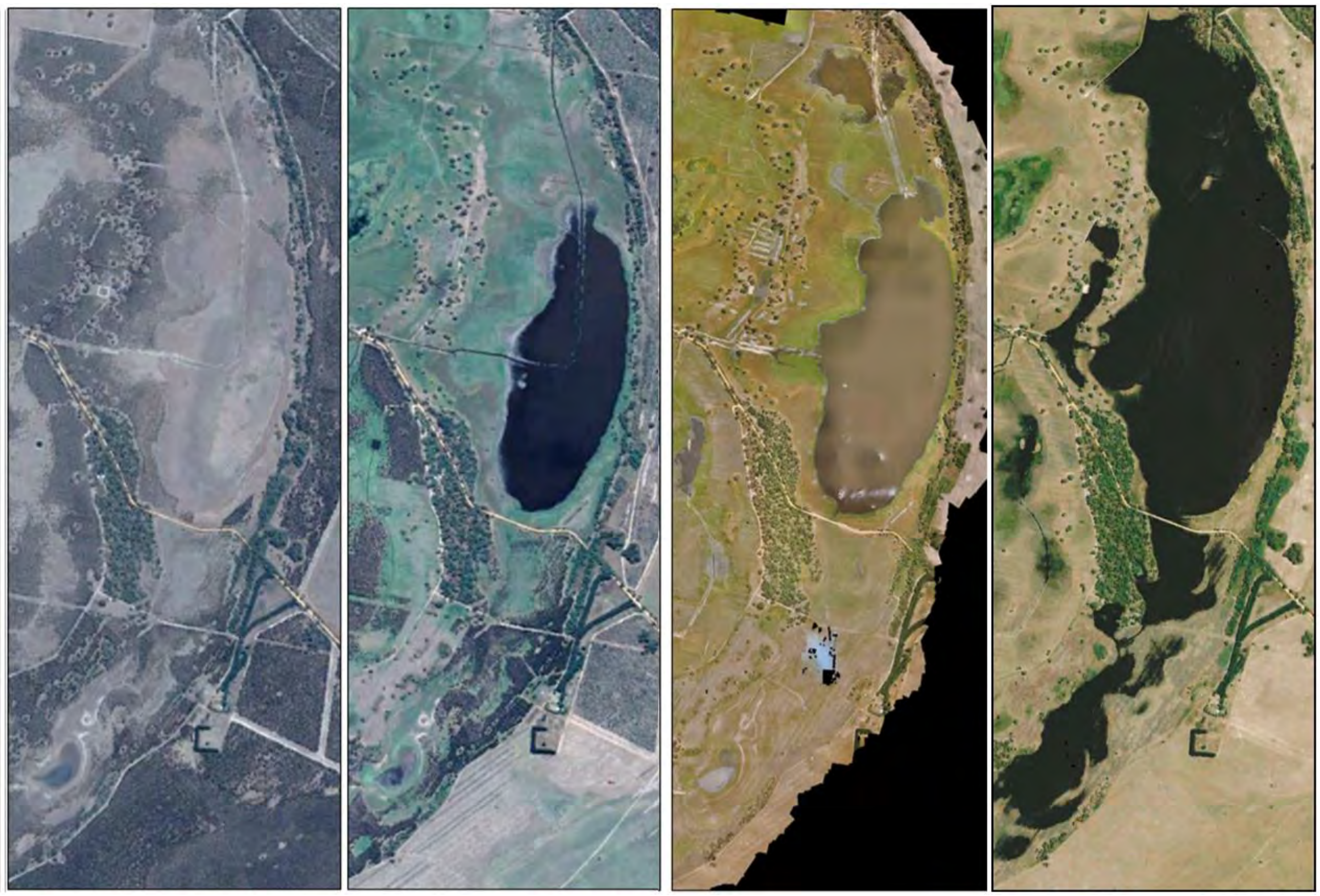
1947 (near intact) ***2012 (drained)*** ***Present (recovering)***

The trajectory of change at Scale Swamp over the past 75 years, based on aerial photography.

As a similar feature, with a parallel history of modification, *burrung buluk* has the same potential.

At Walker Swamp (which is a short distance to the north-east of Scale Swamp), we are fortunate to have a more complete record of pre- and post-restoration bird monitoring to call upon. Data from 48 surveys of waterbirds at Walker Swamp were available between 2002 and 2020, noting that partial restoration (via a trial) occurred in 2014, and subsequent full restoration of the water regime occurred in 2019 after the property was acquired by NGT in 2018[15]. Fifty-three wetland dependent bird species were recorded over that 18 year period[16].

To give the reader a sense of the impact and scale of hydrological restoration, the change in water retention within Walker Swamp over that period is shown below.



Pre-2014 (drained) ***2014-2018 (trial phase)*** ***2019 (post-restoration)*** ***2020 (first filling event)***

The trajectory of change at Walker Swamp over the past 20 years, based on aerial photography.

Initial results indicate that both waterbird abundance and diversity have increased markedly in response to the increase in duration and extent of water, associated changes to floral diversity and abundance, and increased habitat and food web complexity within Walker Swamp. While Walker Swamp is not intended to provide a direct comparison to *burrung buluk* (it is a different wetland type), it does illustrate how fauna generally – and birds in particular – respond to increased availability of habitat in the landscape over time. Hence it is the trend of utilisation and value of restored seasonal wetland habitat that is of most direct relevance to *burrung buluk*.

For example, a sample based species accumulation curve for Walker Swamp reveals that new waterbird species are still being added and that this trend is continuing (the asymptote had not been reached), despite the relatively high sample intensity, as shown below.

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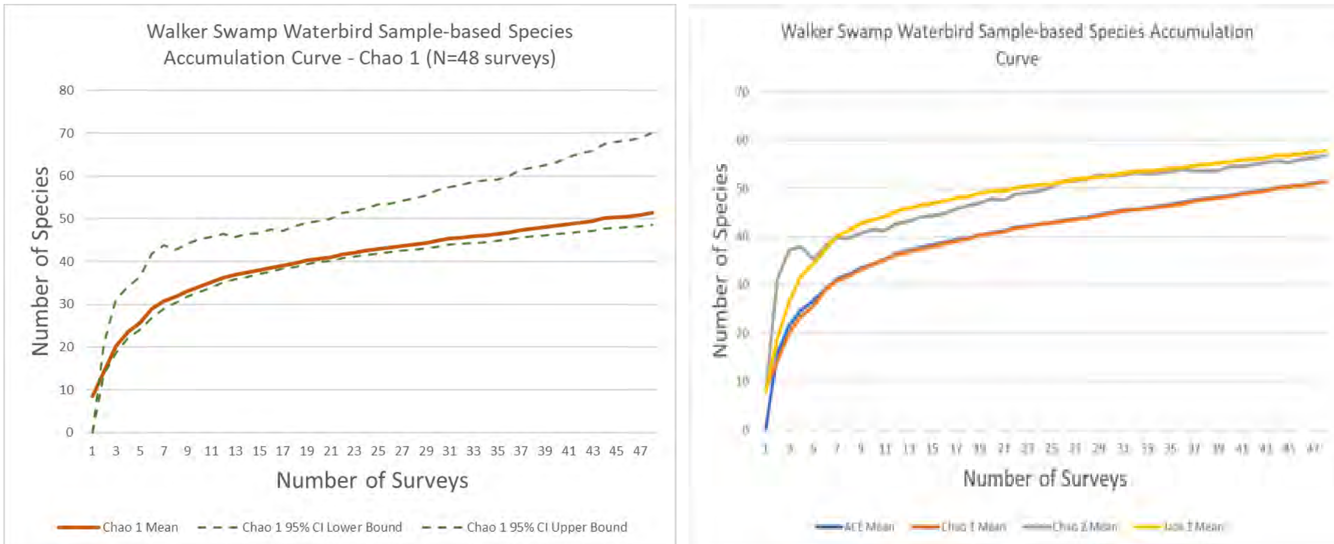
15 For more information on NGT Reserves see: https://natureglenelg.org.au/ngt-reserves/

16 Kerr, G.D., M. Peters, L. Farrington & M. Bachmann (2020). Walker Swamp Restoration Reserve Monitoring Plan March 2020. Nature Glenelg Trust.

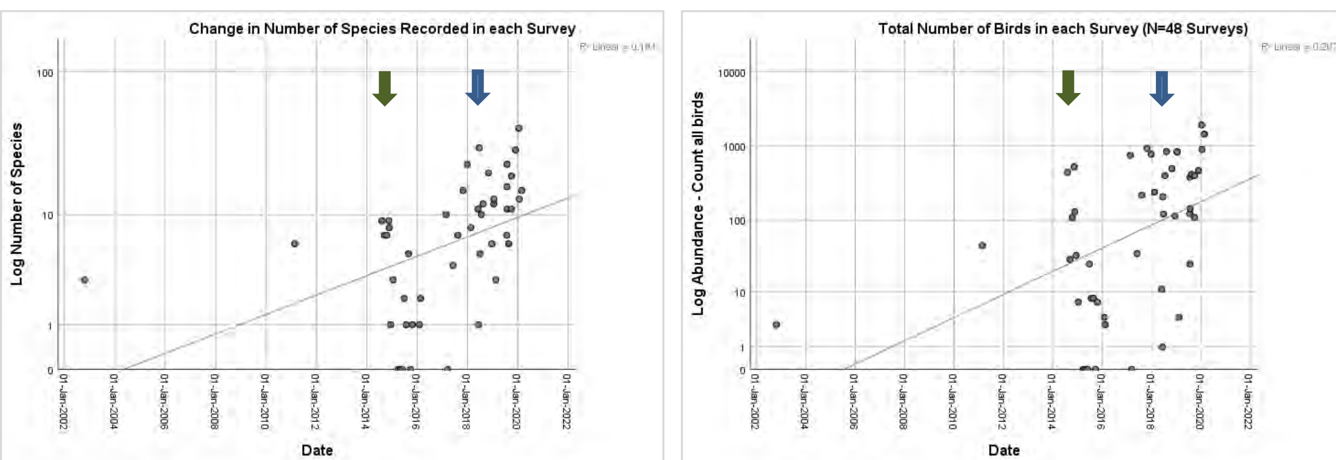


Sample-based species accumulation curves for waterbirds at Walker Swamp, showing that new species are being detected over time in response to hydrological restoration and associated ecological recovery.

Both waterbird diversity and abundance have increased throughout the time of monitoring in association with each of the major phases of works and the consequent increase the duration and extent of inundation in the wetland, as shown below.

The timing of these changes is indicated by:

- Green Arrow: the construction of a temporary sandbag structure (wetland sill level of 242.90 m AHD) in August 2014.
- Blue Arrow: the construction of the permanent spillway 60 cm higher in March 2019 (set at 243.5 m AHD) to restore the original full supply level of the wetland.



Change in number of waterbird species (R^2=0.194) (left) and total abundance of waterbirds (R^2=0.207) (right) for each survey between 2002 to 2020 at Walker Swamp. N=48 surveys.

Recovery for fauna like birds involves not just restoration of a diverse range of foraging habitats, but importantly the restoration of breeding habitat where the period of inundation and types of habitat inundated address a range of limiting factors.

For example, most waterbirds need a minimum of four months of inundation to enable successful breeding. In shallower seasonal wetlands like *burrung buluk*, this period of inundation can usually only be achieved if the wetland is hydrologically restored (reinstating the natural sill level) to reverse artificial drainage impacts.

PART 5: Developing the restoration vision for *burrung buluk*

Using the DEM to conceptualise an alternative future for *burrung buluk*

With the benefit of the DEM, we can (a) calculate approximately what volume of water it would take to inundate the wetland once again and (b) illustrate how *burrung buluk* fills up from empty.

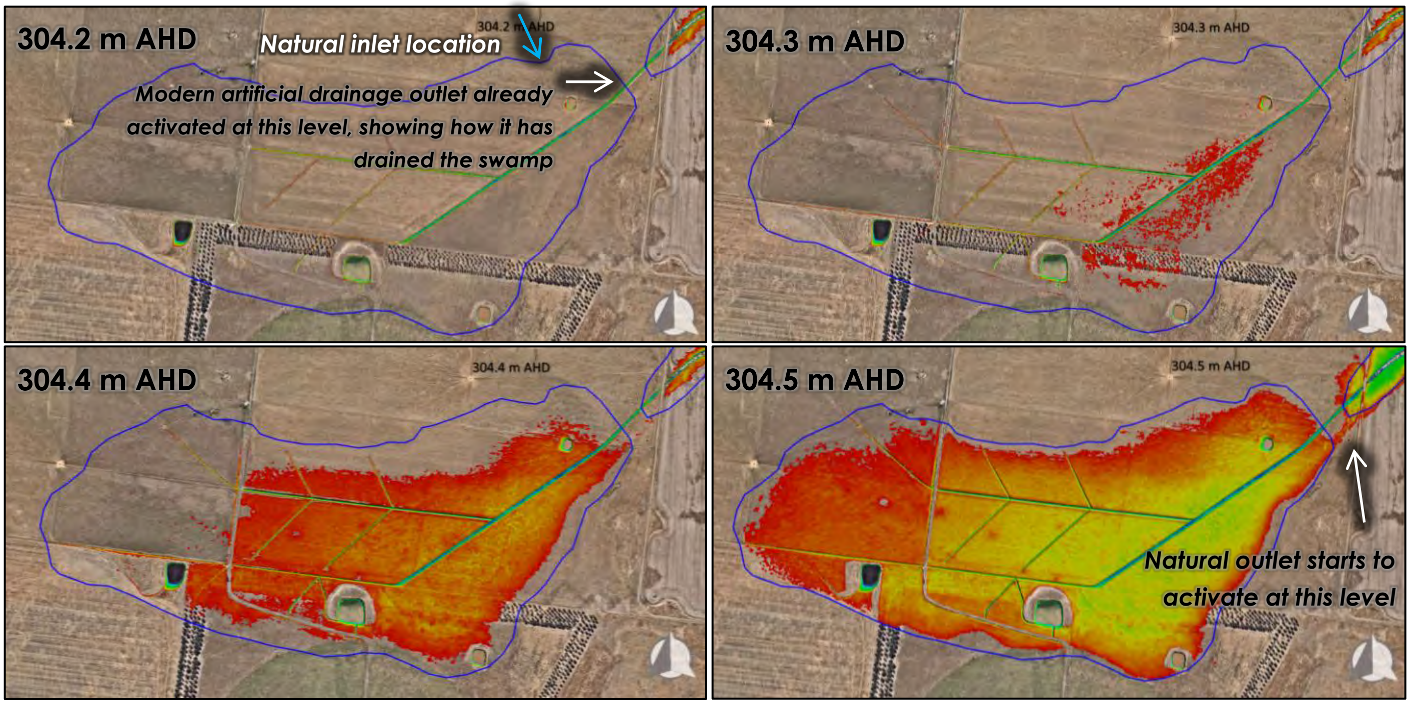
The relationship between inundation depth, volume and area inundated is displayed below. This was calculated on the basis of current conditions, which means that a small amount of the volume and area shown is occupied by drains when the wetland is otherwise empty.

BASE HEIGHT (m AHD)	Volume (ML)	Area (ha)
303.8 (drain depth, 0.4 m below wetland bed level)	0.00	0.00
304.2 (wetland empty, but drains starting to fill)	2.31	1.35
304.25	3.05	1.61
304.3	4.11	3.86
304.35	8.91	15.93
304.4	20.12	27.82
304.45	36.50	38.24
304.5 (approximate cease-to-flow full supply level)	58.09	46.89
304.55 (likely regular surcharge level during flows)	83.04	52.20
304.6 (likely regular surcharge level during flows)	109.89	55.13
304.65 (15 cm surcharge level)	138.15	57.84
304.7 (20 cm surcharge level)	167.69	60.50

The relationship between inundation depth, volume and area inundated at burrung buluk. Rows highlighted green are the six scenarios that are mapped to show inundation extent and depth later in the paper.

Illustrating the area within the wetland subject to, and capable of, inundation highlights the broad range of hydrological conditions that could once again be experienced within *burrung buluk*. While the probability of seasonal inundation in winter/spring is greater, when evaporation rates are lower and runoff potential is higher (followed by complete summer drying), the hydrological regime for this site could also be more complex depending on climatic trends over time.

The sequence of images below shows the modelled filling of *burrung buluk* in 10 cm increments.



Using modern GIS tools and the DEM, we can illustrate how burrung buluk used to fill, noting that the outlet would not activate with flows until the water level reached about 304.5 m AHD, as shown by the connectivity in flows over the outlet illustrated in the final image. Approx. depth guide: red/orange - up to 10 cm; yellow - up to 20cm; light green - up to 30 cm.

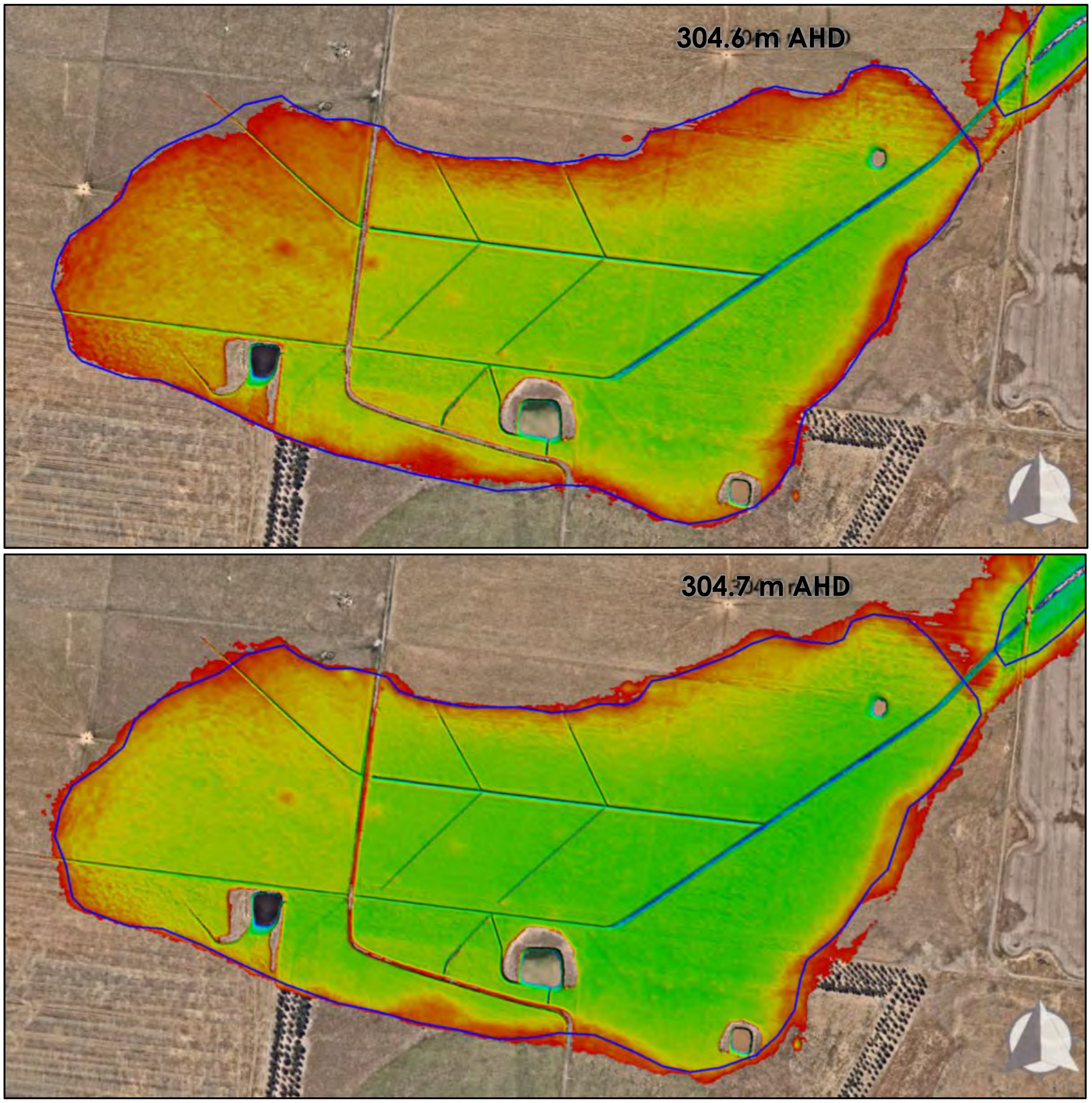
Irrespective of whether the wetland was filled by local runoff from the surrounding landscape, as well as inflows from Strathaird Creek prior to its diversion, it is clear from the physical shape of *burrung buluk* that flows could not be discharged downstream from the wetland until this full supply (sill) level was reached. With this in mind, the relatively close proximity of the inlet and outlet are not relevant because under natural conditions, incoming flows simply could not bypass the wetland basin. Above this sill level, flows would spill through the outlet at natural surface.

Note that although tilling, vegetation clearance, or other farming activities at the natural outlet are likely to have slightly modified (potentially lowered) the surface level at this location, we are fortunate that the artificial drainage network is not directly superimposed over the original outlet. This commonly occurs due to the natural outlet being situated at the lowest point, which can make it difficult to determine the natural full supply level. In this case, the artificial drain is offset to the north-west which removes this potentially confounding factor from our analysis.

In the previous sequence, we can also see how the deeper artificial drains across *burrung buluk* now activate under all of the scenarios shown. These modern drains were clearly constructed and then deepened in an attempt to prevent the wetland from inundating, because both the aerial photographic record and Landsat data (as shown earlier) demonstrate that it continued to inundate regularly for many decades, after the diversion of Strathaird Creek.

Having illustrated what the filling process looks like from empty, it is important to also consider what surcharging of the wetland looks like during high inflows. Wetland basins are naturally capable of temporarily inundating above their cease-to-flow sill level to varying degrees when inflows exceed outflows, or when a downstream constriction causes backwatering.

The images below show two depth scenarios when the wetland is already full but the catchment is generating additional runoff, causing surcharging above the natural cease-to-flow level. This cease-to-flow sill level is the height that the wetland will gradually return to by discharging flows downstream through the natural outlet above that level.



The surcharging of burrung buluk: the top image above would see approximately 10 cm running through the outlet, while the bottom image above would result in approximately 20 cm running through the outlet and generating a wider sheet flow. Approx. depth guide: red/orange - up to 10 cm; yellow - up to 20 cm; light green - up to 30 cm; dark green and blue - over 40 cm.

The first image (above, top) also shows how the 10 cm surcharge level, which also corresponds well with the wetland vegetation present in the historic aerial photography from 1946, was used by NGT to define the edge of the wetland feature, giving a broadly similar extent to the current DELWP wetland layer polygon.

In-stream wetlands (especially large ones) are incredibly important natural equalisation basins for catchment management purposes, attenuating flows during floods, by delaying the time it takes for water to reach the downstream waterway. Despite drainage of, or diversion around, in-stream wetlands being common practice for 150 years, this has the opposite effect and increases downstream flooding risk, by increasing the speed and magnitude of flows passing downstream.

This is a key consideration for Merri Creek, which has well documented flooding risks in various reaches of its catchment.

As the second image (previous page, below image) indicates however, this edge is not fixed in space and time, with additional inundation possible during flood events. While a useful guide, it also does not fully account for the fact that wetland edge plant species with wider tolerances can often be found growing further up the elevation gradient beyond the static high water mark caused by inflows, in response to soil type and conditions, including potential sub-surface moisture, slope saturation or seepage.

It is worth noting that the regularity of inundation, to the extent and depth shown in the surcharging examples or beyond, would have been impacted significantly as a result of the diversion of Strathaird Creek flows away from *burrung buluk*. Despite the wetland remaining somewhat functional on the basis of the aerial photographic evidence, it was still being starved of a major portion of catchment inflows for many decades which would have impacted on its inundation regime, especially the regularity of these larger surcharging events.

Of course, it is worth emphasising that floods are a natural process that we should expect and plan for. Floods have shaped the Australian landscape, and have a key role in driving river, floodplain and wetland health and productivity. Major rainfall events will continue to be a part of the story of *burrung buluk* and hence planning to accommodate future flood events is incredibly important. With the urbanisation of the Wallan area, the physical placement (especially elevation and set-back distance) of built infrastructure from *burrung buluk* is a key consideration that needs to take account of the type of surcharging that occurs in flood events by having an adequate elevation buffer above the cease-to-flow high water mark.

Mapping the extent of October 2022 inundation of *burrung buluk*

The October 2022 inundation event has provided some interesting insights into the hydrological restoration potential of *burrung buluk*. This is because large rainfall events, which temporarily overwhelm artificial drainage channels, provide real-time experimental conditions that can give a glimpse of the type of inundation effect that could be regularly achieved if artificial drainage was reversed. Put another way, if artificial drains were backfilled, the natural sill level reinstated, and creek inflows restored, then water would immediately re-inundate this footprint every time the catchment produces even relatively modest flows. In the case of *burrung buluk*, modest catchment flows are a regular seasonal occurrence in most years.

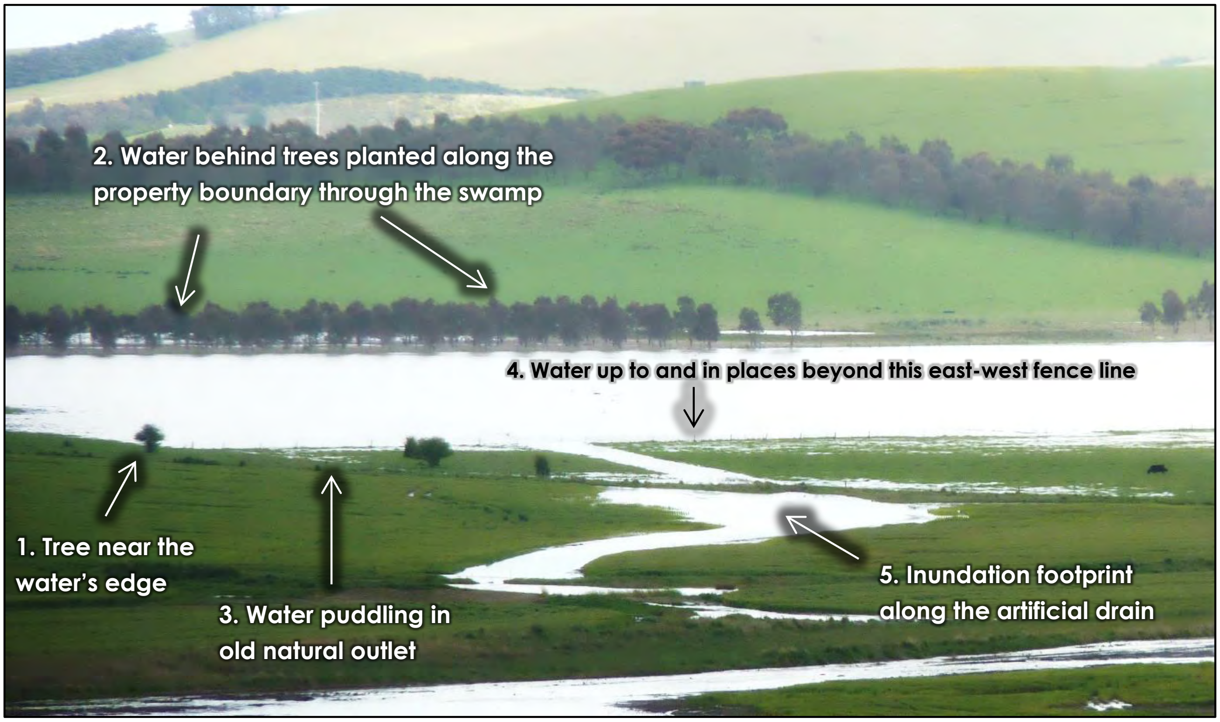
So just how close did the most recent episodic rainfall event get to demonstrate what a restored water level in *burrung buluk* would look like?

It is unlikely that any aerial or satellite imagery was captured at the peak of this event, because it only lasted for a brief time, as a result of the comprehensive artificial drainage network now in place across the wetland quickly carrying the water away. However, we are able to take the ground-based imagery that was captured and triangulate this with other data sources to estimate and map the extent and depth of inundation present in the morning of the 14th October 2022.

Firstly, in the close-up image below, you can see five key things which are marked:

1. The water's edge is not far below the tree marked in the left of the image.
2. Water is clearly present in the southern part of the swamp, beyond the property boundary planted to trees.
3. Water is puddling in the old natural outlet.

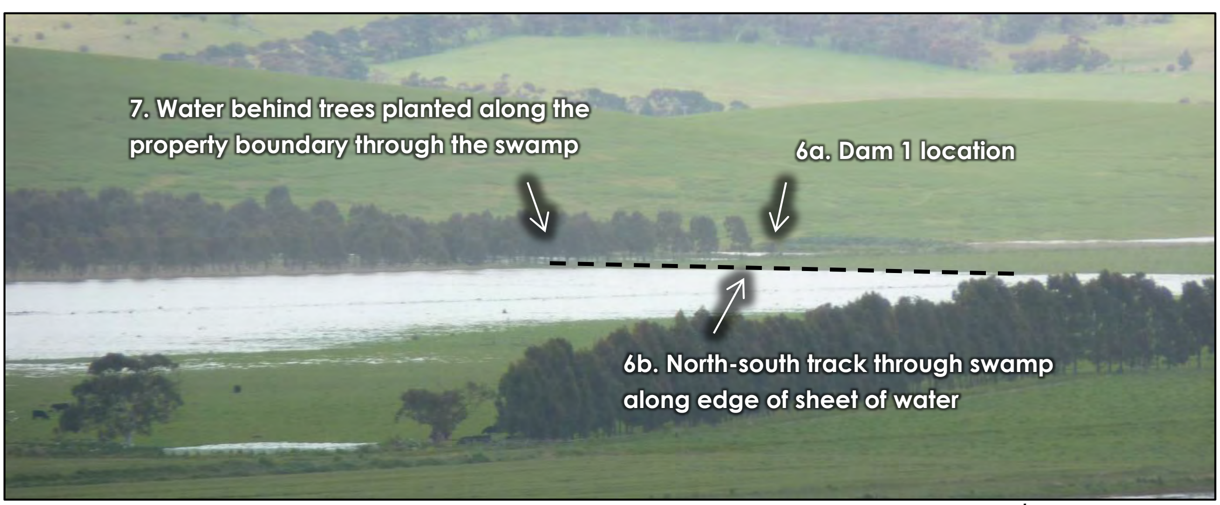
4. The artificial drain is backing up with water near another tree on the fence line, adjacent to the artificial drain.
5. The inundation footprint along the artificial drain shows this channel is breaking its banks.



Close up of central portion of burrung buluk (Hanna Swamp) taken from Green Hill on the 14th October 2022. Photo: Rob Eldridge.

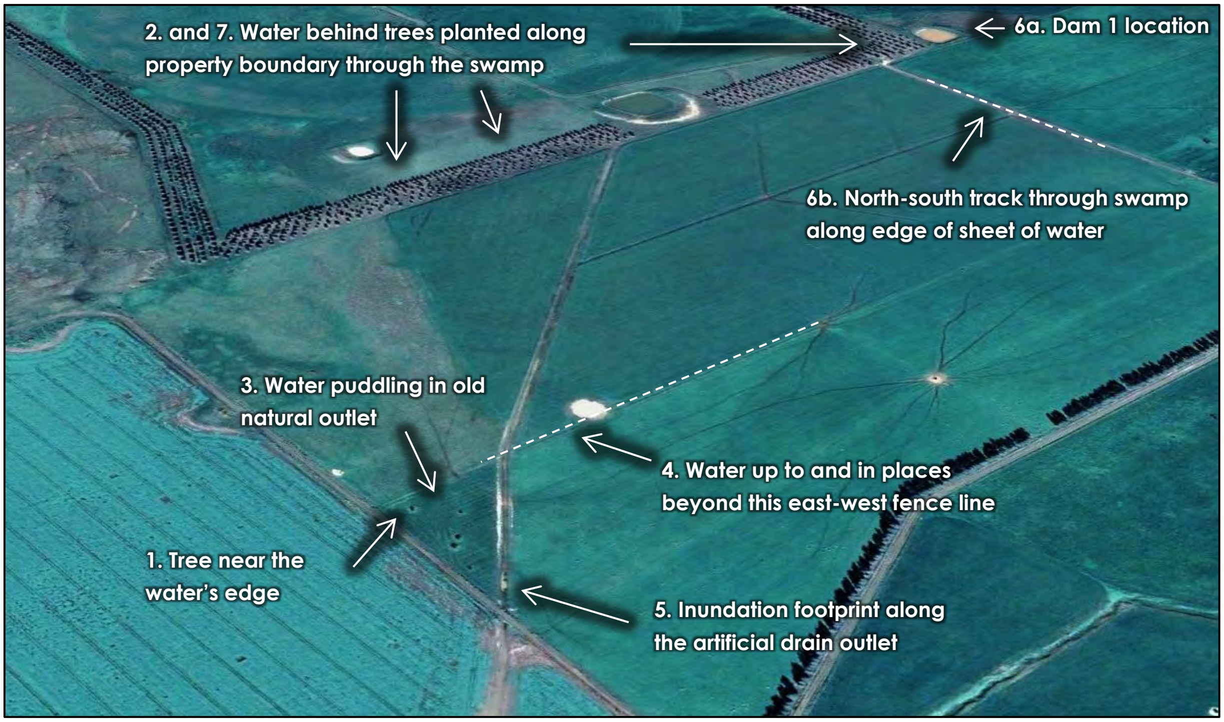
Secondly, in the additional close-up image below, you can see two further items of interest:

6. Water in the northern part of the swamp is not in a continuous sheet with the dam marked (a), nor does it appear to extend to the western side of the north-south track through the swamp (b).
7. Water in the southern part of the swamp continues further west behind the tree line towards the dam.



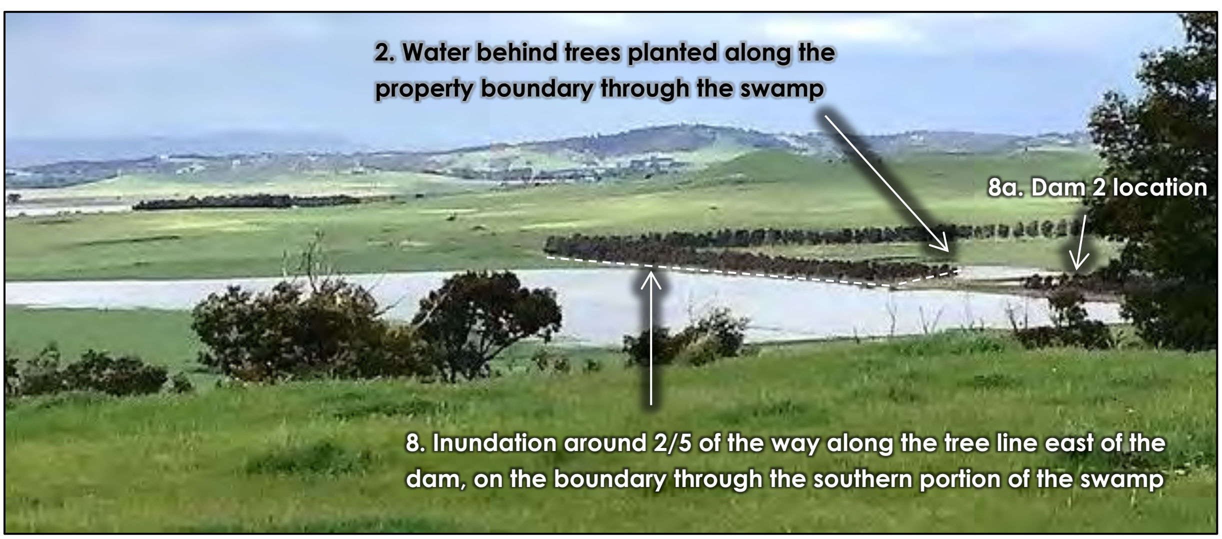
Close up of western end of burrung buluk (Hanna Swamp) taken from Green Hill on the 14th October 2022. Photo: Rob Eldridge.

Now we can take these features and identify them in in the aerial imagery. First we will locate them in an oblique image – to ensure we have correctly positioned these features based on the angle and perspective from Green Hill.



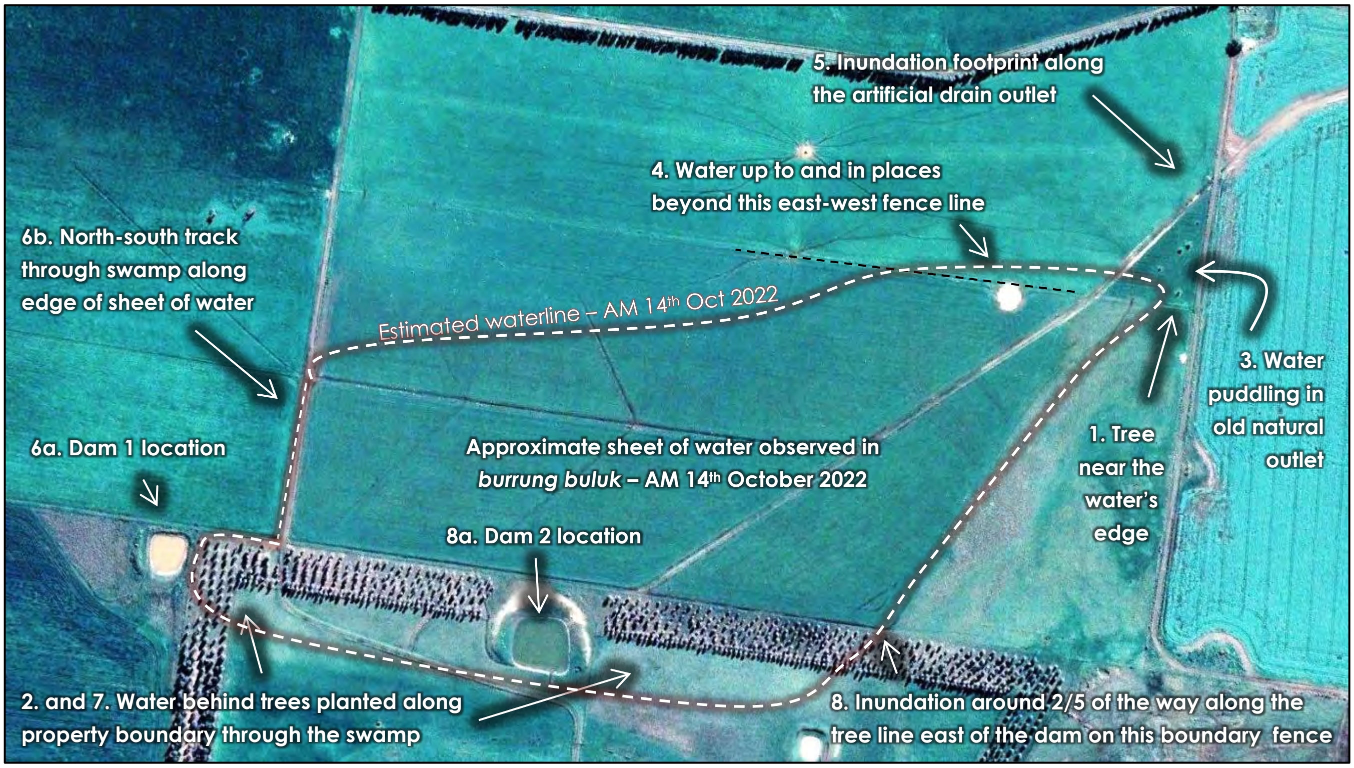
Oblique Google Earth aerial image of *burrung buluk (Hanna Swamp) to pick up features identified in the 14th October 2022 inundation photos. Image looking south-west over burrung buluk from Green Hill.*

We also have access to a further photo of the same inundation event, also taken on the morning of the 14th October from a different angle, as shown below. In conjunction with the previous perspective, this can be used to identify additional landscape features and calibrate their position relative to the water extent at that time.



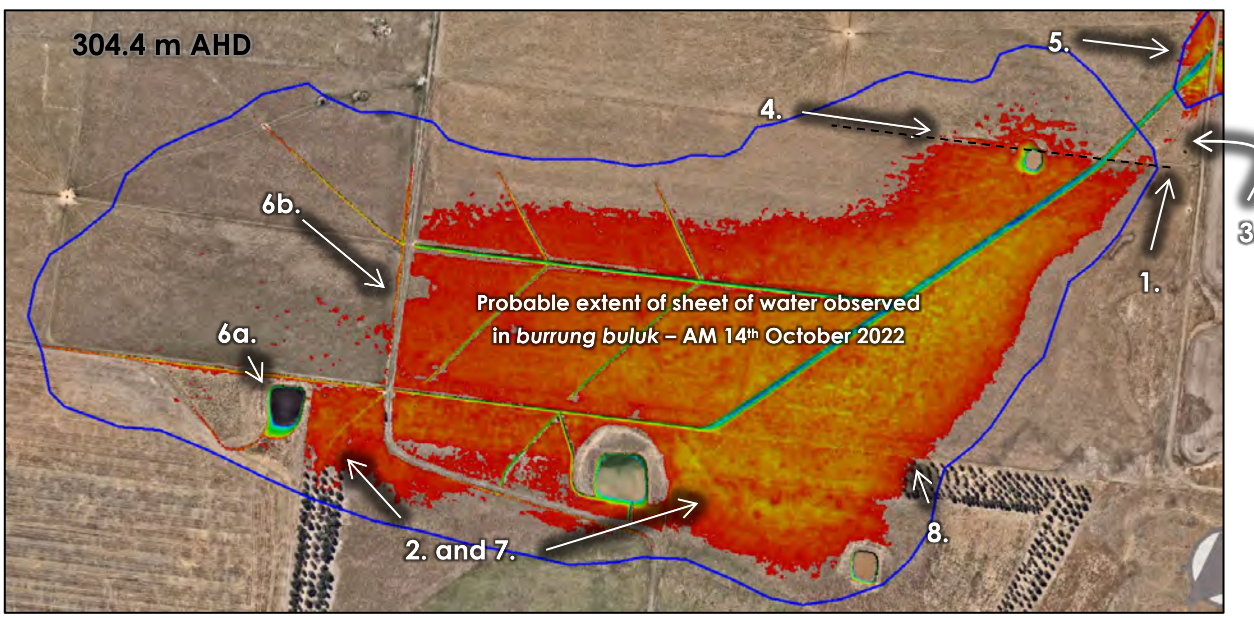
The view of burrung buluk (Hanna Swamp) looking south-east across the wetland towards Spring Hill from Old Sydney Road on the 14th October 2022. Photo: Claudia James.

Next we can identify all of these same features on a standard aerial image from above, which allows us to mark up an estimated waterline.



Standard Google Earth aerial image of burrung buluk (Hanna Swamp) with features identified in the 14th October 2022 inundation photos marked up.

Finally, we can now compare this spatial information with the Digital Elevation Model inundation scenarios, locate the various markers in the previous images, and combine and compare them, to more accurately determine the inundation footprint on the morning of the 14th October 2022.



The approximate temporary inundation extent within burrung buluk (shaded orange / red) caused by heavy rainfall in mid-October 2022, which has been determined by cross referencing the images taken in the morning of 14th October 2022 with features on the ground that are also identifiable in the aerial imagery.

This analysis shows that despite being artificially drained for decades, and Strathaird Creek flows diverted long ago, *burrung buluk* reached a water level of approximately 304.4 m AHD and was inundated to within 10 cm of its natural sill (304.5 m AHD) in the morning of 14th October 2022.

If we revisit a subset of the technical information presented earlier in this paper looking at the depth / volume / area relationship for *burrung buluk* (refer to key elements presented in the table below), we can see that at this depth, the wetland was temporarily holding approximately 20 ML (mega-litres / million litres) of water, covering an area of about 27 hectares. However, closer analysis reveals that if *burrung buluk* one day had its hydrological regime restored by reinstating its natural sill (cease-to-flow level), then the possible role of the wetland basin in attenuating flows and buffering downstream areas against flood risk, is greatly enhanced above this level.

BASE HEIGHT (m AHD)	Volume (ML)	Extra volume (and as a %) above 304.5 natural sill level	Area (ha)	Extra area required (and as a %) over 304.5 natural sill level	Notes
304.4	20.12		27.82		Approx. level observed on the 14th October 2022
304.5	58.09		46.89		Approx. natural cease-to-flow level prior to artificial drainage
304.6	109.89	**51.8 ML (89% increase)**	55.13	**8.2 ha (18% increase)**	When surcharging by 10cm, storage almost doubles from full level, but inundation footprint only increases by 18%.
304.7	167.69	**109.6 ML (189% increase)**	60.50	**13.61 ha (29% increase)**	When surcharging by 20cm, storage almost triples from full level, but inundation footprint only increases by 29%.

Analysis relevant to the relationship between inundation depth, volume and area at burrung buluk.

This is an important topic to consider carefully, because if *burrung buluk* had this natural sill level one day restored then based on seasonal conditions it would likely have already been inundated with water, either at or near its full supply level (304.5 m AHD = approximately 58 ML of storage, covering 46 hectares), when the heavy rainfall occurred in mid-October.

However, it is actually above that cease-to-flow level that the capacity for the wetland to temporarily hold even more water is realised. Crucially, in addition to this and of particular note, only a relatively modest additional area of land is required to achieve that strategic outcome. In this way, *burrung buluk* could be managed to (a) host and sustain ecological values (across the basin within the inundation footprint of the natural sill) made possible by inundation being retained in the wetland after flows, but also (b) be available to temporarily attenuate major flows (behaving in a similar way to a retarding basin) for catchment management purposes when levels surge above the natural sill.

For example, the first 10 cm of temporary storage above the cease-to-flow level almost doubles the volume of the wetland (an 89% increase), but only requires 18% extra land area to accommodate this increase in volume. Likewise, an additional 20 cm increase almost triples the volume of the wetland, but only increases its footprint area by 29%. Offering an extra 52 ML and 110 ML of storage respectively (above natural full supply level), these two scenarios produce figures that greatly exceed the approximately 20 ML of floodwater that was being temporarily attenuated within *burrung buluk* on the morning of 14th October 2022.

Finally, it is important to note that these flows above the natural sill level would not be permanently retained in the wetland, because it would gradually drain freely back down to this restored natural sill. However in flood events, having the capacity to attenuate flows in this manner in real time within a catchment can make a critical difference to the timing and duration of downstream flooding risk, which is known to be a major issue in the upper Merri Creek catchment. This risk is only likely to be exacerbated via the urbanisation of this catchment.

Historic water availability

From the extensive material provided in this discussion paper, it is clear that, despite the diversion of Strathaird Creek over 100 years ago, and partial drainage circa 1973, *burrung buluk* continued to receive sufficient water from a reduced local catchment for it to remain a semi-functional wetland, over the bulk of its original footprint, for most of the past 200 years.

This is supported by the fact that:

– Firstly, water remained in the wetland long enough to be detectible from space (Landsat data), across the bulk of the wetland in 1989, 1992, 1996 and 2000, which shows that this wetland was semi-functional across the entire basin until it was more comprehensively drained circa 2004.

– Secondly, if it were not still regularly experiencing waterlogging or inundating, then there would have been no need for the property owner/manager to invest in the installation of a more comprehensive artificial drainage network approximately 20 years ago, circa 2004, to facilitate more intensive agricultural use of the land.

  The fact that the wetland avoided comprehensive drainage until this time can be explained by the fact that many farmers who primarily used their land for grazing, would often value shallow grassy wetlands, which would provide green 'pick' (of later seasonal plant growth) for livestock to utilise into the summer months, when adjacent higher ground was usually dry and less productive.

  Over recent decades, we have since witnessed a trend of the conversion of vast areas of agricultural land that was previously used for grazing, to more intensive land uses like cropping (or sowing of improved pastures) across southern Victoria[17]. Impacts on shallow wetlands in the landscape have intensified as a result of this immense scale of land-use change[18].

– Thirdly, there is residual native flora still found in parts of *burrung buluk* which has been sustained for more than 100 years since the diversion of Strathaird Creek, and remains even now, despite the partial drainage of *burrung buluk* approximately 50 years ago and comprehensive drainage less than 20 years ago.

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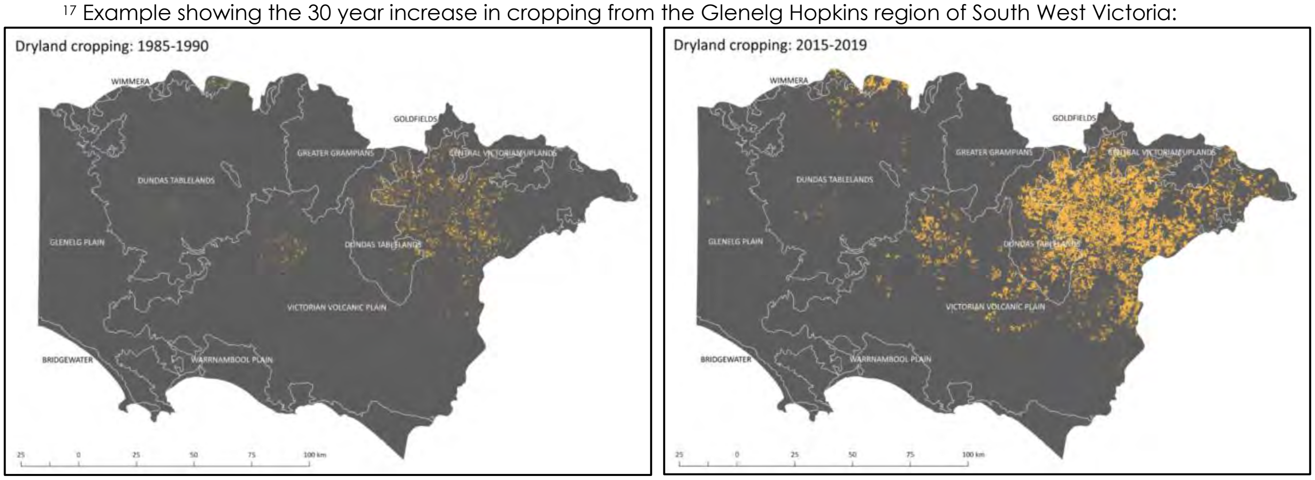
17 Example showing the 30 year increase in cropping from the Glenelg Hopkins region of South West Victoria:



18 Casanova M.T. and Casanova A.J. (2016) Current and Future Risks of Cropping Wetlands in Victoria: Technical Report. Department of Environment, Land, Water and Planning, East Melbourne.

Future water availability is dependent upon the ecological and water management philosophy adopted for *burrung buluk*

If the artificial drainage of *burrung buluk* were reversed and the wetland retained as part of a plan to integrate the wetland feature into the future urban structure, then water availability is unlikely to be a limiting factor.

This is because in addition to having the option of reinstating Strathaird Creek flows back to *burrung buluk* for the first time in over 100 years, the newly urbanised catchment with vast areas of hard surfaces would produce an additional volume of runoff that is not currently available from the rural catchment (noting that rural areas infiltrate (via soil) and evapo-transpire (via vegetation) more water than urbanised catchment areas).

Dry phases for the wetland will still happen, but be more consistent with natural drying phases (indeed no worse than the current, very long, drainage-induced, artificial ‘drought’) and they are unlikely to persist for extended periods.

Indeed, the question for waterway managers is more likely to be how to direct, treat and manage those additional flows if the optimisation of seasonal grassy and herbaceous wetland flora in *burrung buluk* is the goal. This is because a regular seasonal drying phase is critical for maintaining the optimum conditions for seasonal herbaceous wetland flora and high wetland productivity. Melbourne Water has expressed concern about the over-watering (i.e. an increase in inundation frequency) of ecological assets connected to urban runoff. Further, the prior treatment of urban runoff to remove excess nutrients is also an important consideration <u>if</u> the goals for *burrung buluk* are primarily ecological and/or flora based.

Such questions were raised in a report on *burrung buluk* prepared by consulting firm Alluvium[19]; however, in that work it appears that the potential ecological and hydrological goals for the wetland have been viewed primarily from the perspective of attempting to sustain residual wetland flora, precisely where it was found in the southern portion of the wetland, based on a once-off survey, in a wet spring in 2020. This perspective does not fully account for the long period of hydrological modification which is still dramatically impacting the water regime of the entire wetland feature, and is responsible for driving and determining current wetland flora distribution. Where this flora grows today is the expression of a modern, modified water regime that is the by-product of 150 years of change.

As a result, we run the risk of missing the wider view about the trajectory of hydrological change experienced by the site and the opportunity to undertake the remedial action capable of correcting those major changes first, across the entire wetland feature. If completed in this order, then the ecological values across the entire wetland would respond, adjust, shift and recover over time.

The value in reinstating the natural footprint of *burrung buluk*

Any option for *burrung buluk* which would see the entire wetland feature given the opportunity to be hydrologically reinstated is most consistent with state policy on waterways and wetlands[20].

[19] Alluvium (2021) ‘Hanna Swamp Investigation Report’ 0120263 by Alluvium Consulting Australia for the Victorian Planning Authority.
[20] See: NGT Discussion Paper 2: Achieving Integrated Water Management of the wallan wallan Wetlands – Recognising gaps, understanding systemic obstacles to adoption, and identifying solutions. July 2020

It would both buffer and provide the opportunity for the expansion of residual flora that has persisted across the wetland, including the southern section that currently retains higher observable values in a wetter year, and provide for the future reconnection of the wetland with Strathaird Creek, underpinning recovery of wetland plant diversity through natural seed dispersal mechanisms. That expansion of native wetland flora would be driven by the drowning of introduced terrestrial flora species, making space available for the natural increase of natives, to find their preferred location in the elevation gradient across the basin. It is worth remembering that – as with the example from Scale Swamp – after the first few months of sustained re-inundation, *burrung buluk* would be immediately and completely transformed in character from its current appearance.

This natural wetland regeneration response can be expected to be more simplistic in terms of diversity in the first instance across the most disturbed parts of the wetland, as the more robust and hardy native wetland species initially take advantage of the change in conditions from any residual seedbank. Over time however, the likelihood of floristic diversity increasing across the wetland will slowly increase, especially given its significant size (60 hectares) and potential reconnection to a waterway, as well as the variable micro-topography available for plants to establish at different elevations within it. We also know from recent surveys that while greater residual diversity appears to exist in the southern part of the wetland basin, both the published literature, and our own restoration experience, indicate that wetland plants are capable of moving over time within a functioning wetland.

Is it reasonable to expect or require rapid achievement of a fixed, idealised state?

Further, if *burrung buluk* is set aside as a community asset, then there is no urgency for it to reach, in quick time, some pre-determined, idealised ecological state from its current condition.

It is worth noting that an average member of the community who does not specialise in botany will not be able to tell the difference between a simplified, remediated and recovering wetland, and something more notionally 'pristine' that meets a pre-defined, narrow legal definition. Both are aesthetically pleasing and both can provide important ecological, hydrological and catchment management functions, irrespective of their initial floristic species diversity. With time and more regular and extensive inundation, coupled with any active complementary revegetation, it can be anticipated that more conventional zonation of wetland vegetation across and around the wetland will evolve. The birds, fish and frogs will return, and the open space and urban cooling effect will be available for all future residents to enjoy. This topic is revisited in the final summary.

The rehabilitation of the site could conceivably remain a slow and gradual work in process, supported by local community groups, noting that hydrologically restored natural wetlands tend to gradually improve over time, as long as the water regime is maintained and not compromised.

If it is deemed necessary to accelerate the process, species enrichment planting could also be used to increase native species richness. For some species this will be desirable as they have become so rare in the landscape that the possibility of them naturally recolonising is low. There are established precedents for where this technique has been used to great effect (e.g. Brolga Swamp at Wirralo Wetlands[21]).

As described in detail throughout this discussion paper, wetland ecology responds to and is primarily driven by hydrology, which in seasonal wetlands is variable. Hence determining the

[21] Damien Cook, Wetland Revival Trust, pers. comm. June 2022.

parameters for a future hydrological regime for *burrung buluk* is the key to paving the way for its future ecological state (or, more accurately, range of states) – not the other way around. In natural wetlands, ecology follows hydrology.

Is it also worth noting that static and permanently full wetlands – which are more typical of constructed urban wetlands – are generally of lower productivity and support relatively simple food webs in comparison with seasonal wetlands.

If one is not fixated on rapidly reaching some idealised ecological state, but rather letting natural wetland processes dictate the recovery process – led by the rapid return of wetland fauna and the spontaneous regeneration of wetland plants – then this process is not as complex or expensive as it is often assumed to be. Under this model of wetland rehabilitation, the key is to physically remediate the site and get the preferred hydrological regime back in place.

An alternative vision for *burrung buluk* as an IWM asset

With this in mind, if the goal for a reinstated *burrung buluk* was to fully integrate the feature into the future urban structure as a large, shallow, natural feature capable of retaining, conveying, infiltrating and attenuating catchment and stormwater runoff, then a wider range of Integrated Water Management (IWM) outcomes are possible. Accepting that the wetland (despite retaining some residual biodiversity value) is highly modified and currently in no way representative of a pristine ecological or hydrological state, opens up the more interesting possibility of the wetland being restored in such a way that delivers the widest range of potential benefits, including to favour the recovery and expansion of the residual seasonal herbaceous wetland flora present at the site, but maybe with that not being the only, or indeed primary, objective.

Such an approach would make the site a unique and much needed case study for the integration of a previously drained wetland feature into an urban development around Melbourne. Natural wetlands in the urban growth zone are typically either (a) protected for having remnant values that subsequently cannot be modified, which complicates water management options by usually excluding them from being used as an urban stormwater compatible catchment management feature, or (b) deemed not to have sufficient value (at the time of assessment) to justify retention, according to a very narrow set of biodiversity triggers, and are then infilled and permanently destroyed. This binary choice which often emerges from the standard planning process risks parts, indeed all, of *burrung buluk*. But there are alternatives that it seems are currently being overlooked.

What if *burrung buluk* offers the possibility of a more nuanced approach that would explore the middle ground options between these two extremes, where other water management objectives are given equal or greater priority? What if those options subsequently improve the broader planning justification for retention of the whole wetland feature, due to the wider range of services and benefits it might provide?

In doing so, such options would help the Victorian Government better achieve its stated objectives in the Healthy Waterways Strategy and for Integrated Water Management, by meeting the wide range of local and state planning policies that point to this very type of integrated solution. This extensive policy material, which supports the restoration of historic floodplains and in-stream wetlands, is not reproduced here, but can be viewed within the second NGT Discussion Paper written in 2020[22].

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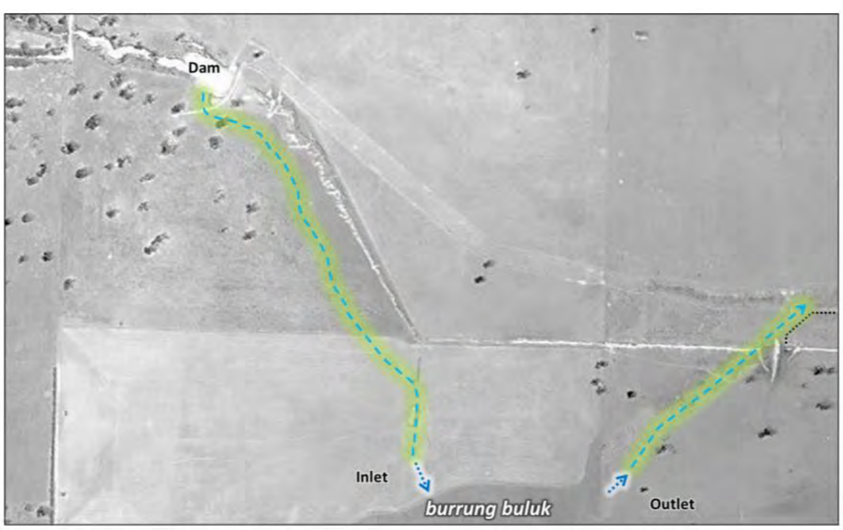
[22] See: NGT Discussion Paper 2: Achieving Integrated Water Management of the wallan wallan Wetlands – Recognising gaps, understanding systemic obstacles to adoption, and identifying solutions. July 2020.

Works required to remediate *burrung buluk*

A method of works capable of re-instating a connection to *burrung buluk* from Strathaird Creek is not just a theoretical possibility; indeed it has been demonstrated previously at the site during the soil conservation works era, as shown earlier in the 1968 image. This is when a check dam was constructed across the deeply eroded channel, lifting the water behind the dam to a sufficient elevation to enable those flows to then be conveyed once again over the natural surface, along the alternative northern bunded drainage alignment. This was all achieved using clever site selection, engineering and gravity, as highlighted below. It is clear from the imagery that the people who undertook those original works were careful not to excavate or expose the dispersive subsoils, as they were aware of the risks of soil disturbance, including the erosion problems caused by the original diversion drain (which, after all, were the reason for their works).

The second diversion of Strathaird Creek utilised a check dam and bunded channel at natural surface.

To facilitate a reinstated southerly flow path above natural surface from Strathaird Creek to *burrung buluk*, it would now need to be determined if that existing upstream diversion point can be modified and used, as illustrated below, or if an alternative location and design is required. Considering that major civil drainage works are typically undertaken as part of suburban development and noting that this particular method was successfully adopted more than 50 years ago in this same location, the feasibility of these works is self-evident.

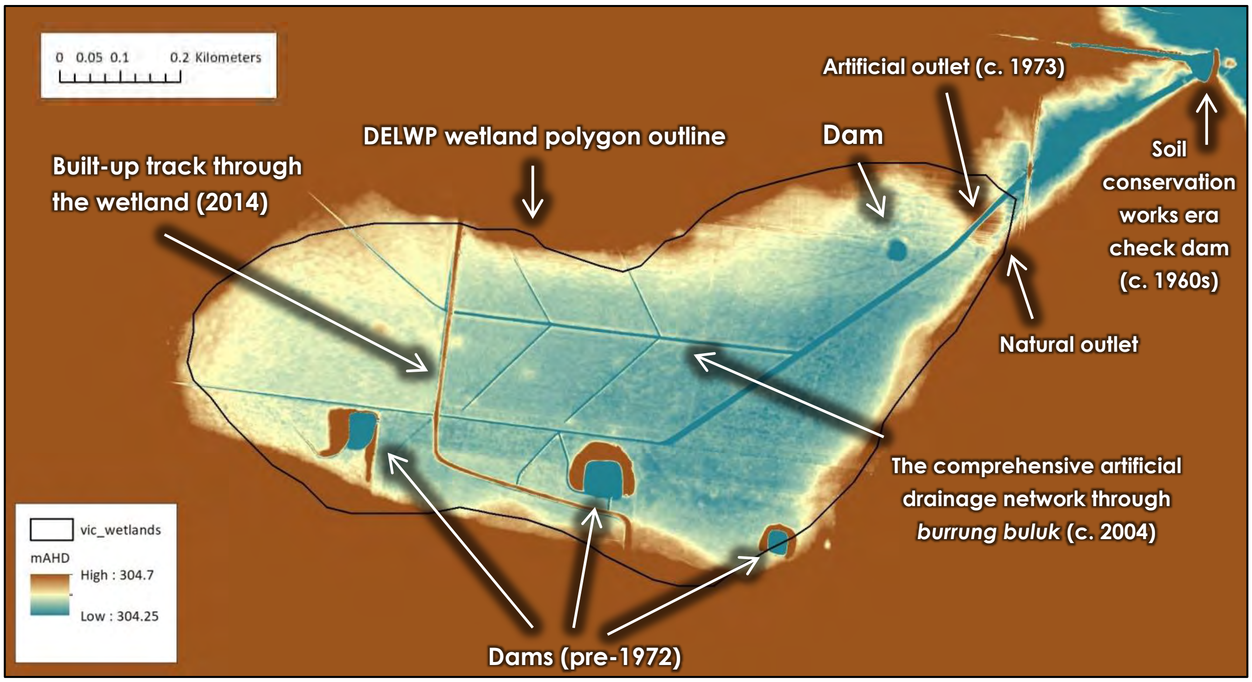


Reconnection of Strathaird Creek to burrung buluk could utilise similar methods via an alternative alignment.

In contrast, the physical works required to remediate *burrung buluk* are very straightforward. A best-practice outcome in the wetland itself simply involves putting things back the way they were, anywhere that the natural surface of the wetland has been interfered with. This is the first and most critical stage in a series of remedial steps.

Initial works are best undertaken in autumn, or when the site is at its driest, and would include:

- Using the existing spoil material still on site from dam and drain construction, to completely backfill the dams and network of drains.
- Removing any road base material through the wetland and levelling that ground.
- Backfilling the artificial outlet drain to natural surface, which would permit the natural outlet to reactivate in future and once again set the restored full supply sill level for the wetland. If the natural outlet is already stabilised with vegetation cover, as this location need not be modified, then it should not present an erosion risk.



Recent DEM showing the comprehensive artificial drainage of burrung buluk in c. 2004 and other features evident in the elevation data.

A recent example in autumn 2022 of NGT supervised bulk earthworks (drain backfilling) to remediate a modified wetland.

Measuring success

In terms of the trajectory of physical and ecological recovery that can be expected from wetland restoration projects at sites like *burrung buluk* and the earlier examples provided at Scale Swamp and Walker Swamp, Moreno-Mateos et al. (2012)[23], in their international review of data from 124 wetland restoration studies, found that typically:

- Physical features (topography, soil permeability, surface and ground water flows) recovered immediately.
- The abundance and composition of wetland vertebrate species (e.g. birds, frogs, turtles, etc.) recovered to reference levels usually within five years.
- Large aquatic invertebrates took five to 10 years to approach (but not meet) reference levels.
- Plant assemblages took on average 30 years to converge on reference states.
- It took 50 to 100 years for wetlands to recover normal nutrient cycling.
- The rate of recovery varied positively with size, climate and hydrological connectivity with other sites. That is, the bigger the wetland, the better it performed.
- Most systems tended to recover rather than be locked in an alternate degraded state.

The authors of this study were at pains to point out that these recovery time-lags mean that restoring wetlands should not be used to directly offset the destruction of pristine sites. However, as a standalone activity, the payback periods are not daunting, if we consider that remedial action at a site would lead to a restored *burrung buluk* becoming part of the urban layout and being protected in perpetuity.

One day, in the very near future, choosing to act now would in hindsight look like a very wise investment.

Setting a future hydrological regime for the restoration of *burrung buluk*

The information presented in this discussion paper outlines how:

- Firstly, prior to the diversion of Strathaird Creek, *burrung buluk* originally experienced more dynamic and variable hydrology, and likely filled, surcharged and overflowed more regularly, with greater catchment flows passing through the wetland.
- Then, after the diversion of Strathaird Creek, *burrung buluk* was starved of those peak flows but continued to inundate and pass flows from its adjacent local catchment, retaining wetland values.
- Finally, after partial drainage 50 years ago, approximately 20 years ago *burrung buluk* was comprehensively drained, no longer functioning as a single hydrological unit, with only residual environmental values persisting in parts of the wetland basin.

While this degree of change is substantial, we have also described how wetland ecology will rapidly adjust to a new hydrological regime, whatever that regime is, and whether the change is driving a positive or negative trend.

After 150 years of a trajectory of change which has seen the wetland experience a drying trend of reduced frequency of flows and inundation, increased terrestrialisation and depletion of biodiversity values, there is now the fresh prospect to reset the hydrological regime and trigger a reversal of that trend.

[23] Moreno-Mateos D, Power ME, Comı´n FA, Yockteng R (2012) Structural and Functional Loss in Restored Wetland Ecosystems. PLoS Biol 10(1): e1001247. doi:10.1371/journal.pbio.1001247

If the wetland is treated as single basin and management unit from a hydrological perspective, then there are different ingredients that can be set to determine both the future catchment function and ecological response of the site.

Those ingredients are:

(1) **How much water (depth / volume) is retained in *burrung buluk*** to allow it to become a functional natural wetland basin again, i.e.:

(a) The **cease-to-flow sill level** that is set, which requires the backfilling of the drains across the wetland and lifting the current artificial outlet to a new outflow level.

For example, this could be set to match the estimated natural full-supply level, and provide for additional temporary storage (behaving as an equalisation / retention basin during peak flows) above that level, or indeed other slightly different options. Whatever the adopted design, it is preferable from a wetland ecology and function perspective that the wetland outlet sill level is not designed to be manipulated (i.e. the basin is allowed to fill and spill, and then dry down), which would allow for the wetting and drying cycle to behave as naturally as possible, despite the modified catchment that will surround the site.

(2) **How much water is directed into *burrung buluk***, i.e.:

(a) Whether the wetland is **reconnected to Strathaird Creek**, becoming an in-stream feature once again.

In much the same way that we have described how Strathaird Creek was dammed and diverted to the north along a new overland bunded flow path circa 1960s, an alternative design with a similar function directed south could readily re-engage something approximating the function of the original flow path. By restoring a surface sheet flow, the original shallow waterway character is replicated and erosion risk is avoided (by not exposing dispersive subsoils through channelisation below natural surface).

and/or

(b) Whether the wetland is **designed to receive all or some of the adjacent urban stormwater runoff**, generated by the newly urbanised catchment surrounding the site.

The potential role of this wetland in the urban environment, as a catchment asset for treating flows is a subject for Melbourne Water to assess in more detail, should this concept be seriously considered.

In general, larger shallow, vegetated wetlands like *burrung buluk* have better prospects for improving water quality as a result of the increased surface area and plant biomass available for treatment. Under this scenario, consideration would be required for the pre-treatment of flows entering the wetland, including rubbish and sediment traps, especially during the high-risk construction phase.

Subject to landholder consent, a hydrological restoration trial for *burrung buluk* is feasible and would be inexpensive to implement

These considerations are not fixed, and some can even be tested. For example, scenarios for testing the restoration potential of the wetland via retaining water within *burrung buluk*, based on present catchment conditions could be completed **at any time** – well ahead of urbanisation – subject to the consent of the two landholders who currently own the site.

This could be achieved as cheaply and simply as temporarily regulating the main drain at the artificial outlet from the swamp, to allow for the drains to spill outside their banks each winter and for the wetland surface to be re-inundated. The level could be readily adjusted to test different scenarios up the natural former full-supply level. NGT undertakes this type of work on a regular basis, to test assumptions and build the confidence of landholders, land managers and other partners in the outcomes that are possible. Such works are inexpensive, can be manipulated in real time and are fully reversible.

PART 6: Conclusion

From the material provided in this discussion paper, it should be clear that although *burrung buluk* is a highly modified wetland feature, this former natural in-stream wetland provides an incredibly valuable and rare opportunity for cross-boundary PSP planning to achieve strategic and lasting catchment, community and environmental benefits.

In summary, there are a number of key issues worth contemplating:

- Wetlands like *burrung* buluk, despite being highly modified and degraded, can be hydrologically restored and set on a long-term trajectory of natural environmental recovery (according to several meaningful bio-physical measures). The process can be accelerated through additional investment.
- Determining the future water regime for *burrung buluk*, informed by its history of change, physical form and potential water sources, is the first and most important consideration on its path to some form of rehabilitation or recovery. Residual biodiversity values are an input item of data, but may not be reliable indicators for defining a prescription for management for the whole wetland basin given its currently degraded hydrological state (noting that wetland ecological values simply respond to the hydrological regime).
- Strathaird Creek flows to *burrung buluk* can clearly be reinstated, as similar surface flow diversions were successfully completed circa 1960s, despite the modified waterway's severely eroded state at the time.

- As a wetland basin, *burrung buluk* can be readily and inexpensively remediated, via the reversal of changes to drainage and the bathymetry of the wetland. Such works are routinely undertaken by NGT, and a trial could even be initiated to test assumptions ahead of urbanisation.

- Natural spontaneous regeneration of native wetland vegetation would occur within *burrung buluk*, should the above actions be completed. Irrespective of the precise initial composition and diversity of that vegetation, valuable wetland habitat would be recreated, even if it does not rapidly match the assumed reference state for the site. A wide range of other important environmental values will also return, some quickly and some gradually. With appropriate management, all values will improve over time.

- Discussion about, and at times a preoccupation with, a single wetland community definition (e.g. Seasonal Herbaceous Wetlands), is often not strategic and distracts from a collective obligation to also consider a much wider range of issues and values under the policy context for wetlands and waterways within the local and state planning framework. (Note that these planning obligations under state legislation include things like: flood mitigation/buffering, water quality, infiltration, liveability, urban cooling, meeting Traditional Owner aspirations, IWM, open space and recreation).

In terms of the size, shape and location of *burrung buluk*, it is worth noting that this is an existing, natural landscape feature, not a drainage scheme asset which needs to be designed and constructed. In this location, urban development is now inevitable; meaning its present degraded state and current use of the land for farming need not dictate or define its future. This is a rare opportunity to fix a legacy detrimental impact of the agricultural era on an important waterway feature, as part of the urban development process. By engaging a natural feature at natural surface and integrating it into future urban waterway infrastructure, it is also a rare opportunity to avoid major soil disturbance (for at least this part of the urban development), concurrently reducing a demonstrated, high risk of mobilising dispersive sodic subsoils in this catchment.

If we collectively get this right, then a wetland feature that for millennia formed a part of the traditional cultural landscape of the Wurundjeri Woi Wurrung people, could be once again be reinstated as an in-stream wetland, managed and preserved in perpetuity.

In doing so, and beyond its practical purpose for water management, *burrung buluk* would also provide an inspiring area of open space – a natural centrepiece with its own unique story of renewal, a place for reconciliation, contemplation and environmental education for all members of the future Wallan community.