Assessment of historical and current vegetation diversity and condition within Big Swamp

Barwon Water

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Template 2.8.1

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Introduction

Recent technical work and modelling confirmed that Barwon Water's pumping from the Barwon Downs borefield over the past 30 years is the main cause of a reduction in baseflow in the lower reach of Boundary Creek, increasing the frequency and duration of no flow periods. This has been a major factor causing Big Swamp to dry out, resulting in the oxidation of naturally occurring acid sulfate soils in the swamp, and release of acidic water downstream of the swamp.

In response to the environmental degradation, Barwon Water was issued with a section 78 Ministerial Notice in September 2018, to legally enforce the development and implementation of a remediation plan for Boundary Creek, Big Swamp and surrounding environments impacted by past groundwater extraction.

Eco Logical Australia (ELA) has been engaged by Barwon Water to undertake an ecological assessment of Big Swamp and provide commentary on how changing the wetting/drying regime in the swamp (from seasonal drying to permanently wet) will impact upon the existing vegetation diversity and condition.

The primary goal of the assessment is to inform the preparation of the remediation plan in accordance with the ministerial notice issued pursuant to Section 78 of the Water Act 1989. The objectives of this study are therefore:

1. establish the baseline ecological characteristics for Big Swamp.
2. determine the hydrological requirements of past and current vegetation communities and advise likely responses to future surface and groundwater regimes.
3. provide recommendations to improve ecological outcomes within the swamp, within the context of the broader objectives of the remediation plan.

The proposed study area covers the wetland and riparian extent of Big Swamp near Yeodene, Victoria within parcels 115A\PP3987 and 1\PS501652.

Methods

Literature and data review

A review of existing literature and data was undertaken to extract information relevant to the past and current ecological and physical conditions of the swamp, along with water requirements of communities and dominant species identified as currently, or previously, present. Information relating to the past ecological and physical conditions of the swamp has been presented in chronological order to align with three time periods:

- Pre-European settlement
- Post-European settlement up until commencement of extraction from the Barwon Downs borefield, and
- Post-extraction from the Barwon Downs borefield up until the current day (i.e. 1983 to 2019).

Field surveys

A vegetation survey was conducted on 21 and 22 August 2019. The aim of the field survey was to collect data on wetland vegetation extent and floristic composition, as well as condition and health. The entire study area was traversed on foot and the distribution of ecological vegetation classes (EVCs) and associations were mapped using a combination of ground-truthing and interpretation of high-resolution aerial imagery carried into the field. All flora and fauna species observed during the survey were recorded and assigned as either indigenous or introduced, whilst significant species observed were spatially referenced. Geo-referenced photographs were taken throughout the study area of the various vegetation communities and points of interest to allow for future comparison.

Vegetation condition was assessed using either the Index of Wetland Condition (IWC) or Vegetation Quality Assessment (VQA) methods, depending on the nature of the vegetation and availability of EVC benchmarks.

A comparison of floristic diversity and structure was undertaken using five 50 metre long transects. These were aligned from the perimeter of the swamp into the core, crossing various vegetation community boundaries in the process. The data provides an overall frequency of each plant species and ground attribute occurring across the transect as well as a snapshot of the distribution of functional plant groups and species across wetland gradients. Transect data has been used to inform the dominant species associated with the vegetation associations and used in the ecohydrological analysis. It will also provide a baseline for future monitoring of vegetation within Big Swamp.

Palynological analysis

A palynological analysis of two cores taken from the western and eastern ends of the swamp is currently being undertaken by the university of Melbourne. The results of this study will be incorporated into the assessment once completed in early 2020.

Ecohydrological analysis

An ecohydrological analysis was undertaken to determine the water requirements of key species and vegetation communities and their relationship with the past and present hydrological regimes. When combined with hydrological modelling, a prediction of the future extent and composition of wetland vegetation within Big Swamp has been made under differing remediation scenarios. The analysis involved:

1. Identifying vegetation communities and associated dominant species
2. Defining water requirements for communities and dominant species
3. Determining past, current and future hydrological regimes across the swamp
4. Establishing a link between dominant species/vegetation communities and past and present hydrological regimes
5. Extrapolating future changes to vegetation composition and structure based on proposed water management scenarios.

Results

Hydrological context

The physical conditions across the site were extrapolated from existing data and literature, and field observations. For the purpose of completing the ecohydrological analysis, the key surface and groundwater parameters for the swamp are presented below for both pre-extraction and post-extraction timeframes.

Prior to the installation of MacDonalds Dam in 1979 and subsequent extraction commencing in 1983, the hydrology of the swamp is assumed to be defined by:

- Seasonal rainfall patterns consisting of dry summers and wet winters. Annual average rainfall is assumed to be 600-700 mm.
- Below average rainfall between 1900 and 1950, switching to above average rainfall in the latter half of the century.
- Surface flows gaining water from the groundwater (baseflow) through Reach 2 prior to entering the swamp.
- Surface flows into the swamp ranging from 2ML/day in summer to 40ML/day in winter.
- Surface flows through the swamp are primarily focused in the main channel around the northern edge. Where flows exceeded the capacity of the channel, water moved through a series of fine, braided channels across the swamp plain in the eastern and central sections of the swamp. This broadly distributed flow converged with the main channel in the north of the site, before again flowing through a series of more confined channels in the eastern section of the swamp.
- Groundwater within the swamp was influenced by a clay aquitard which thins in the west of the site and is absent upstream of the swamp. As a result, surface water infiltration leads to development of localised perched aquifers, with the overlying alluvium and humous-rich substrates becoming saturated.
- Groundwater tables at or near the surface across much of the swamp, with seasonal variation of 1-2 metres in parts of the swamp.
- Complete drying of soils within the swamp very uncommon, with moisture ranging from saturated to damp throughout the year.

Following the installation of MacDonalds Dam in 1979, extraction from the borefield commencing in 1983 and major droughts through much of the 1990s and 2000s, changes to the hydrology of the swamp are assumed to include:

- Below average rainfall as a result of drought events in 1982 and between 1995 and 2010 (i.e. the Millennium drought).
- Surface flows losing water to groundwater through Reach 2 prior to entering the swamp (loss of baseflows).
- Yearly cease-to-flow events in summer and reduced winter flows (<20ML/day). Noting that 2ML/day releases have prevented cease-to-flow events in recent years.
- Surface flows through the swamp remain in the main channel around the northern edge. Where flows exceed the capacity of the channel, water moves through the flood plain along a limited

number of channels that have been scoured and deepened by increased rates of erosion and collapse of soil structure following recent fire events. Flows through the swamp still converge with the main channel in the north of the site, before flowing through a narrow band of interconnected channels at the eastern end of the swamp.

- Groundwater across much of the swamp has dropped below 1 metre, with near-surface water table levels only persisting at the eastern-most end. Throughout much of the central and western sections of the swamp, water levels are below 2 metres. This represents an overall drop in the water table across the swamp of between 1 and 2 metres.
- Drying within the swamp has exposed acid-sulphate soils (ASS) down to a depth of 2 metres, with low pH surface and ground water, along with heavy metals, being released. Heavy iron flocculation covering inundated surfaces is also present.

In addition, drying of the swamp has caused a loss of soil bulk density with slumping now present across much of the swamp plain. This has been exacerbated by the burning of organic deposits further reducing soil bulk density. This loss of structure has likely been a key contributor to erosion within the swamp leading to the formation of a sediment plug, and an open water pool, at the eastern most end.

Historic vegetation communities

Historically, the swamp is likely to have supported a diverse wetland ecosystem comprised of four distinct vegetation associations:

1. A low scrub community through the central and northern sections of the swamp plain. This is likely to be an association of the Riparian Fern Scrub vegetation community which is tolerant of frequent or prolonged inundation and saturated soil conditions. As a result, sedges and rushes are likely to be dominant in the understorey.
2. A tall scrub at the western end and fringing the swamp plain, considered to be an association of the Riparian Fern Scrub vegetation community which is differentiated from the above due to less frequent or prolonged periods of inundation and moist rather than saturated soil conditions. Likely that ferns were dominant throughout this association.
3. A highly variable, low riparian woodland along the main channels around the northern edge and eastern parts of the swamp. Swamp Gum is likely to have been the dominant canopy species, however the community would have included other Eucalypts tolerant of wet conditions as well as a high diversity of understorey shrubs, ferns, sedges, rushes and herbs.
4. A damp woodland fringing the swamp plain and areas of riparian woodland, primarily along the southern edge and across much of the eastern third of the swamp outside the influence of existing channels. This varied woodland would have supported a range of tall Eucalypts as co-dominants in an open canopy, over a dense understorey tree / shrub layer.

In addition to the dominant associations listed above, there would have also been small pockets of unique vegetation communities throughout the swamp that persisted due to a combination of local conditions. An example of this is the small patch of Wet Verge Sedgeland which was identified at the western end of the swamp during field surveys.

Current vegetation communities

Currently, the swamp supports the following vegetation communities:

- **Riparian Fern Scrub (EVC A120)** occurs across the swamp plain in the western and central sections of the Swamp. The majority of this EVC has been significantly modified by the previous fires resulting in the loss of much of the original understorey diversity. The most heavily affected areas are now dominated by Prickly Tea-tree (*Leptospermum continentale*) or Scented Paperbark (*Melaleuca squarrosa*) with occasional patches of Austral Bracken (*Pteridium esculentum*) and/or Red-fruit Saw-sedge (*Gahnia sieberiana*). More intact patches occur in the far west of the swamp in areas apparently less affected by fires, supporting a diverse ground layer dominated by various sedges such as Tall Sedge (*Carex appressa*) and Tassel Sedge (*Carex fascicularis*). Areas closer to the main channel in the north of the site contained a braided system of channels and supported a higher cover of sedges and ferns, including additional species such as Spreading Rope-rush (*Empodisma minus*) and Scrambling Coral-fern (*Gleichenia microphylla*).

- **Swampy Riparian Woodland (EVC 83)** occurs along the main channel and adjacent terraces of Boundary Creek, sharing a broad ecotone with the adjacent Riparian Fern Scrub. This vegetation contained a scattered tree layer, dominated by Swamp Gum (*Eucalyptus ovata*), Brooker's Gum (*Eucalyptus brookeriana*) and Manna Gum (*Eucalyptus viminalis*), often over a secondary tree layer. In elevated sections with limited inundation a variety of ground, scrambling and tree ferns were common. The creek channel supported a range of aquatic and semi-aquatic forbs and sedges.

- **Wet Verge Sedgeland (EVC 932)** occurs at the western end of the swamp in a small patch adjacent to the main channel. The patch shared floristic affinities with the adjacent Riparian Fern Scrub but woody species were mostly absent and the vegetation was dominated by relatively dense Tall Sedge and Tassel Sedge. Associated species included White Purselane (*Montia australasica*), Common Spike-sedge (*Eleocharis acuta*), Rushes (*Juncus* spp.) and Slender Knotweed (*Persicaria decipiens*).

- **Damp Sands Herb-rich Woodland (EVC 3)** occurs on the lower slopes to the south and east of the swamp plain. This community was dominated by young Swamp Gum with a very species-poor understorey containing Austral Bracken and Red-fruit Saw-sedge. Whilst this community has been described as Damp Sands Herb-rich Woodland due to its current structural and floristic characteristics (which is likely a result of recent fires and changes in hydrology), this vegetation is considered to represent a derived state of the Swamp Gum (*Eucalyptus ovata*) Forest described by Carr and Muir (1994).

- **Lowland Forest (EVC 16)** occurs on the slopes surrounding Big Swamp, upslope from areas historically effected by water-logging or inundation. This floristically diverse community was dominated by Messmate Stringybark (*Eucalyptus obliqua*) and Manna Gum with a high cover of Austral Bracken. Prominent shrubs included Silver Banksia (*Banksia marginata*), Prickly Moses (*Acacia verticillata*) and Sweet Bursaria (*Bursaria spinosa*).

Ecohydrological analysis

The ecohydrological analysis compares the historic relationship between water and vegetation with the current conditions measured and modelled within the swamp across three zones:

- **Swamp Plain** – The Riparian Fern Scrub community that would have occupied the swamp plain requires near-continuous waterlogging of the soil with shallow, often prolonged, periods of inundation. Where conditions result in frequent or prolonged inundation, sedges and rushes are likely to become dominant in the understorey. Alternatively, drier conditions would have seen a shift to a fern dominated understorey with emergent trees common.

  In recent years, this part of the swamp has seen significant drying of the substrate, resulting in fires and the loss of vegetation cover. Dominant species such as Prickly Tea-tree and Scented Paperbark have re-colonised the swamp plain however understorey species are absent in many areas. A diverse and structurally complex understorey remains only at the west and northern edges of the swamp plain where strong interaction with the main channel likely protected fern and sedge species from the impacts of drying and fires.

  The reduced water-table currently present throughout much of the swamp plain is unlikely to support a Riparian Fern Scrub community in the long-term, leading to a gradual shift to a terrestrial damp woodland community over time. Evidence of Swamp Gum encroachment in the form of recruitment cohorts progressively expanding into the swamp plain were observed along the eastern edges and to the east of the small hillock during the field survey.

- **Main channel** – The Swampy Riparian Woodland community is likely to be reliant on surface flows along the main channel and associated infiltration into the surrounding ground layer. The depth of the channel and variation in elevation along the banks means inundation may have been limited to seasonal floods and localised depressions. Tall forest species less tolerant of inundation, such as Brooker's Gum and Manna Gum, where also present further up the bank as the community shifted into Lowland Forest.

  Surface flow modelling indicates that even under relatively low flows (e.g. 2ML / day) water persists in the channel. As a result, this community is likely to be more tolerant of long-term reductions in surface flows and the associated reduction in water tables within the swamp. However, should cease-to-flow events continue for extended periods, as has occurred in recent years, this community is to likely to be affected through a reduction in species diversity and encroachment by Lowland Forest species.

- **Damp woodlands** - Based on current high flow modelling (20ML/day), these Damp Sands Herb-rich Woodlands are unlikely to have experienced inundation in normal years. They would still have been heavily dependent on ground water with near-constant access to water within the root zone of mature trees and shrubs (Jacobs 2016). These conditions are likely to have been a strong driver of this community and differentiated it from the Lowland Forest EVC on the slopes above.

  Currently, this community is in a state of transition, with species tolerant of wet conditions (e.g. Swamp Gum) expanding into the scrub dominated areas of the swamp. Without the restoration of ground water levels, opportunities may be created for Lowland Forest species to colonise this area as the canopy matures and thins. In time this would have the effect of reducing the overall extent of the wetland as the surrounding forests move in.

Discussion

The ecology of Big Swamp is complex and intricately linked to the hydrology of the site. The hydrology is in turn informed by a range of factors including soils, topography and climate, as well as surface water use upstream and ground water extraction from the underlying deep aquifer leading to greater rates of surface water infiltration throughout the catchment.

From as early as the 1800s, the swamp has been affected by changing land and water use as vegetation clearance and agricultural practices expanded across the region. This activity has continued to the current day, with the extraction of ground water from the deep Tertiary aquifer, and subsequent reduction in surface flows into the swamp, the most recent pressure on the system. Unfortunately, the cumulative effects have come to a head over the past 20 years with drought conditions triggering intensive ground water extractions and severely limiting surface flows into the swamp. The result was the drying of the swamp through the 1990s and 2000s. While difficult to ascertain, the this drying may have commenced prior to groundwater extraction as the installation of MacDonalds Dam would have changed the flow regime along Boundary Creek from the late 1970s. As the water table dropped and drying occurred, both the vegetation and underlying soil layers rich in organic carbon became susceptible to fire, with two major events occurring in 1998 and 2011. The latter fire resulted in an almost complete loss of vegetation cover across the swamp, substantially altering the structure of the communities throughout. Subsequently, it appears erosion of the swamp plain, likely driven by large rainfall events combined with exposed post-fire soils, has concentrated surface flows into a primary channel that now bisects the plain. The resulting eroded sediment appears to have in part accumulated at the eastern end of the swamp in the form of a plug, leading to the formation of a small pool of standing water which now persists year-round.

Whilst there is likely to have been a gradual shift in community structure and composition since European settlement, and even prior due to decadal shifts in climate, the last 30 years has seen significant and potentially irreversible changes to the ecology of the Swamp. The fires have had the greatest direct impact on vegetation, resulting in a reduction of both floristic and structural diversity across the swamp plain and damp woodlands. While a high cover of canopy species has regenerated in both these areas, the understorey is absent in many places and where it has recovered consists almost exclusively of a few common species. Fires are a natural phenomenon in the Australian landscape, even in swamps, and are therefore not necessarily considered a degrading event that would have long term consequences for the Swamp's ecosystem. However, when combined with a distinct shift in the hydrological regime, widespread modification of the under lying substrate due to drying and sub-surface fires and the development of acid sulfate conditions, the consequences are potentially severe in the long term. Two major trends, which can currently be observed in the swamp, will likely continue and result in a shift in the composition of vegetation and associated habitat across the swamp. These include:

- Restriction of flows through the swamp plain to a narrow, central channel, that in the worst-case scenario may only flow intermittingly during seasonal, high rainfall events. Combined with a continuing failure to restore a near-surface water table across much of the plain, the current Riparian Fern Scrub community is likely to reduce in extent to a narrow band limited by proximity to the remaining channels (i.e. one or two through the plain and the main channel along the northern edge). Vegetation outside of this band will in time be replaced by damp woodlands, with Swamp Gum progressively colonising the plain and eventually forming a mature canopy. The resulting consequence will be a significant depletion of the extent of the Riparian Fern Scrub and simplification of the floristic and structural diversity likely to have been present prior to extraction. In a worst-case scenario, the encroachment of woodlands may have a feedback effect, leading to further drying of the swamp plain as species with higher evaporation rates establish and mature. This could theoretically lead to the permanent loss of the Riparian Fern Scrub community from the swamp in the long term. Given climatic trends towards lower average annual rainfall, this scenario cannot be discounted.

- Similar to the Riparian Fern Scrub, a failure to restore ground water levels across the swamp may also see the encroachment of the surrounding Lowland Forest into areas historically dominated by damp woodlands. Whether the overall extent of the damp woodlands will change is difficult to say, however it will have the effect of reducing the extent of the swamp and ecosystem as a whole.

Remediation

Remediation of the swamp recognises that the original, pre-extraction condition cannot be practicably attained, either via an interventionalist or hands-off approach. The aim is therefore to improve ecological values to a satisfactory end-point. In order to provide a definition of this state, the following is proposed as the remediation goal for Big Swamp:

> *"Ensure the long-term persistence of a diverse, functional wetland community across the pre-extraction swamp's full extent"*

While the swamp does not currently meet this goal, it can reasonably be assumed that should suitable hydraulic regimes be returned, communities will re-establish a degree of structural and floristic diversity over time. Supporting this hypothesis is the persistence of floristic elements in the western end of the swamp and along the main channel which currently contain a high diversity of lifeforms and species in sufficient numbers to allow for re-colonisation of the swamp as conditions improve. Complimenting this is the distinct lack of introduced species within the swamp, despite the substantial disturbance that has occurred over the past 20 years. It is also widely recognised that wetland communities are particularly resilient to modification provided suitable conditions are re-established within an acceptable timeframe. Whether this remains the case for Big Swamp, given the multiple issues confronting it, is difficult to say.

To achieve the above goal, the following objectives are proposed to address the negative trends identified within the swamp. These objectives, which can also be considered 'health indicators' or 'success measures', include:

- No further encroachment of terrestrial woodland into the swamp plain over the next 15 years.
- No encroachment of Lowland Forest dominant species into areas of Damp Forest over the next 15 years.

- No loss of structural or floristic diversity along the main channel and western end of the swamp over the next 15 years.
- Increase diversity of understorey species within the swamp plain, with a focus on ferns and sedges, over the next 25 years.

Monitoring of these objectives can be achieved through repeat transect surveys of those established during the field survey. To cover all relevant ecological gradients identified in the study and ensure sufficient data is available to assess the objectives listed above, an additional three transects are recommended to complement the existing five. Monitoring is recommended every two years.

Given the significant and fundamental changes that have occurred to the substrate across much of the swamp as a result of fires and subsequent erosion, a focus on flow intervention is unlikely to be sufficient to restore ecological function to the site (with the long-term aim of allowing pre-extraction wetland communities to return). Physical works may therefore be required to distribute the flow of water evenly across the swamp plain to mitigate the effects of drying and subsequent colonisation by woodland communities.

Whilst specific quantities are still to be determined, this assessment indicates rehabilitation of the swamp will be more reliant on surface flows than restoration of groundwater levels. Raising groundwater levels also has the unwanted potential to liberate additional acidity from ASS from depth to the surface, further exacerbating the current issue. The wetting of the swamp from the ‘top down’ using surface flows, in association with physical works to distribute flows across the swamp, will help to contain immediate issues associated with ASS whilst preventing the current south-to-north drying of the swamp and transition of the wetland to a woodland community.

Whilst the substantial impacts to the swamp’s substrate cannot be reversed, the restoration of a functional hydrological regime across the swamp will allow for the re-colonization of modified areas with a range of species currently persisting in small pockets throughout the swamp, thus restoring a degree of diversity and function to the wetland overtime.

To achieve the goals and objectives, the following actions are proposed:

A. Ensure surface flows into the swamp are sufficient to maintain year-round waterlogging within the top metre of the swamp plain. Flows however should not result in inundation of the swamp plain for a continuous period of more than 6 months, and ideally should be designed to result in continuous seasonal inundation (maximum 30cm depth) of the plain for between 2 – 3 months.

B. Install a limited number of low bund/weirs through sections of the swamp plan. Ideally this would utilise existing tracks and disturbed areas for construction and access. The objective of the bunds would be to block the deeper channels that have formed in the swamp plain and distribute flows across the broader area. While it may be unavoidable in places, it is important to avoid the creation of permanently inundated areas of open water. Gradually vegetation and sediment will fill the existing channels and any small areas of open water created by the bunds and over time start to return the profile of the swamp plain to a fine series of braided channels as believed to have originally occurred.

C. Refill/block-off the fire trench (and other unnecessary drains) and re-establish flow of the southern tributary into the swamp along the original alignment. Given the modification of the substrate, small diversion barriers may be required to direct flows into and through the swamp plain.

D. Considered potential use of the recently-formed open water area at the eastern end of the swamp to treat water quality issues created by ASS. Potential options may include the use of specific wetland species (e.g. *Phragmites australis*) as bio-accumulators to treat water quality issues associated with acid-sulphate and heavy metals. However, such an approach would require further investigation as there is the potential for secondary degradation through the introduction of aggressive species into a damaged ecosystem.

E. Undertake continued monitoring of the swamp against the objectives listed above.

In addition, further investigations are recommended to inform the design of remediation actions and long-term management of Big Swamp. These include:

- Condition assessments in high quality Riparian Fern Scrub and Swamp Gum remnants in the region to establish benchmarks against which monitoring data can be assessed. Existing quadrat plots and transects may be suitable for comparison of damp woodland communities however there is currently a lack of monitoring data related to the Riparian Fern Scrub EVC from the local region.

- Assessment of the connectivity between the shallow and deep aquifer systems and relationship to Big Swamp.

- Survey of the swamp plain profile to inform design of proposed weirs/bunds.

1. Introduction

1.1 Background

Recent technical work (Jacobs, 2018) confirmed that Barwon Water's pumping from the Barwon Downs borefield over the past 30 years is the main cause of a reduction in baseflow (groundwater contribution to streamflow) in the lower reach of Boundary Creek, increasing the frequency and duration of no flow periods. The dry climate experienced in the same period and ineffective management measures were also considered contributing factors.

Lack of flow, especially during summer months has caused:

- Big Swamp to dry out,
- The oxidation of naturally occurring acid sulfate soils in the swamp, and
- The release of acidic water (pH less than 4) downstream of the swamp.

In response to this, Barwon Water was issued with a section 78 Ministerial Notice in September 2018, to legally enforce the development and implementation of a remediation plan for Boundary Creek, Big Swamp and surrounding environments impacted by past groundwater extraction.

A requirement of the s78 Notice includes the need to undertake any necessary environmental assessments to inform the development of the remediation plan due for submission on December 20 2019. Eco Logical Australia (ELA) has been engaged by Barwon Water to undertake an ecological assessment of Big Swamp and provide commentary on how changing the wetting/drying regime in the swamp (from seasonal drying to permanently wet) will impact upon the existing vegetation diversity and condition.

1.2 Study area

The proposed study area covers the wetland and riparian extent of Big Swamp near Yeodene, Victoria within parcels 115A\PP3987 and 1\PS501652 (Figure 1-1). This 22 hectare area is defined by the hydrological influence of Boundary Creek and the dependant ecosystem. Areas outside of the immediate influence of the swamp's hydrology, including those upstream/slope of the swamp and downstream of the parcels identified, are not included in the study area for the purpose of this technical study.

1.3 Goals and objectives

The primary goal of the assessment is to inform the preparation of the remediation plan in accordance with the ministerial notice issued pursuant to Section 78 of the *Water Act 1989*. In this context, remediation is deemed to be "the controls and actions that could be practicably carried out to achieve improved environmental outcomes for Boundary Creek, Big Swamp and the surrounding environment that has been impacted by groundwater pumping at Barwon Downs."

Given this goal, the objectives of this study are:

1. establish the baseline ecological characteristics for Big Swamp through:

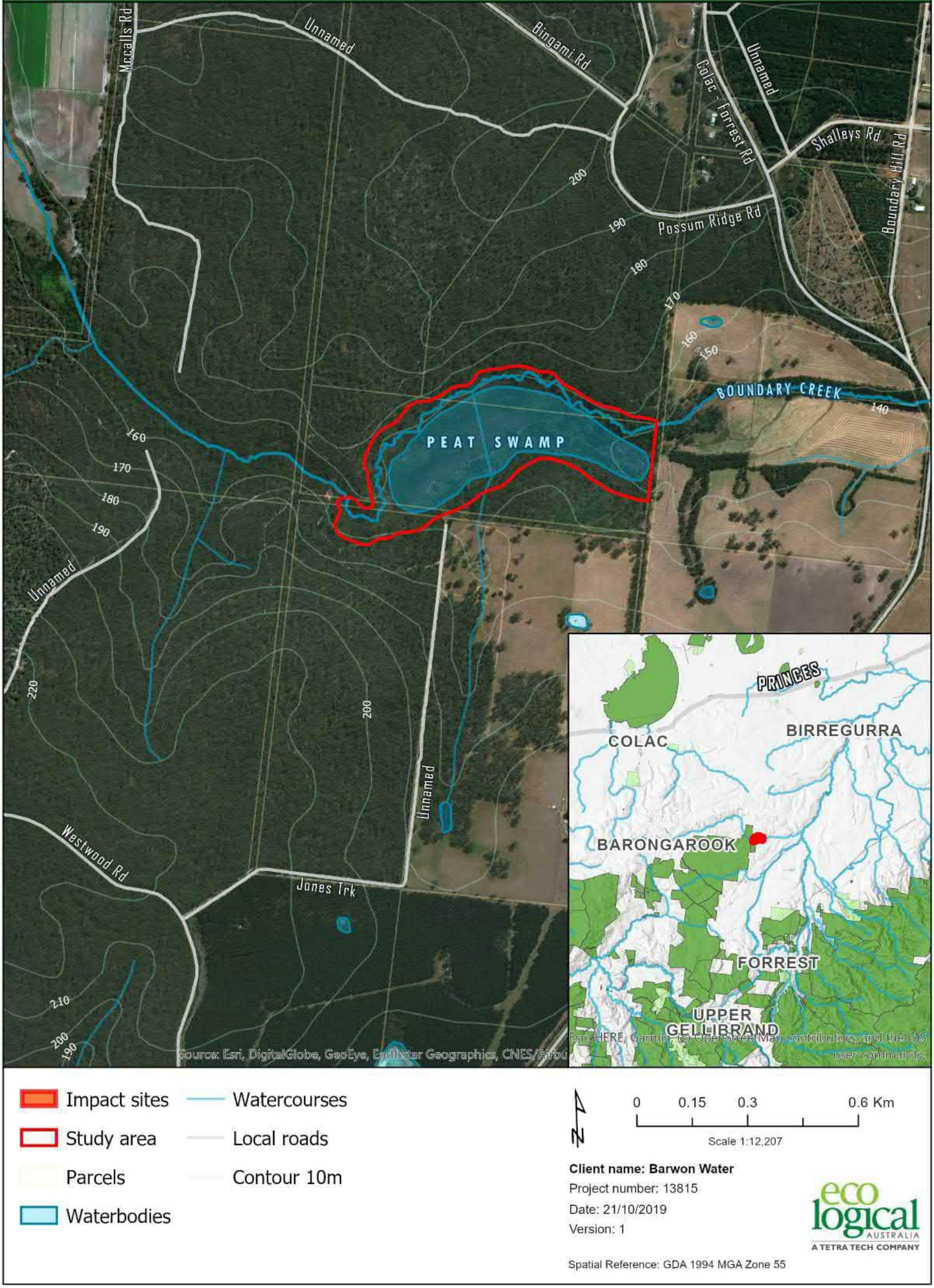
    - site investigations focused on describing the extent and condition of vegetation within and adjacent to the swamp.
    - review of existing literature, imagery and data to determine past ecological conditions within the swamp focusing on pre-extraction and pre-colonisation time periods.

2. Determine the hydrological requirements of past and current vegetation communities and advise likely responses to future surface and groundwater regimes.

3. Provide recommendations to improve ecological outcomes within the swamp, within the context of the broader objectives of the remediation plan. This includes identifying "reasonable targets and/or measures of success to be adopted for the purpose of the implementation of the Plan" (s78 notice).

Figure 1. Location of study area

Big Swamp ecological assessment



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbu

Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

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2. Methods

2.1 Literature and data review

A review of existing literature and data was undertaken to extract information relevant to the:

- Past and current ecological and physical conditions of the swamp
- Hydrological requirements of communities and species identified as occurring, or previously occurring, within the swamp.

A bibliography containing documents reviewed for this study is provided at the end of the report.

Information relating to the past ecological and physical conditions of the swamp have been presented in chronological order to align with three time periods:

- Pre-European settlement and modification of the landscape for agricultural production. This is assumed to be prior to 1820, based on European expeditions west of Werribee to identify land suitable for pastoral production in the early 1800s. Conditions within the swamp will be informed by the palynological analysis (still to be completed) and comparison with monitoring data collated over the past 30 years from relatively unmodified wetland ecosystems in the region.

- Post-European settlement in the area up until commencement of extraction from the Lower Tertiary Aquifer via the Barwon Downs borefield. This period extends from the early 1800s through to 1983 when the first major extraction event occurred. Key information to inform changes over this period includes aerial imagery dating back to 1946, botanical studies in the Barwon Downs and greater Otways region and comparison with monitoring data collated over the past 30 years.

- Post-extraction from the Barwon Downs borefield up until the current day (i.e. 1983 to 2019). The change in conditions during this 36-year period has been informed by the numerous technical studies completed during this time, and in particular the last 15 years. This has been complimented with a review of aerial imagery and recent spatial products produced by DELWP.

2.2 Field surveys

A vegetation survey was conducted by ecologists James Garden (ELA) and Karl Just (sub-contractor) on 21 and 22 August 2019. The aim of the field survey was to collect data on:

- Wetland vegetation extent;
- Current floristic composition; and
- Vegetation condition and health.

The entire study area was traversed on foot, during which time the distribution of ecological vegetation classes (EVCs) and associations[1] was mapped using a combination of ground-truthing and interpretation of high-resolution aerial imagery carried into the field. All flora and fauna species observed during the survey were recorded and assigned as either indigenous or introduced, whilst significant species observed were spatially referenced. Geo-referenced photographs were taken throughout the study area of the various vegetation communities and points of interest to allow for future comparison.

2.2.1 Vegetation Condition Assessment

In order to determine the current, relative condition of vegetation within the study area, assessments were carried out using the Index of Wetland Condition (IWC) and Vegetation Quality Assessment (VQA) methods. In general, the VQA is not an accurate method for assessing wetland vegetation due to the paucity of wetland EVC benchmarks and absence of a method for assessing altered wetland processes, whilst the IWC is not applicable to terrestrial vegetation. Both methods were therefore utilised, so that the wetland EVCs of the site were assessed using the IWC and the terrestrial areas using the VQA.

The IWC assessment followed the methods as described in the Index of Wetland Condition Methods Manual version 14 (DELWP, 2018). The IWC assesses the state of the biological, physical and chemical components of the wetland ecosystem and their interactions. The method has six weighted sub-indices based on the characteristics that define wetlands: wetland catchment; physical form; hydrology; soils; water properties; and biota. It is primarily a site/habitat-based assessment although some measures require wetland catchment scale assessment.

The VQA followed the methods as described in the Vegetation Quality Assessment Manual Version-1.3 (DSE 2004). The method has ten weighted sub-indices including Large Trees, Tree Canopy Cover, Lack of Weeds, Understorey, Recruitment, Organic Litter, Logs, Patch Size, Distance to Core Area and Neighbourhood.

These condition assessment methods are designed to provide a relative measure of condition that can be compared across vegetation onsite and against ‘typical’ benchmarks developed for the broader bioregion (in this case the Otway Plains). Due to the coarse nature of the assessment method and potential influence of both seasonal variations and assessor bias, it is not recommended for ongoing monitoring of vegetation within the swamp. The use of point transects is instead proposed for this purpose with the collection of baseline data during this assessment described below.

2.2.2 Vegetation transects

The vegetation of the study area was sampled using five 50m long vegetation transects aligned from the perimeter of the swamp into the core, crossing various vegetation community boundaries in the process. The start of each transect was permanently marked with a 1500mm high, yellow-capped star picket so that the transects can used for ongoing monitoring.

The location of transects were chosen so as to intersect vegetation association boundaries which are considered to align with environmental gradients or features (e.g. inundation, soils etc). This will allow for the future comparison of floristic diversity and structure associated with the differing vegetation

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[1] The term ‘association’ is used here to describe variation within vegetation classes, consistent with the Zurich-Montpellier tradition of phytosociology.

associations (and therefore underlying environmental drivers), whilst also providing the basis for tracking gradual changes in the extent of vegetation communities over the long-term.

All flora species at each 25cm interval along the transect were recorded. In addition, the ground attribute occurring at each 25cm point was recorded, including one of either bare ground, bryophytes, litter, water and log. The data provides an overall frequency of each plant species and ground attribute occurring across the transect as well as a snapshot of the distribution of functional plant groups and species across wetland gradients. Transect data has been used to inform the dominant species associated with each vegetation association for use in the ecohydrological analysis. It will also provide a baseline for future monitoring of vegetation within Big Swamp.

The results of the transect assessment is provided in Appendix B.

2.3 Palynological study

During the field surveys two cores were taken from the western and eastern ends of the swamp to a depth of 1.5 metres and 2.5 metres respectively. Samples were taken from 10 cm intervals within each core and have been provide to the University of Melbourne for analysis. The results of this study are expected in early 2020 and will be incorporated into this assessment once received.

2.4 Ecohydrological analysis

The ecohydrological analysis builds upon the findings of the literature review and field surveys. Its aim is to determine the water requirements of key species and vegetation communities and their relationship with the past and present hydrological regimes. When combined with hydrological modelling, a prediction of the future extent and composition of wetland vegetation within Big Swamp can be made under differing remediation scenarios.

The steps undertaken to complete this analysis include:

1. Identifying vegetation communities and associated dominant species - Information collected during the field survey was used to inform the type, extent and condition of vegetation associations throughout the swamp. The survey also identified dominant species within each association which are considered critical to the ecological character and function of the wider wetland ecosystem. The loss of these species would therefore represent a fundamental shift in the ecosystem to a different functional state (e.g. aquatic to terrestrial).
2. Defining water requirements for communities and dominant species. This process involved a literature review and included collation of information from the following key sources:
   - Peer-reviewed scientific research, as listed in the bibliography.
   - Technical publications, including Arthur Rylah Institutes' *A Guide to water regime, salinity ranges and bioregional conservation status of Victorian wetland Ecological Vegetation classes* (Frood and Papas 2016).
   - Previous studies, including: Jacobs (2015) which assigned functional groups to species throughout the Barwon Downs region based on previous analyses and Orrelana *et al*. (2012); and, SKM (2009) which identified water dependency on a 5-point scale for 108 species in the region.

  - Sinclair *et al*. (2019; Arthur Rylah Institute unpublished dataset) which captures both waterlogging and inundation tolerance for a broad range of species across Victoria.

3. Determining past, current and future water regimes across the swamp using existing monitoring data and surface and ground water models. The ground and surface water models have been produced by Jacobs (2019) and provide key flow and water table metrics including frequency, extent, duration and depth of inundation and variation in water table under differing management scenarios based on water extraction and release upstream of Big Swamp.
4. Establishing a link between dominant species/vegetation communities and past and present hydrological regimes. Based on the data available key metrics will be identified that are assumed to underpin ecosystem function and drive community structure and species distribution across the site. This step combines information from steps 2 and 3.
5. Extrapolating future changes to vegetation composition and structure based on proposed water management scenarios.

The assessment of key water quality indicators and relevance to ecosystem health, particularly for groundwater, has also been made where sufficient information exists.

Using the findings of this analysis, recommendations for ideal watering conditions have been provided to ensure a functional, diverse wetland ecosystem is maintained at the site. Where applicable, other interventional management actions have been recommended to address issues associated with physical changes to the wetland over the past 30 years.

3. Results

3.1 Bio-physical environment

This section describes the bio-physical environment within the swamp and broader region, with a particular focus on hydrology, soils and drivers of change (e.g. fires and landuse). Figure 3-1 provides temporal context to the events describe in the following sections.

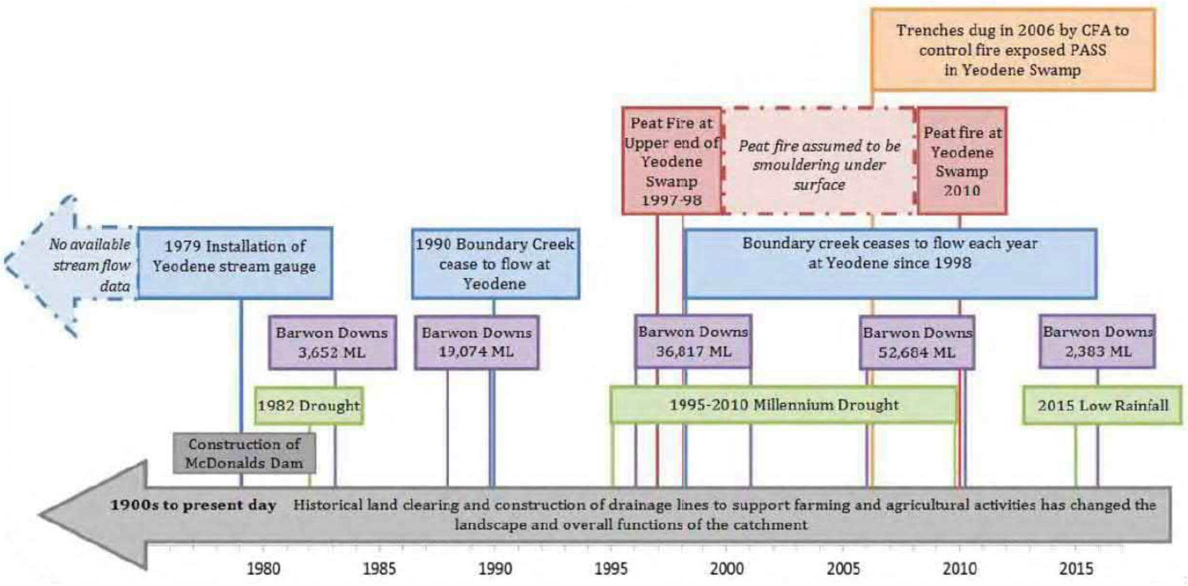


Figure 3-1. Recent events that have affected Big Swamp (Barwon Water 2019)

3.1.1 Regional hydrological context

The Barwon River and its tributaries rise in the Otway Ranges and flow north through Forrest and Birregurra. The Barwon River West Branch and East Branch drain the southern half of the catchment and come together just upstream of the confluence with Boundary Creek. Boundary Creek flows east across the Barongarook High and joins the Barwon River around Yeodene.

The regional groundwater system extends beneath two surface water catchments, the Barwon River catchment and the Otways Coast catchment. The Otways Coast catchment is a large catchment with many rivers that flow towards the coast. The Gellibrand River is in the Otways Coast catchment and rises near Upper Gellibrand and flows in a westerly direction towards Gellibrand. The Gellibrand River discharges to the ocean at Princetown.

The Barwon Downs bore field is located approximately 70 km south west of Geelong and 30 km south east of Colac. The surrounding land is a mixture of state forest and agricultural land that has been farmed for over a century, resulting in some parts of the landscape being highly modified compared to the surrounding natural environment.

The borefield taps into an underground source of water, known as the Lower Tertiary Aquifer, with depths of up to 600 metres at the borefield. The aquifer covers an area of approximately 500 km2 below the surface and is connected to the surface in both the Barwon River catchment (Barongarook High) and the Otways Coast catchment near Gellibrand. Barongarook High is the main recharge area of the aquifer because of its unconfined nature.

Groundwater and surface water condition is monitored through a series of bores and gauges situated along the main channel of Boundary Creek.

3.1.2 Land-use

The review of literature identified a range of land-use activities and changes across the catchment which has likely impacted the hydrology of Boundary Creek and associated ecology of Big Swamp. A comprehensive list was provided by Carr and Muir (1994), and include:

- widespread clearing of catchments or sub-catchments, notably the greater part of Boundary Creek catchment, post European settlement in the area. This has led to increased runoff and moisture availability in creeks along drainage lines, and more rapid runoff
- increased runoff resulting from soil compaction and reduced infiltration on cleared land by cattle trampling
- draining of swampy areas throughout the catchment, which likely resulted in greater flooding or waterlogging of downstream substrates
- much higher water use by plantations of Radiata Pine (*Pinus radiata*) compared with indigenous vegetation leading to reduced ground water percolation downslope
- oxidation and loss of water holding peats resulting in increased runoff and greater fluctuations of runoff
- impounding of water in farm dams.

The key water uses in the catchment are surface water extraction from Boundary Creek for pasture/crop irrigation and stock watering, and ground water extraction from the Lower Tertiary Aquifer via the Barwon Downs borefield.

Whilst there is insufficient data to quantify the extraction of surface water from the creek, ground water extraction has been carefully monitored with five extraction events occurring since the borefield was commissioned in 1983. These include extractions of:

- 3,652 ML from February to April in 1983 due to drought;
- 19,074 ML during a long-term pump test in the late 1980s;
- 36,817 ML during the 1997 - 2001 drought;
- 52,684 ML during the 2006 – 2010 millennium drought, and
- 3,449 ML in 2016 to boost storages after a record dry summer.

The licence to operate the Barwon Downs borefield was issued by Southern Rural Water in 2004 and was due to expire in June 2019. Barwon Water submitted a groundwater licence renewal application to Southern Rural Water in late November 2018, however, the licence application for the Barwon Downs borefield was withdrawn in March 2019 over concerns about the environment and a commitment to the remediation of historical impacts caused by groundwater pumping.

3.1.3 Climate

There have been significant changes in long-term climatic conditions across the Boundary Creek catchment. The cumulative departure of rainfall from the mean demonstrates these multi-decadal trends (Figure 3-2). Increasing trends indicate periods of above average rainfall whereas the declining trends indicate drought periods. In the first half of the 20th century, before the extraction of groundwater from the Barwon Downs bore field, there was an extended period of reduced rainfall from 1900 to 1955. This was followed by a period of increased rainfall between 1955 and 1997 which spans the period before and after the implementation of the bore field (1985). Recent droughts include one 1982-1983 and the millennium drought between 1995 and 2010, and below average rainfall between 2014 and 2017.

Future climate projections for the Barwon basin indicate that there will be ongoing reductions in annual rainfall, with corresponding reductions in available runoff. Median projections forecast a 5% reduction in annual rainfall from present and more conservative predictions are as high as 20% reduction. The corresponding catchment runoff median reduction is predicted to be 22%, with conservative predictions forecasting a 48% run off reduction by the year 2065 (DELWP 2016).

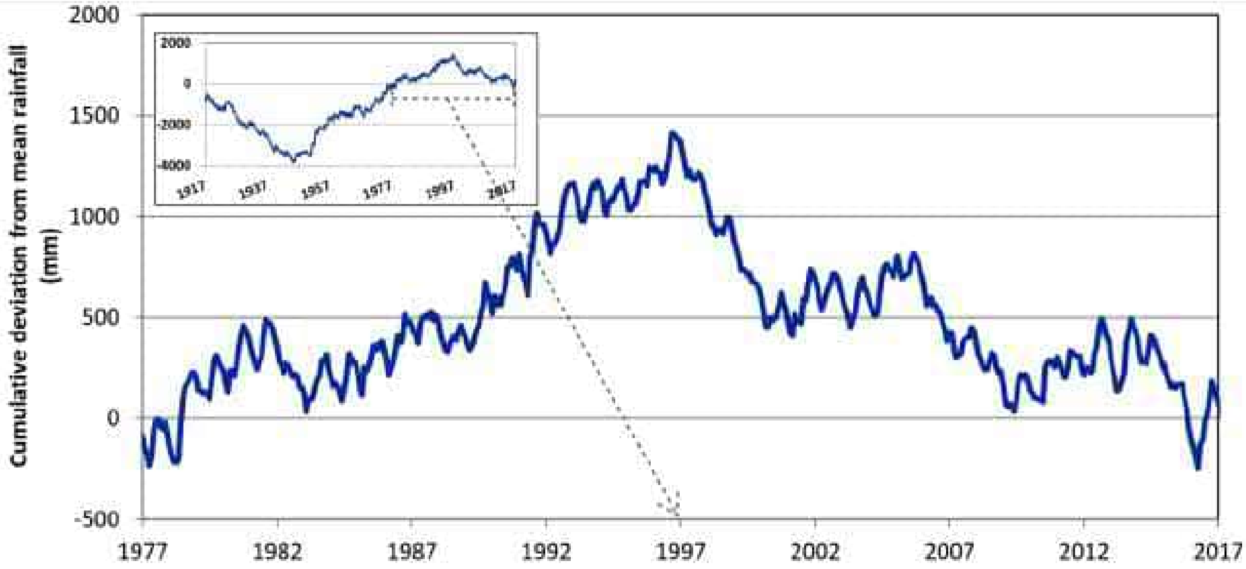


Figure 3-2. Cumulative deviation from mean annual rainfall at Forest State gauge (BOM gauge 090040) (Jacobs 2017)

3.1.4 Surface water

There is also seasonal, spatial and interannual variability in surface flow at Big Swamp. The seasonal variation is due to changes in rainfall and evapotranspiration whereas the spatial variation in surface flow is due to changes in topography and the degree of groundwater connectivity (discussed further in section 3.1.5). Finally, the interannual variability in surface flow is determined by intermittent pumping from the Barwon Downs bore field and to a lesser extent, a drying climate.

The streamflow in Boundary Creek above Big Swamp has been monitored since 1979 (Figure 3-3). There were additional stream gauges installed above and below McDonald’s Dam in 1979 with an interval between 1994-2014 where gauges fell into disrepair (Jacobs, 2018). Historically, Boundary Creek stream flow is lower in summer than in winter due to seasonal fluctuations in rainfall and subsequent surface run off. Spot gauging reveals that stream flow is more than 4-5 times higher in August than May. The loss of streamflow was estimated to range between 2.9 ML/day in May and 9.9 ML/day in August 2017. These volumes of water were representative of the swamp re-wetting after a period of no flow. It is estimated that the majority of the loss is recharge to groundwater with evapotranspiration making up less than 1 ML/day during these months (Jacobs, 2017).

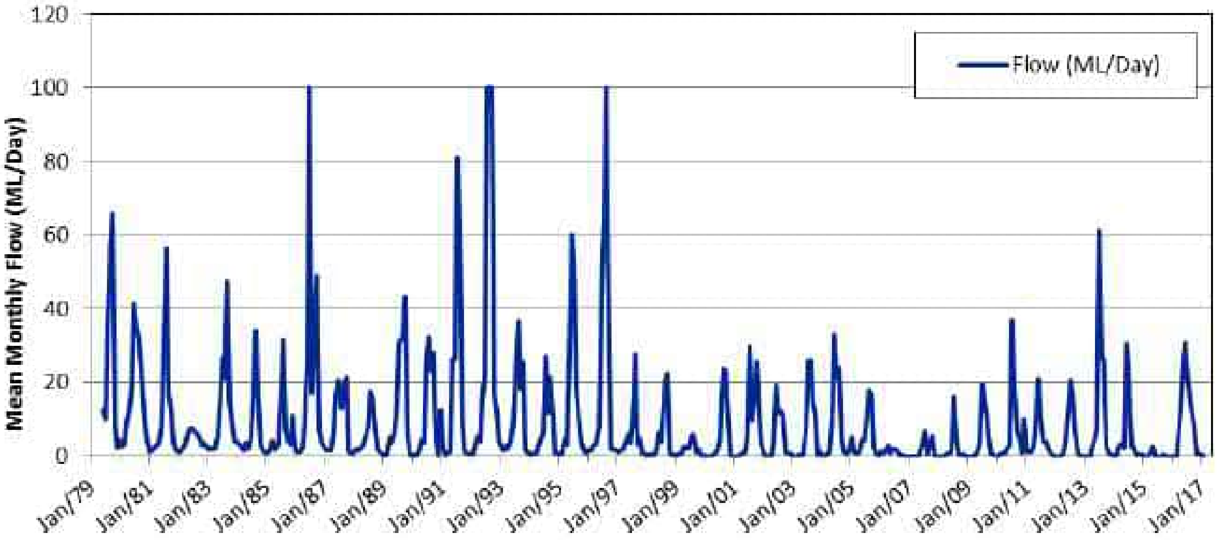


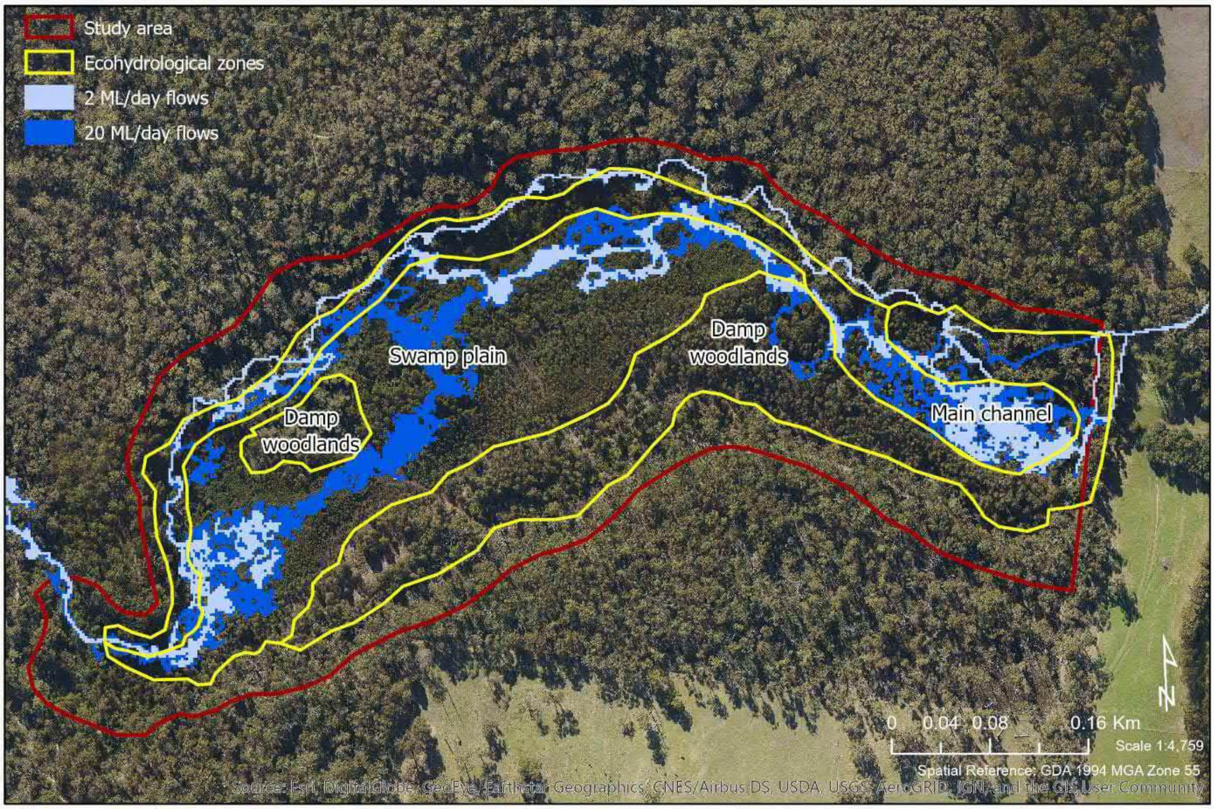
Figure 3-3. Average monthly flow in Boundary Creek at Yeodene (Jacobs 2017)

The spatial variation in surface flow across Big Swamp has been influenced by changes in the topography as a result of direct and indirect intervention. There was dramatic change in the stream flow when McDonald's Dam was installed in 1979. The dam has a storage capacity of 160 ML and is a source of evaporation and flow retardation in the catchment. Furthermore, a fire trench installed in 2006 around the southern and eastern edge of the swamp intersected an ephemeral drainage line that would have provided surface flows to the central part of the swamp. Whilst limited, surface flows from this source are likely being diverted along the trench to the eastern end of the swamp.

The decline of soil structure and woody vegetation cover has increased susceptible to erosion within the swamp during high flow events. This erosion appears to have led to the formation of a single channel through the swamp plain with sediment being transported and deposited at the eastern end of the swamp. The resulting 'sediment plug' may have been the driver for the formation of a small pool of standing water which now persists year-round in this location.

This channelization of the swamp plain is a concern as it may reduce the dispersion of water across the swamp during low to moderate flow events, as shown in preliminary modelling conducted by Jacobs (Figure 3-4). Importantly, the western end of the swamp does not appear to have been as adversely affected by conditions over past 20 years and the interaction between main channel and swamp, including overflow events inundating the plain, appears to be functioning well. Based on the surface flow modelling of this western-most section of the swamp, it can be surmised that much of the swamp plain may have consisted of a similar network of small braided channels. The result would have been a much broader dispersal of surface flows across the plain prior to the fires.

The long-term interannual streamflow is characterised by a declining base flow and an increase in the frequency of no flow periods. Since monitoring commenced in 2014, flows downstream of McDonalds Dam during the warmer months (November to April) was significantly less than 2 ML/day (Jacobs, 2018). Figure 3-3 shows a significant step change in surface flows in Boundary Creek at the Yeodene gauge in 1998. Groundwater modelling of Boundary Creek shows significant drawdown of groundwater impacting stream flow (Jacobs, 2017). Previous literature has shown that this decline in stream baseflow is primarily due to the groundwater extraction from the Barwon Downs borefield over the past 30 years (Jacobs, 2018). However, a dry climate and ineffective management measures were also deemed to be contributing factors.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 3-4. Modelled surface flows (2ML and 20ML / day) through Big Swamp

3.1.5 Conceptualisation of the hydrogeology at Big Swamp

Jacobs (2017) have summarised the conceptualisation of current water dynamics in the vicinity of Big Swamp (Figure 3-5). The key findings from Jacobs (2017) include:

- Saturated alluvial sediments are likely to be present upstream of Big Swamp as a localised perched aquifer.
- Depth to water table in the regional aquifer is 10-15 m below ground level upstream of Yeodene Swamp.
- Saturated sediments in Big Swamp are hydraulically separated from the underlying regional aquifer (LTA) by the aquitard.
- The eastern end of swamp comprises saturated alluvial deposits overlying aquitard.

- The aquitard thins to the west and is absent upstream of the swamp, however the exact location where the aquitard is absent is not known. Shallow bores indicate that the western end of the swamp the alluvial deposits overlie the regional aquifer.
- Immediately downstream of McDonalds Dam to the Damplands the spot flow measurements indicate the creek could be gaining water. Inflows to the creek are likely to be result of surface runoff from the wider catchment and potential inflow from the local (perched) alluvial aquifer. This is new information and improves the conceptualisation of the Reach 2.
- The Damplands and Big Swamp were observed to be losing water to groundwater, which is consistent with the existing conceptualisation.
- Reach 3 of Boundary Creek is variable gaining/losing to groundwater, consistent with the existing conceptualisation.
- The greatest losses of surface water occur through the Damplands and Big Swamp. This is estimated to range between 2.9 ML/day in May and 9.9 ML/day in August 2017. These volumes of water are representative of the swamp re-wetting after a period of no flow. It is estimated that the majority of the loss is recharge to groundwater with evapotranspiration making up less than 1 ML/day during these months.
- Evaporation losses will be higher during the summer months and could be up to 2.5 ML/day.

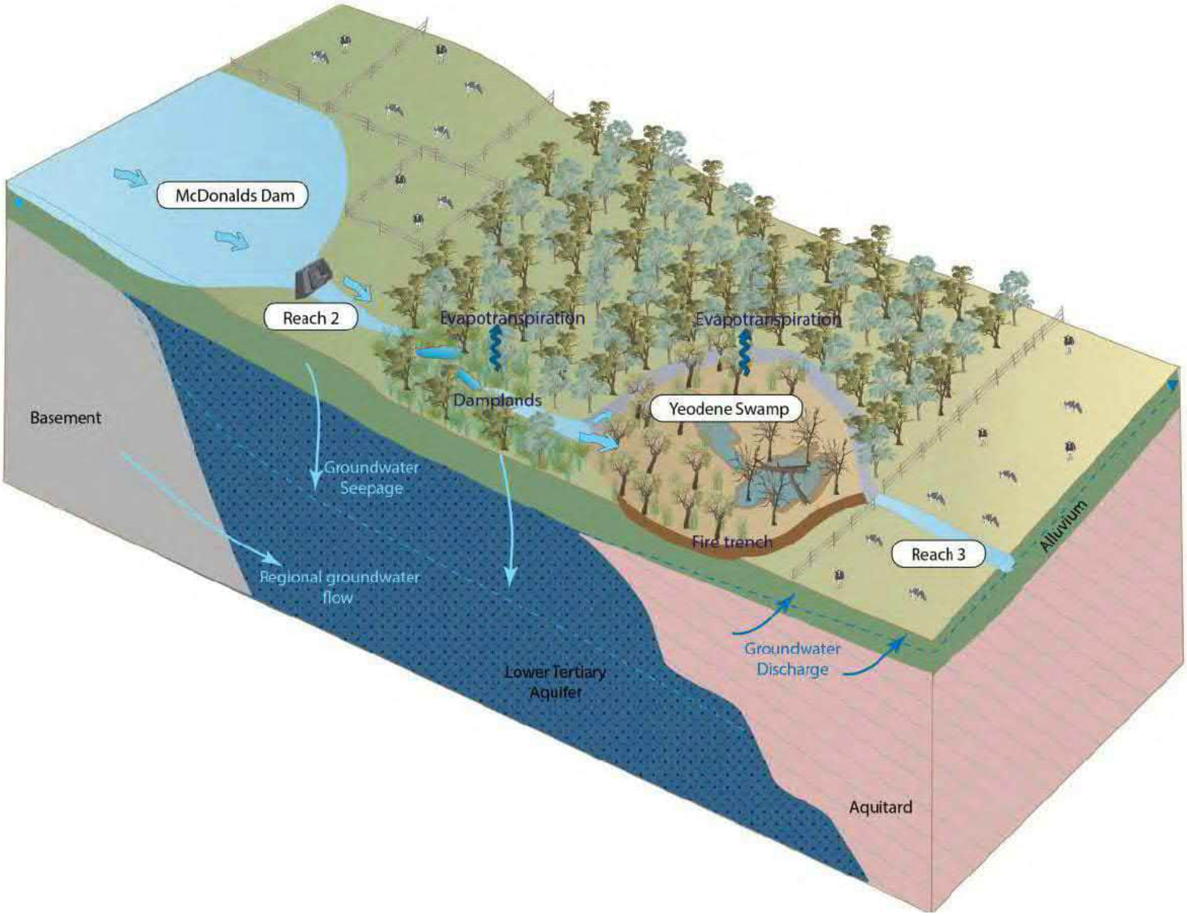


Figure 3-5. Working conceptualisation of the hydrogeology of Big Swamp (Jacobs, 2017)

3.1.6 Groundwater

The hydrogeology of the site is characterised by shallow perched aquifers, aquitards and the deep lower tertiary aquifer. The degree of interconnectivity between the shallow aquifer, deep aquifers and Boundary Creek, in relation to the water levels within Big Swamp, is the subject of ongoing investigation. Conceptual long-section diagrams are shown in Figure 3-6.

Big Swamp is formed from saturated sediments that are separated from the underlying regional aquifer (Dilwyn Formation) by a less permeable, silty-clay aquitard (Mid-Tertiary Aquitard) (Jacobs 2017). The hydrogeological features vary across the swamp and this is particularly apparent when examining the NDVI data which shows flourishing vegetation in the eastern part of the swamp during dry periods, indicating evapotranspiration dependent on the groundwater available (Jacobs, 2016). The eastern end of the swamp is comprised of saturated alluvial deposits overlying an aquitard. The aquitard thins to the west and is absent upstream of the swamp, however, the exact location where the aquitard is absent is not known (Jacobs 2017). Shallow bores indicate that alluvial deposits overlie the regional aquifer at the western end of the swamp. Saturated alluvial sediments are also likely to be present upstream of Big Swamp as a localised perched aquifer (Jacobs 2017). Furthermore, a stream gauge in the eastern section of the swamp has been unaffected by dramatic changes in streamflow providing further evidence for the presence of a shallow aquifer recharged by vertical seepage through the swamp and Boundary Creek.

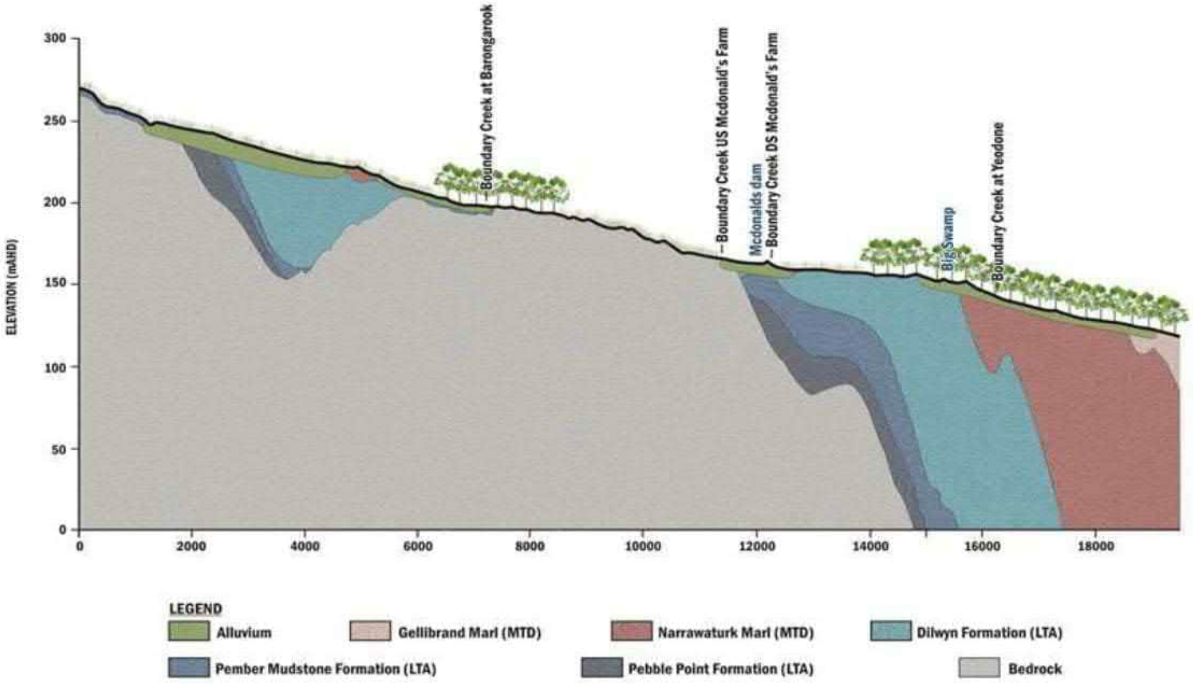


Figure 3-6. Long section along Boundary Creek (Jacobs 2017)

Since European settlement of the area, there has been significant land use change as parts of the catchment have been cleared for agricultural purposes. While this is unlikely to have affected the hydrostratigraphy, land clearing could have altered groundwater levels in the swamp, however, there is no scientific evidence to support this. Hydrogeological monitoring data from Big Swamp before the Barwon bore field installation in 1985 is sparse. There are observations from landholders recorded by

Gardiner (2012) that state there was water consistently in Boundary Creek until the 1990s. Recent groundwater monitoring shows that groundwater levels in Big Swamp have recently fallen.

Studies have confirmed that pumping from the Barwon Downs borefield over the past 30 years is the main cause of a reduction in baseflow (groundwater contribution to streamflow) in the lower reach of Boundary Creek, increasing the frequency and duration of no flow periods (Jacobs, 2018). Groundwater modelling shows that Boundary Creek, which discharges into Big Swamp, was previously gaining water from groundwater and is now losing water to groundwater (Jacobs, 2018). There are also significant seasonal changes in groundwater levels at Big Swamp due to evapotranspiration (i.e. water use by plants) over the summer period when water requirements are at their highest, representing seasonal variation in the groundwater levels as shown in the monitoring borehole data (Jacobs, 2015).

Preliminary modelling of current groundwater levels within the Swamp by Jacobs is presented in Figure 3-7.

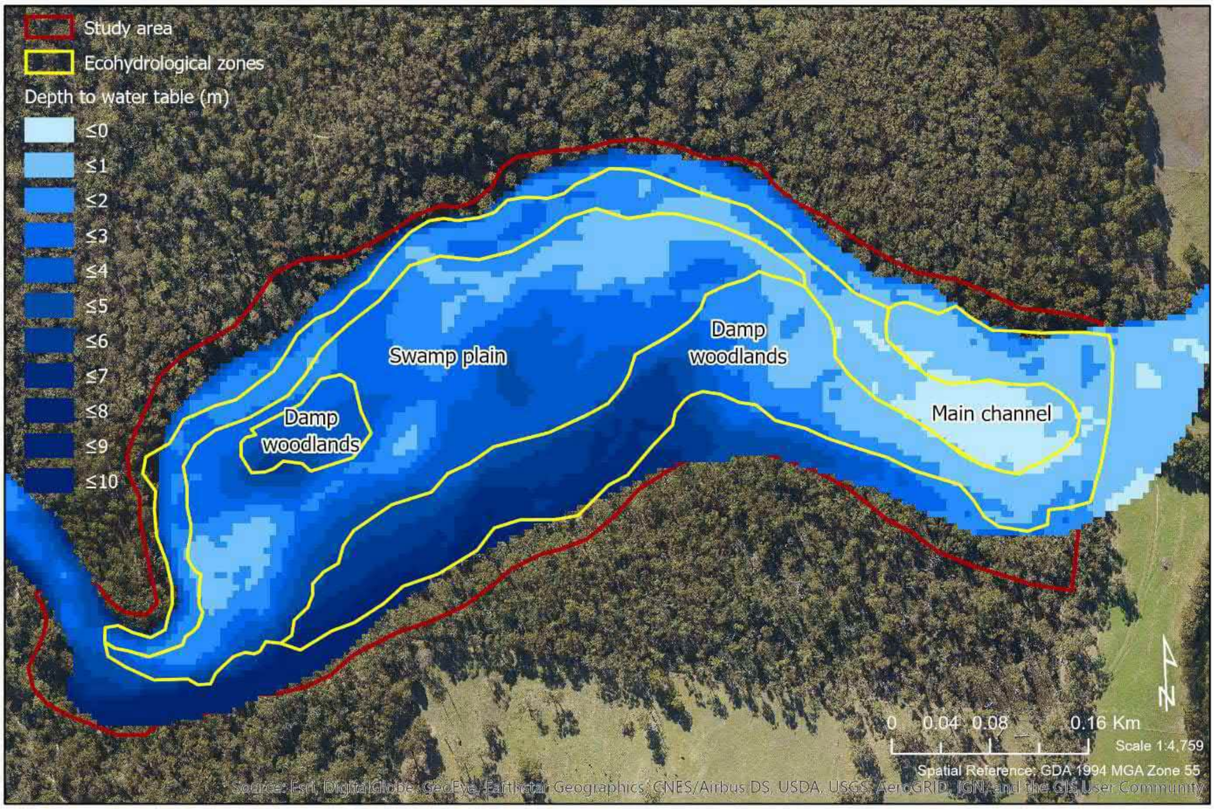


Figure 3-7. Groundwater modelling of Big Swamp

3.1.7 Groundwater-surface water connectivity

Surface water and groundwater are intimately connected at Big Swamp and Boundary Creek. Bore data collected from immediately upstream of Big Swamp (YS06 and YS05) and within the swamp at the eastern (YS02) indicates that the flow between surface water and groundwater at Big Swamp varies seasonally, with different parts of the system gaining and losing throughout the year (Table 4-5 and Fig. 3-1). During the first flow, Boundary Creek Reach 2 and the Swamp are both losing whereas during the Winter high flow, Big Swamp is neutral.

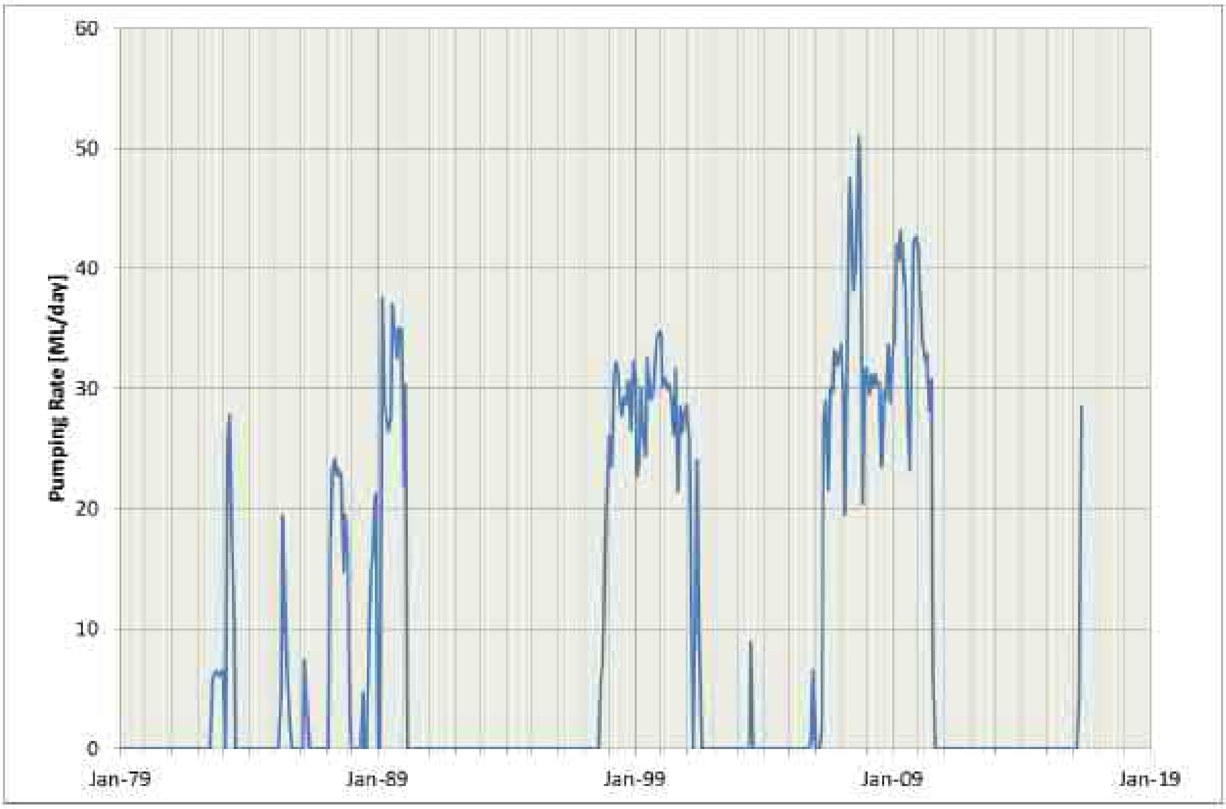


Figure 3-8. Combined borefield extraction for the Barwon Downs production wells

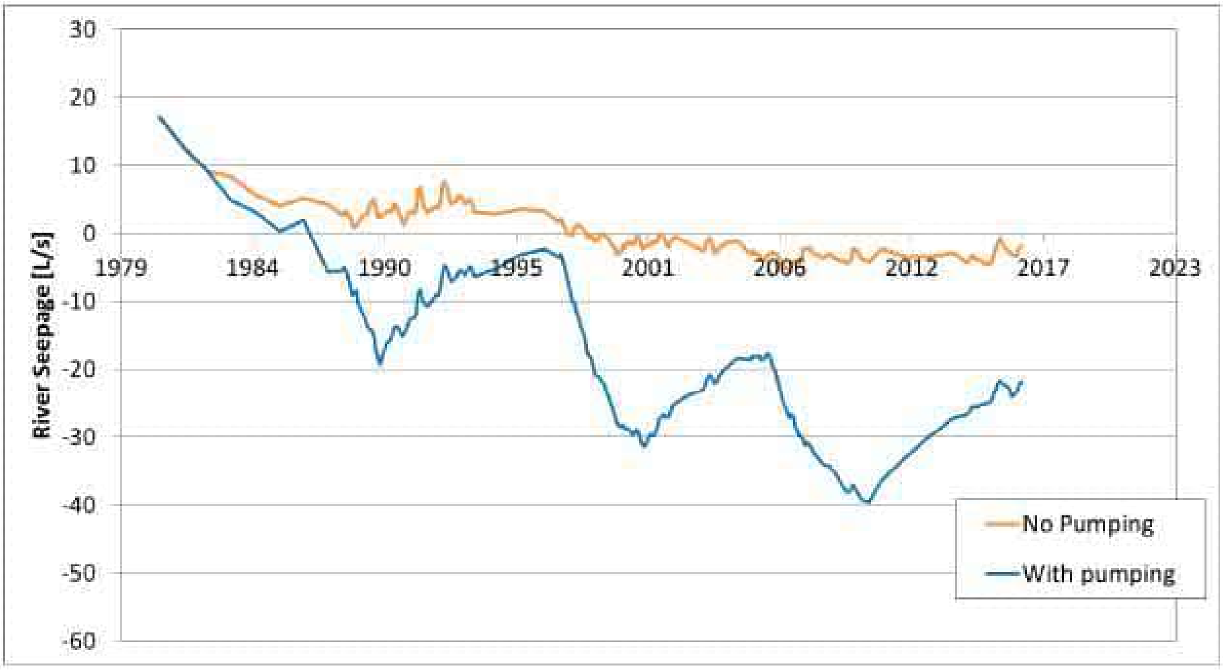


Figure 3-9. Modelled (predicted) baseflow contribution to Boundary Creek (Reach 2) with and without pumping (Jacobs 2018)

This connectivity between the groundwater and surface water is further demonstrated by the groundwater model (Jacobs, 2018). The combined extraction rate ranges up to 50 ML/day and there are periods of high extraction intermittently from 1983-1989, and consistently between 1998-2001 and 2006-2011 (Figure 3-8). Figure 3-9 shows the modelled river seepage for Boundary Creek Reach 2 during the period 1979-2016 under two different scenarios: “no pumping” and “with pumping”. Under the “no pumping” scenario, the river seepage declines steadily. Whereas under the “with pumping” scenario, the river seepage declines in a rebounding pattern, where the river seepage declines steeply and then partially recovers. Comparing Figure 3-8 with Figure 3-9 illustrates the likely impact of pumping in the Barwon Downs borefield on river baseflow. The trend in lost river seepage corresponds with periods of increased extraction. Overall, this demonstrates that the surface water in Boundary Creek Reach 2 upstream from Big Swamp is losing significant amounts of water to the groundwater when the Barwon bore field is under extraction.

3.1.8 ASS and water quality

Potential acid sulphate soils (PASS) form under reducing conditions in water logged soils, such as in submerged humous-rich soils. The reduced sulfur combines with any iron present to result in pyrite-containing acid sulphate soils (ASS) that remain inert and do not have a negative environmental impact unless they are exposed to air, in which case the pyrite minerals are oxidised and can release sulfuric acid. The introduction of this sulfuric acid into an aquatic system lowers the water pH which generally has negative impacts on the surrounding aquatic biomass.

The literature shows there have been significant declines in pH of surface water in Boundary Creek since 1999 (Jacobs 2017) and as early as 1993 (Gardiner, 2012). This decrease in pH was due to the drying of acid sulphate soils in Big Swamp. EAL (2011) found extremely high acidic soil conditions in areas of permanently or seasonally exposed wetland in Big Swamp and classified these soils as “Inland Acid Sulphate Soils”. Consistent with the effects of acid sulphate soils, the most significant changes in water quality occur through Big Swamp and included reduced pH, increased salinity, and increased concentrations of sulphate and dissolved metals. High flow conditions (> 15 ML/day) did not significantly dilute the acidic inputs or the concentration of dissolved metals.

A study conducted by Jacobs (2017) showed that groundwater quality was also affected by acid sulphate soils, particularly in the centre of the swamp, with the downstream swamp area less affected. However, the groundwater upstream of the swamp and in Reach 3 was almost unaffected by the negative consequences of the acid sulphate soils.

3.1.9 Soils

Jacobs were engaged in 2019 to undertake a program of soil sampling to a depth of 6 metres across 17 sites within Big Swamp. The sampling indicated that clays and silts are the dominant lithologies throughout the swamp with discrete sands present along the southern edge and western end. Clay was dominant through the upper reaches of the swamp, while in the lower reaches silt dominated. This is consistent with the occurrence of alluvial deposits (Jacobs 2019).

The majority of soil samples contained organic carbon, with 24% classified as mineral soils with organics, 43% as organic soils and 8% as peat (Jacobs 2019).

Charring and the occurrence of burnt material within soil profiles was limited to the upper 0.5 m of the soil profiles in cores taken towards the western portion of the swamp (Jacobs 2019). Soils that have been burnt in recent fires are characterised by a reddish humus, ash at ground level and embedded charcoal at varying depths (Jacobs 2015) Plate 1). On the terrace to the south of the swamp plain, and in the eastern end of the swamp, soils consistent of an extremely friable loamy sand to a depth of more than a metre (Plate 2).

Consistent with observations of peat soils made by Gibbons and Rowan (1993), the drying of the swamp has resulted in a collapse of pore structure and slumping. This has likely been exacerbated by sub-surface peat fires further reducing soil bulk density. This decline in structure may have led to erosion within the swamp as discussed in Section 3.1.4 above. The decline in soil structure has also likely impacted infiltration rates.

Plate 1. Soils within the swamp plain of Big Swamp

Plate 2. Soils from the terraces above the swamp plain

3.1.10 Fires

Reduced inflows and a lowering of the water table since groundwater extraction commenced has led to a drying of the surface and sub-surface layers within the swamp. The high carbon content in these soils (51% of soils sampled had an organic carbon content > 15%) can lead to ignition in low moisture conditions resulting in sub-surface fires smoulder for long periods of time. This increased susceptibility to prolonged and sustained burning is evident in the intermittent fires that have occurred within the swamp over the past 20 years. Soil sampling indicates that organic content and charring was most prevalent in the western half of the swamp correlating to the swamp plain and associated scrub communities.

In 1997, an escaped surface fire burnt over 1 hectare of the swamp resulting in the loss of mature trees and the presence of hot ash beds across the area. In 1997 and 1998, hazard reduction fires were ignited to secure the area, with a fire escaping from the swamp in May 1998.

A large (2m wide x 2m deep) trench was constructed along the southern and eastern edge of the Swamp to prevent further sub-surface fires escaping to surrounding areas. There was a long dry period between 1998 and 2006, with a small upstream fire occurring in 2006. The majority of the swamp was burnt intermittently between 1998 and 2010 (Jacobs, 2017). These fires have severely depleted organic-rich layers throughout the swamp and resulted in a substantial change in the structure and composition of the soils.

In 2010, SKM advised the local agencies that creating a dam to flood the area and control the subterranean fires could have negative environmental consequences such as further mobilisation of acidic sulphate soil and heavy metals into Boundary Creek. Sprinkler systems were installed along the southern edge of the swamp to contain the subterranean fire and prevent spread to surrounding areas during high fire risk periods.

3.2 Historic vegetation communities

3.2.1 Pre-European settlement

A palynological analysis of two cores taken from the western and eastern ends of the swamp is currently being undertaken by the University of Melbourne. This analysis may shed light on the nature of pre-European vegetation communities within the swamp. The results of this study will be incorporated into this assessment once completed in early 2020.

3.2.2 Pre-extraction

Information describing the nature and extent of vegetation within the swamp prior to extraction is limited. The primary source of reference are two aerial images taken in 1946 and 1969 along with descriptions of wetland and riparian vegetation communities from the region in the literature. Based on this information, these images appear to show three distinct vegetation communities within the swamp boundary prior to extraction commencing in 1983 (Figure 3-10 and Figure 3-11):

A. Homogenous, dense, low vegetation located within the central portion of the swamp, which may represent a scrub, sedge-, rush- or grassland community. Potential candidates include:
   - Wet-verge Sedgeland (EVC 932), as identified during the field survey (Section 3.3.1)
   - A low or open Riparian Fern Scrub community as described by Frood (2019).
   - A low sedge-dominated community similar to Sub-community 6.2: Pithy Saw-sedge (*Lepidosperma longitudinale*) Sedgeland or Sub-community 6.3: Fine Twig-sedge (*Baumea arthrophylla*) Sedgeland described from other swamps in the region (Carr and Muir 1994). An aerial image of sub-community 6.2 taken in 1993 is provided in Plate 3.
   - Alternatively, the low vegetation may be representative of a cleared and/or grazed swamp plain, which may explain the potential fence and/or drainage line, closely aligned with the current northern parcel boundary, visible in the 1946 image.

B. A homogenous, tall scrub at the western end of the swamp, likely comprised of *Melaleuca squarrosa* and *Leptospermum* species with a varied understorey of either sedges and/or ferns. This vegetation likely corresponds to the Riparian Fern Scrub community described by Frood (2019) and identified during the field survey in 2019. This community was previously included in forms of Riparian Scrub and Swamp Scrub, with the latter still being common in many contexts throughout the region. This community has also previously been described by Carr and Muir (1994) as Community 5.0: Scented

Paperbark (*Melaleuca squarrosa*) – Wholly Tea-tree (*Leptospermum lanigerum*) Swamp Forest or Scrub.

C. Damp woodlands of varying height and canopy cover along the southern edge and across the eastern end of the swamp. This vegetation type may in fact represent several distinct riparian and low-slope woodland or forest communities or ecotones. It is likely this vegetation type closely aligns with the 'Community 4.0 Swamp Gum (*Eucalyptus ovata*) Forest' described by Carr and Muir (1994) from Porcupine Creek, which occurs on "floodplains, particularly braided streams, swampy flats and swamp margins" with "organic rich, brown silty clay loams". Historically, the woodlands are likely to have supported several *Eucalyptus* species, including Swamp Gum, Manna Gum, Messmate and Brookers Gum, as could be elicited from dead stags still remaining and small pockets of woodland unaffected by the fires.

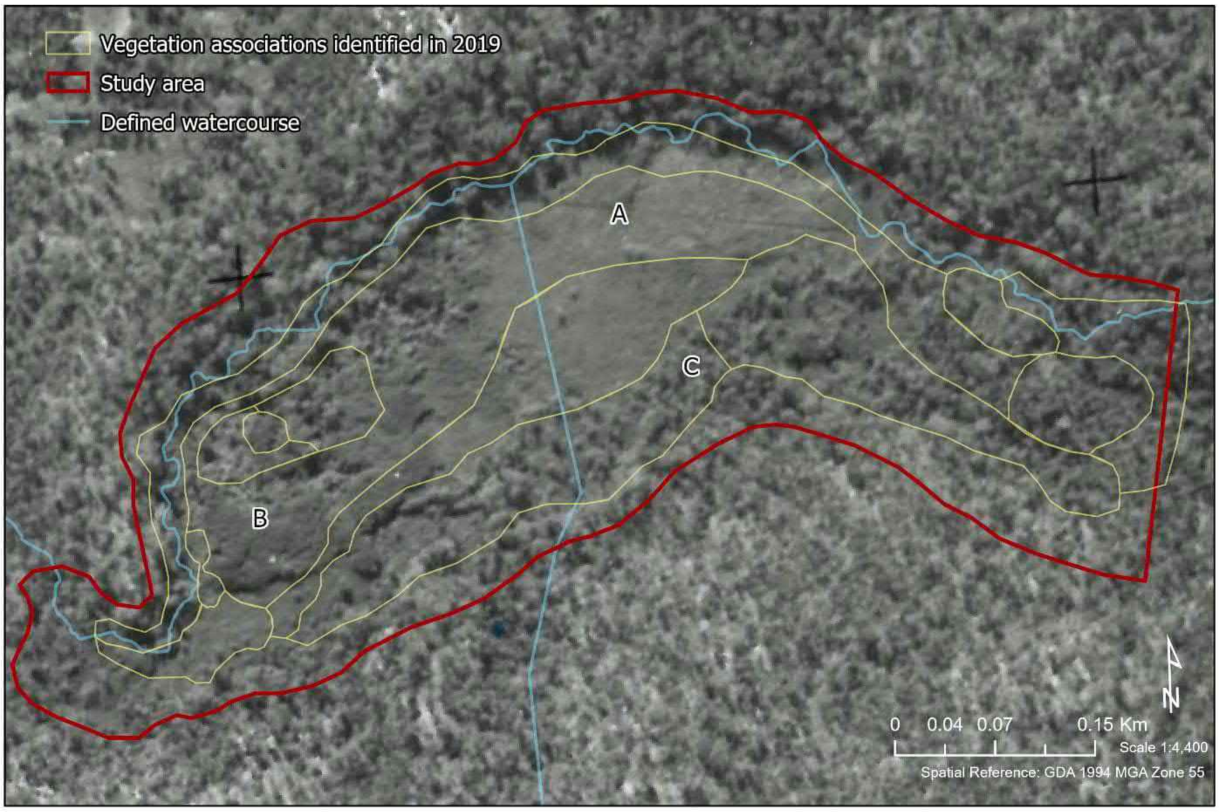


Figure 3-10. Aerial imagery of Big Swamp from 1946

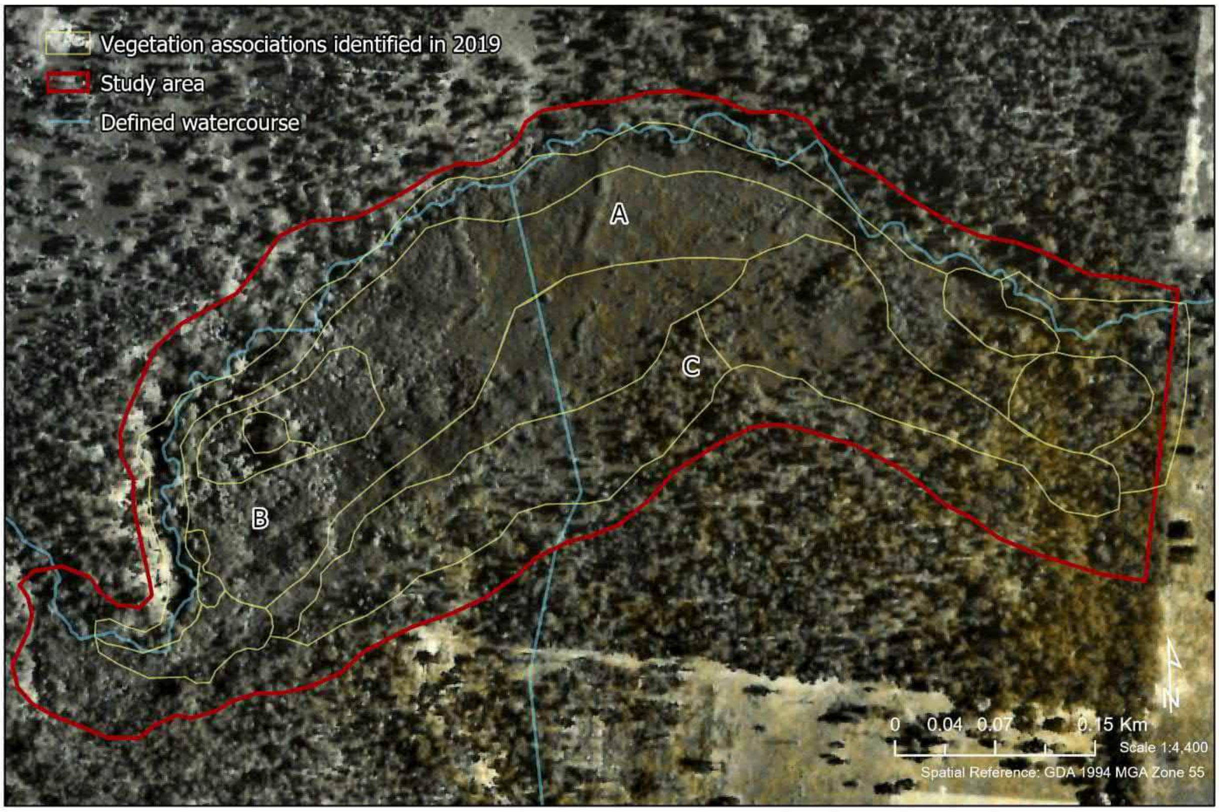


Figure 3-11. Aerial imagery of Big Swamp from 1969

Plate 3. Aerial photo of a Barwon Downs swamp dominated by Fine Twig-sedge (*Baumea arthrophylla*) (Carr and Muir 1994)

3.2.3 Post-extraction

Extraction from the Barwon Downs borefield commenced in 1983 however significant extraction did not occur until 1988 when 19,074 ML was extracted over a two-year period. Subsequently, large extraction events occurred between 1996 - 2001 (36,817 ML) and 2006 - 2010 (52,648 ML).

The nature and extent of vegetation within Big Swamp at the start of the extraction period can be elicited from aerial imagery capture in 1991 (Figure 3-12) and the vegetation surveys undertaken in 1993 by Carr and Muir (1994). Based on this, the following is assumed:

- Three main vegetation communities are present within the swamp at the start of the extraction period. As previously described in Section 3.3.2, this includes a dense scrub, sedge-, rush- or grassland community (A), a taller scrub community (B) and damp woodlands (C).
- A woodland community appears to have established along the main channel (D).
- There has been minor changes in the extent of each community over the past 40 year (i.e. 1946 to 1991), with tall scrub vegetation appearing to have expanded eastwards into the central section of the swamp. There also appears to be a change in structure within the damp woodland community with a loss of large trees and a denser (potentially lower) canopy of young Eucalypts or scrub expanding throughout the area.

Over the next 15 years (1994 – 2010) the swamp underwent significant change due to reduced surface flows, as a result of groundwater extraction and the Millennium drought, and subsequent fires, first across the western end in 1998 and then through the centre of the swamp in 2010. The consequences can be seen in the substantial loss of vegetation cover across the western end of the swamp by 2004 and then throughout the entire swamp by 2011 (Figure 3-13 and Figure 3-14). At this point in time the vegetation communities within the swamp are assumed to be substantially modified and in a state of regeneration. It appears all trees have been burnt and either fallen or remained standing as dead stags, with the understorey likely to be restricted to a few native or introduced species adapted to colonisation in post-disturbance environments (e.g. Prickly Tea-tree and Austral Braken). An open water pool has formed at the eastern end of the swamp by 2011, potentially behind a sediment plug formed due to the erosion of exposed soils upstream.

With several wet years since the end of the drought in 2011, and cessation of fire within the swamp, vegetation has re-established across the area with immature woodland (A) and scrub (B) communities visible three years later in 2014 (Figure 3-15). Transect data recorded in 2015 from regenerating scrub provides an indication of the low diversity present within the swamp, with the only native species recorded being Swamp Gum, Prickly Tea-tree, Bracken and Annual Fireweed (*Senecio glomeratus*) (Jacobs 2015) (Plate 4).

The extent of the woodland and scrub communities still largely aligns with those seen pre-extraction, with the exception that the potential low scrub or sedgeland community (that may have been present in the center of the swamp) has been replaced by a modified scrub. Regeneration of scrub also appears to vary across the site, with low cover still visible through central sections of the swamp in 2016 (A; Figure 3-16). This may be cause by changed drainage patterns, due to post-fire erosion and collapse of soil layers, reducing water availability at these locations, or poor conditions for regeneration due to changes in soil or water chemistry.

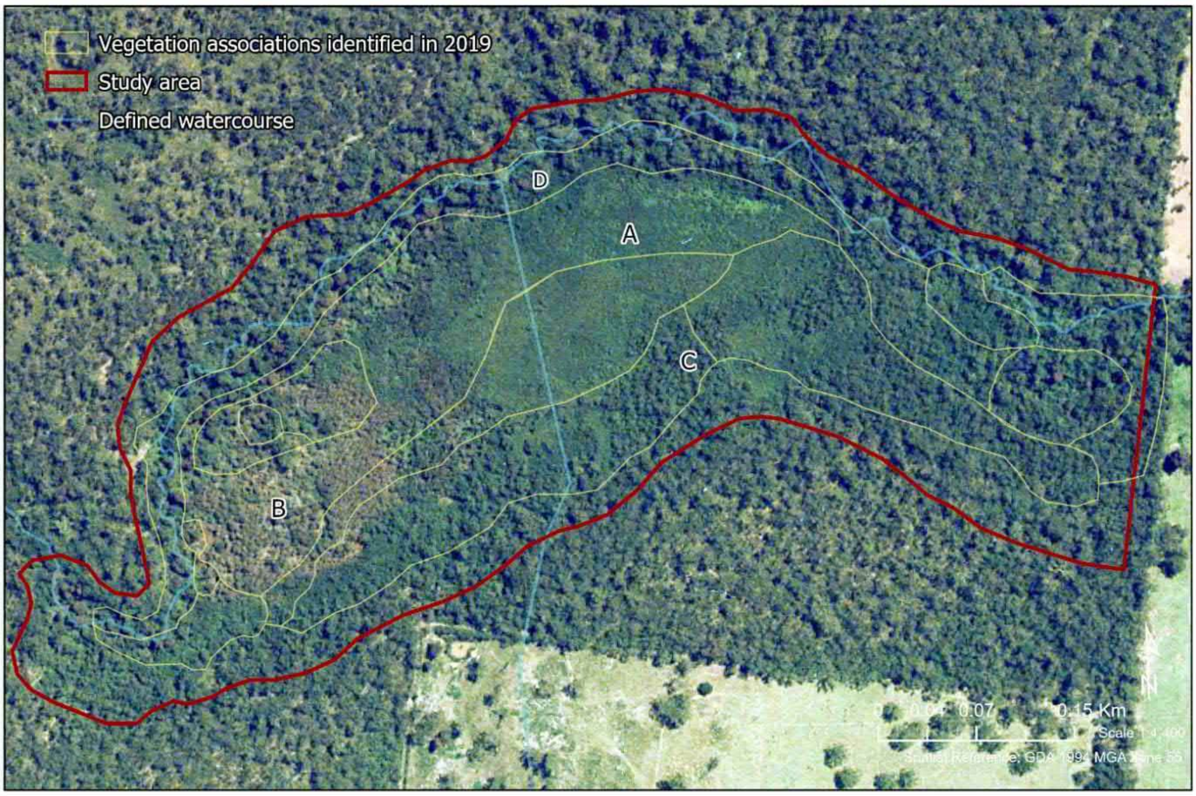


Figure 3-12. Aerial imagery of Big Swamp from 1991

Figure 3-13. Aerial imagery of Big Swamp from 2004

Plate 4. Scrub regrowth within the swamp post-fire (charred, moss covered soil present in foreground) (Jacobs 2015)

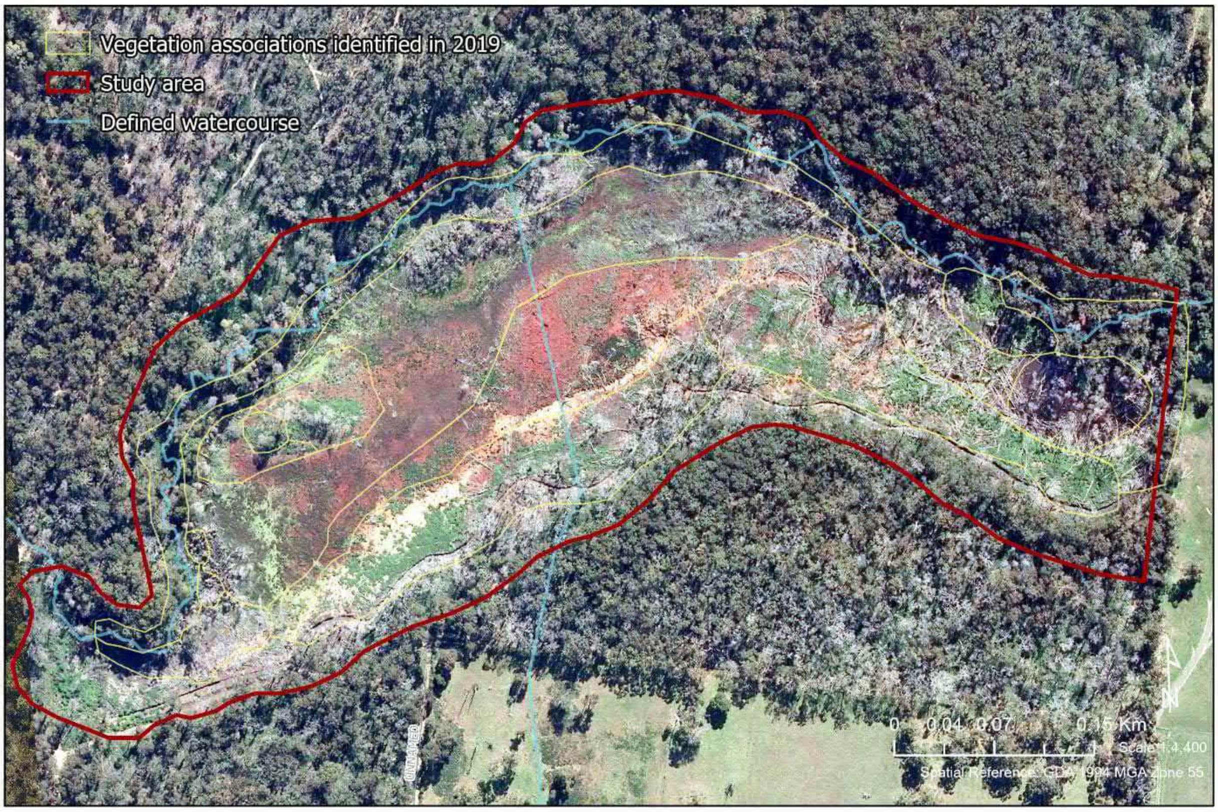


Figure 3-14. Aerial imagery of Big Swamp from 2011

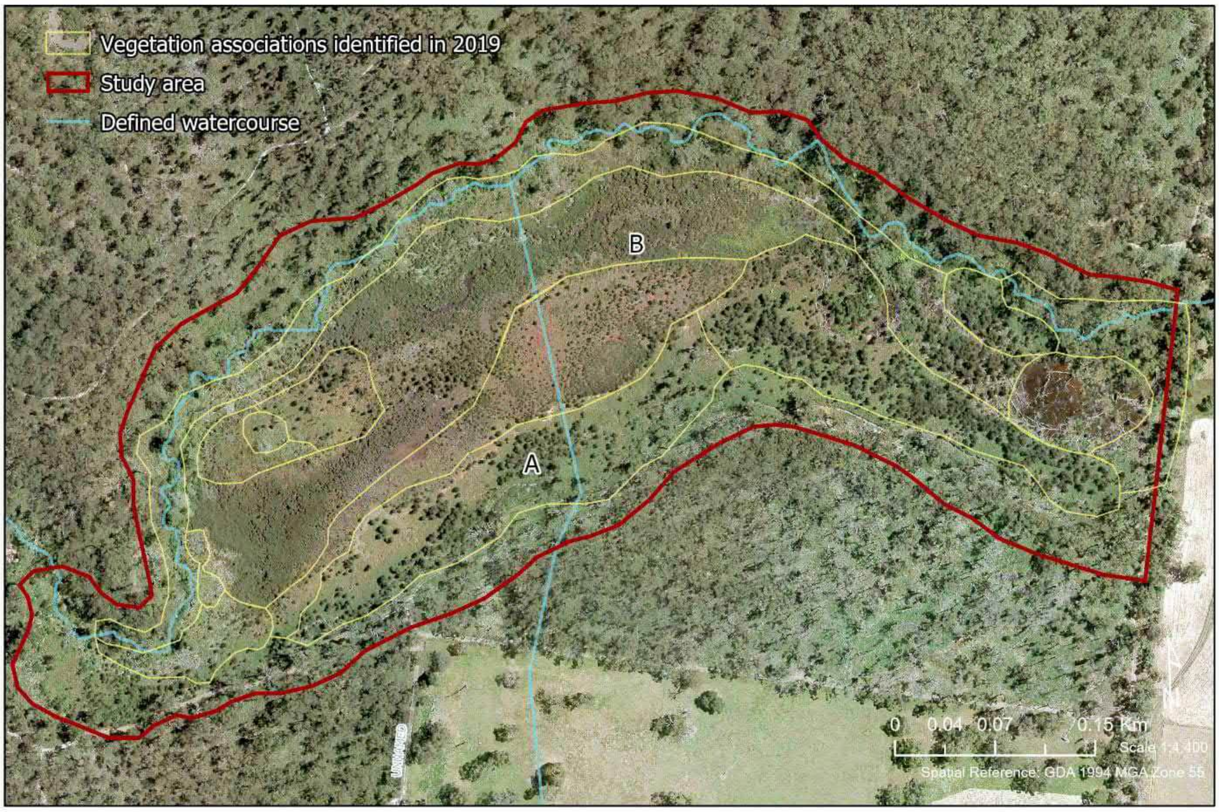


Figure 3-15. Aerial imagery of Big Swamp from 2014

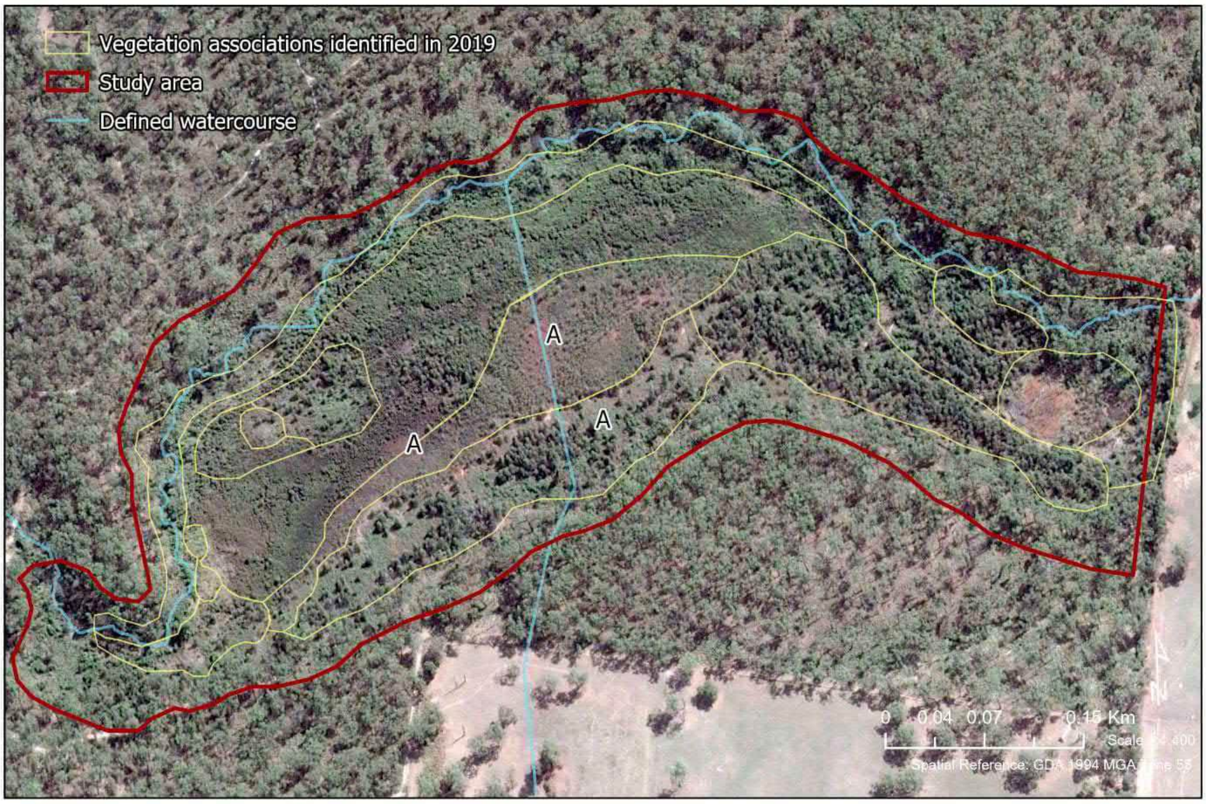


Figure 3-16. Aerial imagery of Big Swamp from 2016

3.3 Current vegetation communities

3.3.1 Vegetation communities

Ecological Vegetation Classes (EVCs) are broad groupings of plant communities that share similar geographic, climatic and edaphic conditions. Each EVC has an adopted benchmark that allows assessment of the approximate condition of the vegetation using the Vegetation Quality Assessment (VQA) method. However, the VQA only has limited benchmarks for wetland plant communities, despite there being a very wide diversity of wetland types across Victoria. In contrast, the Index of Wetland Condition assessment, which was only developed in the mid 2000’s, lists over 140 wetland benchmarks.

For this study, the chosen method was to utilise the Index of Wetland Condition benchmarks wherever possible, even if these are not assessable using the VQA. Four EVCs were recorded within the study area, one of which does not have a VQA benchmark (Wet Verge Sedgeland). These EVCs are described below.

Riparian Fern Scrub (EVC A120)

Riparian Fern Scrub is a recently described EVC that is distinguished from the similar Riparian Scrub by the taller canopy and more diverse ferny understorey. Riparian Fern Scrub is endangered and restricted to the Otway Ranges and possibly higher rainfall areas of the Gippsland Plain (Frood unpublished). This EVC was dominant throughout the study area where occurring on humous-rich soils influenced by the underlying perched watertable (Plate 5 and Plate 6).

The majority of the EVC has been significantly modified by reduced surface flows and subsequent fires which burnt deeply into the soil, leading to loss of humous layers, collapse of soil structure and significant soil erosion. This process very likely removed much of the original ground layer vegetation. The most heavily affected areas were dominated by Prickly Tea-tree (*Leptospermum continentale*) or Scented Paperbark (*Melaleuca squarrosa*) with occasional patches of Austral Bracken (*Pteridium esculentum*) and/or Red-fruit Saw-sedge (*Gahnia sieberiana*), with very minimal associated ground-layer species. More intact patches occurred in the far south-west of the study area in areas apparently less affected by the fires, containing Woolly Tea-tree (*Leptospermum lanigerum*) and a ground layer dominated by various sedges such as Tall Sedge (*Carex appressa*) and Tassel Sedge (*Carex fascicularis*). Areas closer to the main channel contained a braided system of channels and supported a higher cover of sedges and ferns, including additional species such as Spreading Rope-rush (*Empodisma minus*) and Scrambling Coral-fern (*Gleichenia microphylla*). Many of the understorey species, particularly patches of *Carex* and *Gahnia,* had recently died, possibly the result of acid-sulphate conditions. Weed cover was generally very low throughout the EVC.

Three vegetation associations were identified for this EVC (Table 3-1 and Figure 3-17).

Table 3-1. Riparian Fern Scrub vegetation associations identified within Big Swamp in 2019

Vegetation associations	Description	Floristic diversity	Structural diversity	Dominant species
High-diversity riparian fern scrub (RFS120-A)	A structurally and floristically complex riparian scrub exhibiting a diversity of fine-scale variation.	High	Moderate-high	Woolly Tea-tree (*Leptospermum lanigerum*), Tall Sedge (*Carex appressa*), Tassel Sedge (*Carex fascicularis*)

Vegetation associations	Description	Floristic diversity	Structural diversity	Dominant species
Dry riparian fern scrub (RFS120-B)	Dense to open scrub with a ground layer of Bracken, occasional emergent *Eucalyptus ovata*.	Low	Low-moderate	Prickly Tea-tree (*Leptospermum continentale*), Scented Paperbark (*Melaleuca squarrosa*), Austral Braken (*Pteridium esculentum)*
Wet riparian fern scrub (RFS120-C)	Dense scrub with little or no understorey, interspersed with narrow channels supporting a low-diversity of sedges and ferns. Occasional emergent *Eucalyptus ovata.*	Low-moderate	Low-moderate	Prickly Tea-tree (*Leptospermum continentale*), Scented Paperbark (*Melaleuca squarrosa*), Red-fruit Saw-sedge (*Gahnia sieberiana*)

Swampy Riparian Woodland (EVC 83)

Swampy Riparian Woodland occurred along the channel and adjacent terraces of Boundary Creek and shared a broad ecotone with the adjacent Riparian Fern Scrub (Plate 7). This vegetation contained a scattered tree layer, which may be reduced in cover due to past fires, dominated by Swamp Gum (*Eucalyptus ovata*)*,* Brooker's Gum (*Eucalyptus brookeriana*) and Manna Gum (*Eucalyptus viminalis*). There was often a secondary tree layer containing Woolly Tea-tree (*Leptospermum lanigerum*), Hazel Pomaderris (*Pomaderris aspera*) and Scented Tea-tree (*Melaleuca squarrosa*). The creek channel supported aquatic and semi-aquatic forbs and sedges including Common Water-ribbons (*Cycnogeton procerum*), Wing Pennywort (*Hydrocotyle pterocarpa*), Broad Water-milfoil (*Myriophyllum amphibian*), Small River Buttercup (*Ranunculus amphitrichus*) and Tassel Sedge (*Carex fascicularis*). Ferns dominated some areas, with prominent species including Fishbone Waterfern (*Blechnum nudum*), Hard Water-fern (*Blechnum wattsii*), Soft Tree-fern (*Dicksonia antarctica*) and Scrambling Coral-fern (*Gleichenia microphylla*). Weed cover was generally low along the channel although the riparian terraces contained grassy weeds such as Yorkshire Fog (**Holcus lanatus*).

Two vegetation associations were identified for this EVC (Table 3-2 and Figure 3-17).

Table 3-2. Swampy Riparian Woodland vegetation associations identified within Big Swamp in 2019

Vegetation associations	Description	Floristic diversity	Structural diversity	Dominant species
High-diversity Swampy Riparian Woodland (SRW83-A)	Following the main channel, this structurally and floristically complex riparian woodland exhibits a diversity of fine-scale variation.	High	High	Swamp Gum (*Eucalyptus ovata*), Brooker's Gum (*Eucalyptus brookeriana*), Woolly Tea-tree (*Leptospermum lanigerum*), Hazel Pomaderris (*Pomaderris aspera*), Common Water-ribbons (*Cycnogeton procerum*), Soft Tree-fern (*Dicksonia antarctica*)
Flooded Swampy Riparian Woodland (SRW83-B)	A flooded section of woodland with only dead stags persisting. Wetland and aquatic vegetation has begun to colonise shallow sections.	Low	Low	N/A

Wet Verge Sedgeland (EVC 932)

Wet Verge Sedgeland is a tussock dominated sedgeland found in cooler areas of Victoria (DELWP 2016). A small area of this EVC was mapped in the western portion of the study area to the east of Boundary Creek (Plate 8). The patch shared floristic affinities with the adjacent Riparian Scrub but woody species were mostly absent and the vegetation was dominated by relatively dense Tall Sedge (*Carex appressa*) and Tassel Sedge *(Carex fascicularis*). Associated species included White Purselane (*Montia australasica*), Common Spike-sedge (*Eleocharis acuta*), Rushes (*Juncus* spp.) and Slender Knotweed (*Persicaria decipiens*).

A single vegetation association was identified for this EVC (Table 3-3 and Figure 3-17).

Table 3-3. Wet Verge Sedgeland vegetation association identified within Big Swamp in 2019

Vegetation associations	Description	Floristic diversity	Structural diversity	Dominant species
Wet Verge Sedgeland (WVS932-A)	A dense, low sedgeland with a diverse, but low cover of rushes and herbs throughout.	Moderate	Low	Tall Sedge (*Carex appressa*) and Tassel Sedge *(Carex fascicularis).*

Damp Sands Herb-rich Woodland (EVC 3)

A large area that was predominately distributed on the lower slopes to the south and east of the main swamp was dominated by young Swamp Gum (*Eucalyptus ovata*) with a very species-poor understorey containing Austral Bracken (*Pteridium esculentum*) and Red-fruit Saw-sedge (*Gahnia sieberiana*) (Plate 9). Whilst this community has been described as Damp Sands Herb-rich Woodland due to its current structural and floristic characteristics (which is likely a result of changes in hydrology and recent fires), this vegetation is considered to represent a derived state of the Community 4.0 Swamp Gum (*Eucalyptus ovata*) Forest described by Carr and Muir (1994). This community has been identified throughout the region on the lowest slopes in association with braided streams, swampy flats and swamp margins, and is believed to have occupied the southern margin and eastern end of Big Swamp prior to extraction commencing.

Two vegetation associations were identified for this EVC (Table 3-4 and Figure 3-17).

Table 3-4. Damp Sands Herb-rich Woodland vegetation associations identified within Big Swamp in 2019

Vegetation associations	Description	Floristic diversity	Structural diversity	Dominant species
Modified, open Damp Sands Herb-rich Woodland (DSHW3-A)	A highly modified, immature woodland comprised of small stands of recruiting Swamp Gum interspersed with open, treeless areas of Austral Braken.	Low	Low	Swamp Gum (*Eucalyptus ovata*) and Austral Braken (*Pteridium esculentum)*
Modified, closed Damp Sands Herb-rich Woodland (DSHW3-b)	A modified, dense woodland of recruiting Swamp Gum. While generally supporting a limited understorey, small pockets of diversity were observed throughout.	Low-moderate	Low-moderate	Swamp Gum (*Eucalyptus ovata*), Austral Braken (*Pteridium esculentum) and* Prickly Moses (*Acacia verticillata*)

Lowland Forest (EVC 16)

Lowland Forest surrounded Big Swamp upslope from areas historically effected by water-logging or inundation (Plate 10). This vegetation was dominated by Messmate Stringybark (*Eucalyptus obliqua*) and Manna Gum (*Eucalyptus viminalis*) with a high cover of Austral Bracken (*Pteridium esculentum*). Prominent shrubs included Silver Banksia (*Banksia marginata*), Prickly Moses (*Acacia verticillata*), Sweet Bursaria (*Bursaria spinosa*) and Grey Tussock-grass (*Poa sieberiana* var. *hirtella*).

A single vegetation association was identified for this EVC (Table 3-5 and Figure 3-17).

Table 3-5. Lowland Forest vegetation association identified within Big Swamp in 2019

Vegetation associations	Description	Floristic diversity	Structural diversity	Keystone species
Lowland Forest (LF16-A1)	A diverse woodland with varied canopy cover dominating the drained, eastern-most edge of the swamp. Likely colonised the area due to draining of the swamp downstream.	High	High	Brooker's Gum (*Eucalyptus brookeriana*), Hazel Pomaderris (*Pomaderris aspera*), Soft Tree-fern (*Dicksonia antarctica*)

Plate 5. Riparian Fern Scrub EVC (dry association)

Plate 6. Riparian Fern Scrub EVC (wet association)

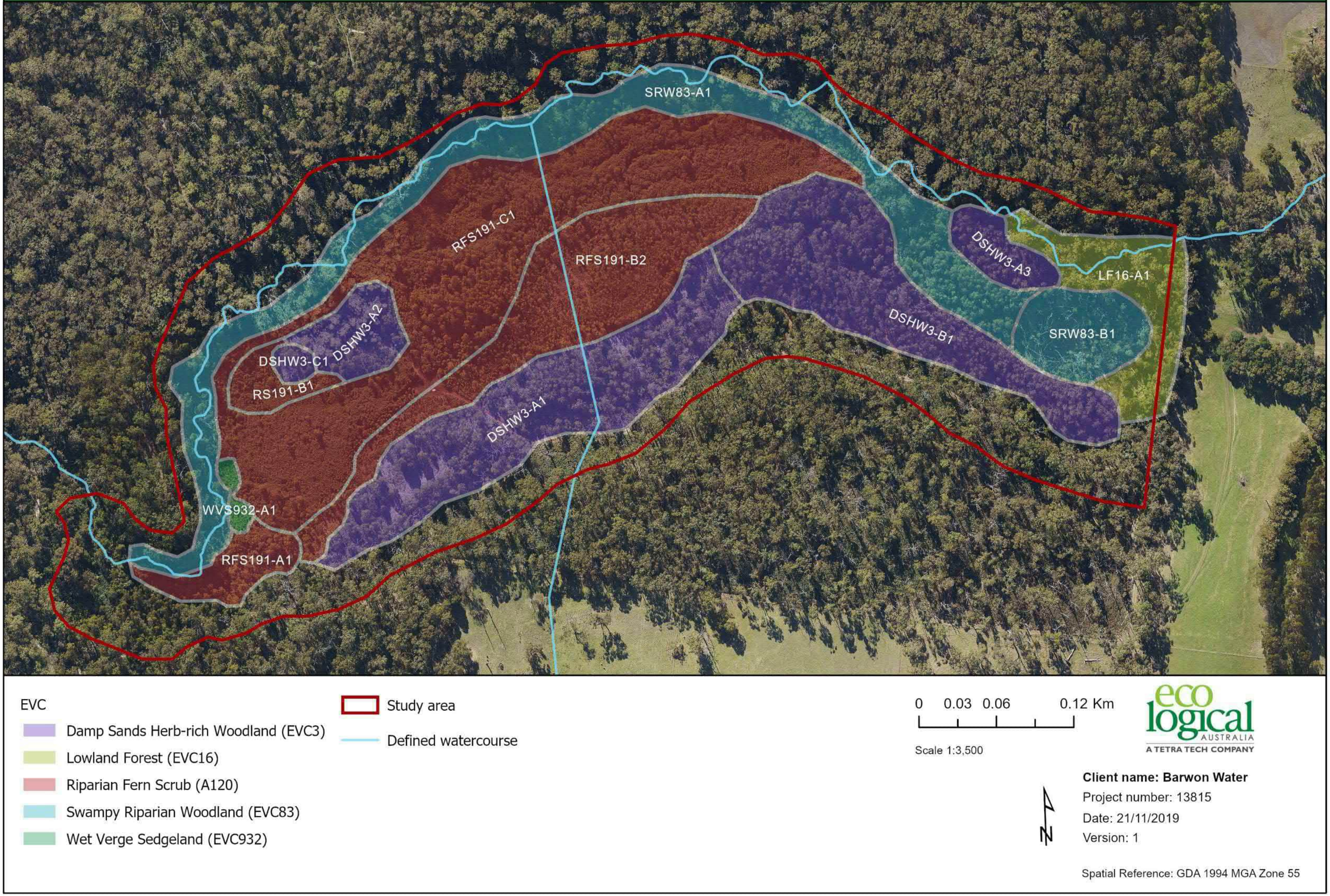
Plate 7. Swampy Riparian Woodland EVC

Plate 8. Wet-verge Sedgeland EVC

Plate 9. Damp Sands Herb-rich Woodland EVC

Plate 10. Lowland Forest EVC

Figure 3-17. Current Ecological vegetation Classes and associations in Big Swamp (2019)



3.3.2 Wetland vegetation condition

The condition of wetland communities within Big Swamp was assessed using the IWC method, as described in Section 2.2.1. As this method is only applicable to wetland EVCs for which an IWC benchmark exists, the assessment was limited to areas of Riparian Fern Scrub and Wet-verge Sedgeland with the study area.

Some challenges to applying the IWC method at Big Swamp were encountered, as the wetland has been affected by some uncommon processes which are difficult to apply to the assessment. For example:

- the IWC does not consider acid sulphate conditions,
- severe sub-surface fires as has occurred at Big Swamp are rare in Victoria, and the resulting effects on soil and bathymetry are not well covered in the assessment.
- the effects of the fires in reducing wetland extent are difficult to accurately assess, and
- assessing the hydrological changes to groundwater wetlands can be challenging without long-term bore data.

Following discussion with one of the lead authors of the IWC, consultant ecologist Doug Frood (who has also recently conducted a survey at Big Swamp [Frood 2017]), the following measures were adopted for the current assessment:

- The process of the sub-surface fire effectively reducing organic layers within the soils and the associated wetland vegetation has been considered a ‘reduction in wetland area’.
- The effect of drying and sub-surface fires, and subsequent decline of soil bulk density has been considered a change in bathymetry.
- The apparent change from a near permanently saturated (boggy) wetland to a much drier state has been considered a change to both the season of inundation and the water regime category.
- The acid sulphate conditions have been assessed using the water properties sub-index, and the salinity change was considered high, even though this measure normally relates to an increase in Electrical Connectivity (EC).
- Large areas of Prickly Tea-tree in the areas affected by the fires were considered invasive and part of an ‘altered process’ rather than a component of EVC Riparian Fern Scrub.

Given the above assumptions, the overall IWC score for Big Swamp was 5, which has a linguistic descriptor of ‘moderate’ (Table 3-6). The assessment scores are provided in Appendix C with the results of each sub-index discussed below. Vegetation condition across the wetland is shown in Figure 3-18.

Wetland Catchment

The Wetland Catchment sub-index received a score of 18, which has a linguistic descriptor of ‘Excellent’. This high score resulted from the fact that the wetland buffer (250m from wetland edge) of Big Swamp is predominately nature conservation reserve, with a small percentage (approximately 20%) comprised of low-density grazing.

Table 3-6. Index of Wetland Condition results for Big Swamp, September 2019

Wetland	**Big Swamp**			
Bioregion	Otway Plain			
Sub-index	**Score**	**Condition Category**	**Weight**	**Adjusted score**
Wetland catchment	18	Excellent	0.26	4.68
Physical form	8.75	Poor	0.08	0.70
Hydrology	0	Very Poor	0.31	0.00
Water properties	7	Poor	0.47	3.29
Soils	6	Poor	0.07	0.42
Biota	13.72	Moderate	0.73	10.02
Total				**19.11**
Overall IWC Score		**Moderate**		**5**

Physical Form

The Physical Form sub-index received a score of 8.75, which has a linguistic descriptor of 'Poor'. This score resulted from reduction of the original wetland area by approximately 45%, caused by hydrological change and subsequent fires, as well as a major change to the wetland bathymetry caused by post-fire erosion and soil collapse and the cutting of a channel on the southern side.

Hydrology

The Hydrology sub-index received a score of 0, which has a linguistic descriptor of 'Very Poor'. This score resulted from the fact that there has been a change to the season of inundation (from inundated-boggy for most of the year to only seasonally inundated) and a change in the water regime category (from 'permanent to 'periodically inundated').

Water Properties

The Water Properties sub-index received a score of 7, which has a linguistic descriptor of 'Poor'. This score resulted from the fact that there has been only low nutrient enrichment (e.g. from feral pigs and agricultural runoff within the catchment), however the change to salinity levels was scored as 'high' due to the acid sulphate conditions. Note that the salinity assessment normally relates to an increase in Electrical Connectivity (EC), but because there is no sub-index within the IWC to assess the impact of acid sulphate soils this was considered the best way to assess this measure (Doug Frood pers. comm. December 2019).

Soils

The Soils sub-index received a score of 6, which has a linguistic descriptor of 'Poor'. This index scored poorly due to the altered state of the soil layer caused by previous sub-surface fires.

Biota

The Biota sub-index received a score of 13.72, which has a linguistic descriptor of 'Moderate'. This score was a combination of the loss of canopy and understorey species from areas of dry Riparian Fern Scrub in degraded parts of the swamp, combined with less impacted wet associations and intact remnants persisting at the western end of the swamp. Weed cover was low across the wetland.

Discussion of IWC results

Although only a rapid assessment method, the IWC assessment provided a snapshot of the overall health of Big Swamp, highlighting the ecological health of separate components of the system. It is apparent from the results that the changes in hydrology and subsequent fires have been one the largest contributors to reducing the condition score, through depleting the diversity and cover of indigenous species and causing severe impacts to the soil structure and health. Although large parts of the wetland have been significantly modified, the overall score of the wetland was increased due to the presence of an intact buffer and catchment, low weed cover throughout the wetland and the presence of some areas of the wetland that are still in moderate condition.

With regards to the condition of specific vegetation associations mapped in the swamp, the IWC assessment shows a marked decline in vegetation structure and health within the Dry Riparian Fern Scrub association (RFS120-B) on the southern edge of the swamp plain (Table 3-7; Figure 3-17). This is likely attributed to poor recovery post-fire resulting in a reduced canopy cover and loss of understorey lifeforms. Whilst severely impacted by a range of soil and water quality issues, the wet Riparian Fern Scrub association (RFS120-C) in the swamp plain still contained a diversity of life forms and structures and scored relatively high on the biota sub-index. Despite this, the relative cover of lifeforms across this association was poor when compared to the areas of high-diversity Riparian Fern Scrub (RFS120-A) and Wet-verge Sedgeland (WVS932-A) remnants at the western end of the swamp plain.

Table 3-7. Biota condition scores for wetland community associations in Big Swamp

	Vegetation association	Riparian Fern Scrub (RFS120-A)	Riparian Fern Scrub (RFS120-B)	Riparian Fern Scrub (RFS120-C)	Wet-verge Sedgeland (WVS932-A)
	Max. Score	*Score*	*Score*	*Score*	*Score*
Critical Life form groupings	25	21.90	6.25	21.90	19.37
Weeds	25	22	22	22	25
Indicators of altered processes	25	20	5	10	25
Vegetation structure and health	25	25	0	20	25
EVC Sub-total	**100**	**88.90**	**33.25**	**73.90**	**94.37**

3.3.3 Terrestrial vegetation condition

The condition of terrestrial woodland communities within Big Swamp was assessed using the VQA assessment method, as described in Section 2.2.1. The assessment results are provided in Appendix C with a summary presented in Table 3-8. Vegetation condition across the wetland is shown in Figure 3 18.

Terrestrial woodland communities varied considerably in condition across the swamp, with the primary difference being the site condition scores. The area of high-diversity Swampy Riparian Woodland (SRW83-A; Figure 3-17) along the main channel was assessed as being in the best condition, due to its diverse understorey containing a range of lifeforms, presence of large trees in the canopy layer and ongoing recruitment. In comparison, the flooded Swampy Riparian Woodland association (SRW83-B) associated with the open water area in the east of the site had a limited understorey containing primarily rushes and no effective canopy layer.

The primary difference between the two Damp Sands Herb-rich Woodland associations was the greater diversity in the understorey in DSHW3-B, largely attributed to a sparse but present shrub layer which was absent from DSHW3-A. DSHW3-B also supported enough mature trees to achieve a canopy cover score.

Logs scored high across woodland associations due to the prevalence of fallen, burnt trees, with the exception of DSHW3-A. This may be due to the higher frequency of surface and sub-surface fires in this part of the swamp.

All vegetation associations received the same, relatively high, landscape context score due to being within a contiguous patch of bushland connected to a large 'core area' extending northward from the Otway Forest Park.

Table 3-8. Vegetation quality assessment conditions scores for terrestrial woodland associations within Big Swamp

VQA component	Benchmark score	DSHW3-A	DSHW3-B	SRW83-A	SRW83-B
EVC		**Damp Sands Herb-rich Woodland (EVC3)**	**Damp Sands Herb-rich Woodland (EVC3)**	**Swampy Riparian Woodland (EVC83)**	**Swampy Riparian Woodland (EVC83)**
Bioregion		Otways Plain	Otways Plain	Otways Plain	Otways Plain
Condition scores	**75**	**30**	**45**	**58**	**25**
Large trees	10	0	0	6	0
Tree Canopy Cover	5	0	2	3	0
Understorey	25	5	15	20	5
Lack of weeds	15	13	13	9	9
Recruitment	10	5	5	10	3
Organic litter	5	5	5	5	3
Logs	5	2	5	5	5
Landscape scores	**25**	**17**	**17**	**17**	**17**
Patch size	10	8	8	8	8
Neighbourhood	10	4	4	4	4
Distance to core area	5	5	5	5	5
Total	**100**	**47**	**62**	**75**	**42**

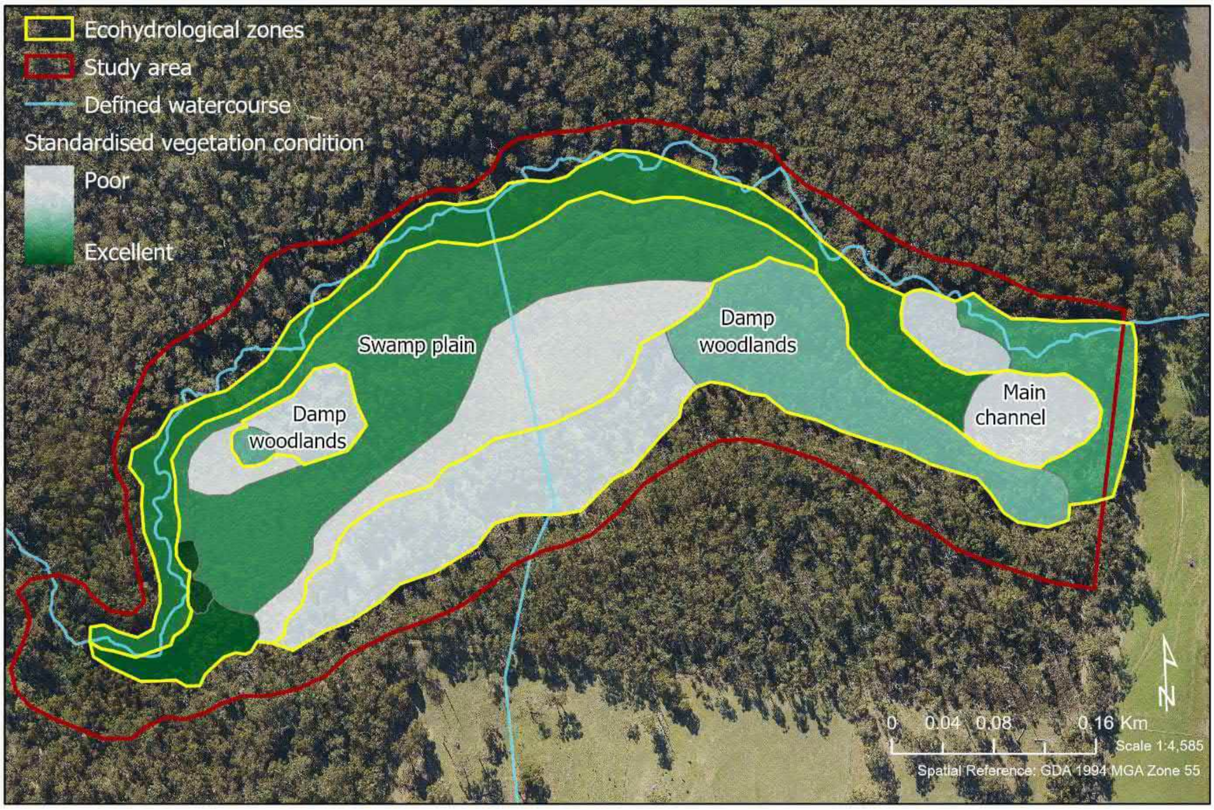


Figure 3-18. Vegetation condition across Big Swamp based on IWC and VQA assessment methods

3.3.4 Biodiversity

During the September 2019 flora survey, a total of 108 vascular plant species were recorded across the study area, including 91 (84%) that are indigenous and 17 (16%) that are introduced (Appendix A). Floristic diversity was generally higher in the western section of the site and along the main channel, whereas the central areas most heavily affected by the reduced surface flows and subsequent fires supported only limited plant diversity.

Of the flora species recorded, five are listed as threatened under the Victorian Advisory List (DEPI 2014), although two of these require flowering material to confirm the identification.

Slender Bitter-cress (*Cardamine tenuifolia*)

One plant of Slender Bitter-cress was recorded on swampy flats adjacent to Boundary Creek in the far western portion of the study area (EVC Swampy Riparian Woodland). This species is listed as ‘poorly known’ in Victoria and there are very few other records for the region. Slender Bitter-cress typically grows in sedgy-herbaceous vegetation of swamps and creek-lines.

Current-wood (*Monotoca glauca*)

Numerous plants of Current-wood were recorded on the slopes to the north of Big Swamp and Boundary Creek within EVC Lowland Forest. This species is listed as ‘rare’ in Victoria and has been recorded at numerous localities in the Otways region. Current-wood is distributed throughout a range of forested habitats.

Small Sickle Greenhood (*Pterostylis lustra*)

Several leaf rosettes were recorded beneath dense Woolly Tea-tree thickets in the north-western section of the study area that are believed to be Small Sickle Greenhood (*Pterostylis lustra*). This assumption is based on the morphology of the leaves, the fact that very few other greenhoods grow in similar swampy habitats and the presence of nearby database records. However, examination of flowering specimens is required to confirm the identification. Small Sickle Greenhood is listed as 'endangered' in Victoria and as threatened under the *Flora and Fauna Guarantee Act*. The species is only recorded elsewhere in Victoria from similar swampy habitats typically dominated by Woolly Tea-tree (Vicflora online 2019). If the species is present within the swamp, it is very likely that the population was heavily impacted by previous fire events.

Showy Lobelia (*Lobelia beaugleholei*)

Several plants of what was presumed to be Showy Lobelia were recorded along Boundary Creek and adjacent swampy flats in the western portion of the study area. Although the leaf shape matched the species, flowering material would be required to confidently identify this species from other closely related taxa within the Campanulaceae family. Show Lobelia is listed as 'rare' in Victoria and has been recorded on Boundary Creek less than one kilometre from the western end of the study area.

Brooker's Gum (*Eucalyptus brookeriana*)

Several large trees of Brooker's Gum were recorded along Boundary Creek in the eastern section of the site. This species is similar to Swamp Gum but can be distinguished by the taller form, cordate juvenile leaves and discolorous adult leaves. Brooker's Gum is listed as 'rare' in Victoria where it is only known from two disjunct localities, including the northern Otways and Daylesford-Trentham area.

Table 3-9. Summary of listed threatened species recorded within the study area in September 2019

Scientific name	Common name	Status
Cardamine tenuifolia	Slender Bitter-cress	Poorly Known in Victoria
Eucalyptus brookeriana	Brooker's Gum	Rare in Victoria
Lobelia beaugleholei	Showy Lobelia	Rare in Victoria
Monotoca glauca	Current-wood	Rare in Victoria
Pterostylis lustra	Small Sickle Greenhood	Endangered in Victoria, Listed on FFG Act

Fauna

Big Swamp and the surrounding forest contained extensive habitat for various fauna species. A total of 49 fauna species were recorded incidentally during the assessment, including 41 bird, five mammal (three of which are introduced), two frog and one crustacean species (Appendix A). Birds were noted to be relatively abundant during the assessment, with many Crescent Honeyeater (*Phylidonyris pyrrhopterus*) feeding on flowering Swamp Gum (*Eucalyptus ovata*) throughout the swamp. Of the recorded species, one is listed as threatened, this being the Rufous Bristlebird (Otways sub-species) (*Dasyornis broadbenti caryochrous*), listed as near threatened in Victoria and as threatened under the FFG Act. This species was observed near the central section of the swamp on two consecutive days and is likely resident within the study area. The Rufous Bristlebird prefers relatively dense near-coastal vegetation and is near the northern edge of its range limit at Yeodene. Burrows observed in swampy vegetation throughout part of the site possibly belong to a species of Burrowing Cray (*Engaeus* spp.), while the threatened Otways Cray (*Geocharax* gracilis) which has been recorded nearby likely occurs along Boundary Creek. Mammals recorded within the site included a low density of Eastern Grey Kangaroo (*Macropus giganteas*), whilst several feral pigs (*Sus scrofa*) were observed.

4. Ecohydrological analysis

4.1 Water requirements

A detailed description of the ecological vegetation classes identified during the field survey is provided in Section 3.3. This includes identification of dominant species for each vegetation association.

Using this information as the basis for the analysis, a detailed literature review has been conducted to identify water requirements at both a community and species level. The results of the literature review are presented in Table 4-1 (communities) and Table 4-2 (species).

4.2 Swamp hydrology

A detailed description of the physical conditions within the swamp, including hydrology, is provided in Section 3.1. The key surface and groundwater parameters for the swamp are presented below for both pre-extraction and post-extraction timeframes.

4.2.1 Pre-extraction

Prior to the installation of MacDonalds Dam in 1979 and subsequent extraction commencing in 1983, the hydrology of the swamp is assumed to be defined by:

- Seasonal rainfall patterns consisting of dry summers and wet winters. Annual average rainfall is assumed to be 600-700 mm.
- Below average rainfall between 1900 and 1950, switching to above average rainfall in the latter half of the century.
- Surface flows gaining water from the groundwater (baseflow) through Reach 2 prior to entering the swamp.
- Surface flows into the swamp ranging from 2ML/day lows in summer to 20ML/day highs in winter.
- Surface flows through the swamp are primarily focused in the main channel around the northern edge. Where flows exceeded the capacity of the channel, water moved through a series of fine, braided channels across the swamp plain in the eastern and central sections of the swamp. This broadly distributed flow converged with the main channel in the north of the site, before again flowing through a series of more confined channels in the eastern section of the swamp.
- Groundwater within the swamp was influenced by a clay aquitard which thins in the west of the site and is absent upstream of the swamp. As a result, surface water infiltration leads to development of localised perched aquifers, with the overlying alluvium and humous-rich substrates becoming saturated.
- Groundwater tables at or near the surface across much of the swamp, with seasonal variation of 1-2 metres in parts of the swamp.

- Complete drying of soils within the swamp very uncommon, with moisture ranging from saturated to damp throughout the year.

4.2.2 Post-extraction

Following the installation of MacDonalds Dam in 1979, extraction from the borefield commencing in 1983 and major droughts through much of the 1990s and 2000s, changes to the hydrology of the swamp are assumed to include:

- Below average rainfall as a result of drought events in 1982 and between 1995 and 2010 (i.e. the Millennium drought).

- Surface flows losing water to groundwater through Reach 2 prior to entering the swamp (loss of baseflows).

- Yearly cease-to-flow events in summer and reduced winter flows (<20ML/day). Noting that 2ML/day releases have prevented cease-to-flow events in recent years.

- Surface flows through the swamp remain in the main channel around the northern edge. Where flows exceed the capacity of the channel, water moves through the flood plain along a limited number of channels that have been scoured and deepened by increased rates of erosion and decline of soil structure following the numerous fire events. Flows through the swamp still converge with the main channel in the north of the site, before flowing through a narrow band of interconnected channels at the eastern end of the swamp.

- Groundwater across much of the swamp has dropped below 1 metre, with near-surface water table levels only persisting at the eastern-most end. Throughout much of the central and western sections of the swamp, water levels are below 2 metres. This represents an overall drop in the water table across the swamp of between 1 and 2 metres.

- Drying within the swamp has exposed acid-sulphate soils (ASS) down to a depth of 2 metres, with low pH surface and ground water, along with heavy metals, being released. Heavy iron flocculation covering inundated surfaces is also present.

Table 4-1. Water requirements of wetland communities identified within Big Swamp

Community	Description	Typical species	Ecohydrological requirements	Management considerations	Source
Riparian Fern Scrub (EVC 191) / Community 5.0: Scented Paperbark (*Melaleuca squarrosa*) - Woolly Tea-tree (*Leptospermum lanigerum*) Swamp Forest or Scrub	A dense tall shrubby vegetation with a primarily ferny ground-layer, associated with waterlogged and inundation-prone soils with a substantial organic content. Distinguished from Riparian Scrub (EVC 191) and Riparian Thicket (EVC 59) by greater height and more open and diverse ferny understorey. Distinguished from Swamp Scrub by being dominated by Scented Paperbark as well as by understorey character. Localised in the Otway Ranges and probably also higher rainfall parts of the Gippsland Plain (Frood, and Papas 2016).	Usually dominated by *Melaleuca squarrosa*, sometimes with *Leptospermum lanigerum*, with *Eucalyptus ovata* generally a relatively minor component where present. Ferns are conspicuous, variously including *Blechnum minus, Blechnum nudum, Blechnum wattsii, Dicksonia antarctica, Gleichenia microphylla, Histiopteris incisa, Hypolepis* spp.*, Pteris tremula* and *Todea barbara*. Other species variously include *Gahnia sieberiana, Tetrarrhena juncea, Isolepis inundata, Cycnogeton procerum s.l., Gratiola peruviana, Juncus* spp. (notably *J. procerus* and *J. gregiflorus*), *Myriophyllum pedunculatum* and *Triglochin striatum* s.l. (Frood, and Papas 2016)	In this EVC, the inundation period is not necessarily continuous, varying with rainfall events. Inundation is mostly relatively superficial outside of flooding events but deep waterlogging from groundwater seepage can be more or less permanent. The extent of inundation is sometimes ambiguous due to soft saturated substrates (Frood, and Papas 2016). Comparable vegetation within region exhibits "water table seemingly at or near surface, with free water often present; subject to regular seasonal inundation - whole site could be flooded to c. 20 cm or more for weeks or months. Sites dominated by Woolly Tea-tree tend to have less frequent or briefer periods of inundation." (Carr and Muir 1994) This EVC is expressed continuously irrespective of seasonal changes to hydrology. **Inundation frequency:** Constant, annual or less frequent but before wetland dries. **Duration of waterlogging:** > 6 months **Duration of inundation:** < 6 months **Inundation depth:** Shallow (< 30 cm)	Protection from drainage and maintenance of groundwater levels are the main considerations relevant to the hydrological requirements of this EVC (Frood, and Papas 2016).	Frood, and Papas (2016), Carr and Muir (1994)
Swampy Riparian Woodland (EVC 83) / Community 4.0: Swamp Gum (Eucalyptus ovata) Forest	Eucalypt dominated woodland vegetation (in mosaic with scrub/reed-beds) associated with very low-gradient streams within areas subject to riparian processes. Typically constitutes linear wetland, but includes drier banks and levees, as for Floodplain Riparian Woodland. Scattered in moister lowland areas.	*Eucalyptus ovata* or *Eucalyptus camphora* subsp. *humeana*, variously *Leptospermum lanigerum*, *Melaleuca ericifolia* (southern Victoria only), *Phragmites australis, Persicaria decipiens, Calystegia sepium* subsp. *roseata, Acacia melanoxylon, Poa labillardierei* and *Poa ensiformis*.	The extent and frequency of inundation of this EVC varies with seasonal/annual rainfall. More prolonged inundation is usually restricted to the lower-lying portions, such as depressions derived from prior channels. Otherwise inundation is mostly relatively brief, following rainfall events, and not necessarily continuous over the wetter months. The habitat may remain waterlogged for substantial periods. Comparable vegetation within region is presumed to have "water table very near surface with some free water present, soil permanently boggy and seasonally inundated." (Carr and Muir 1994) This EVC is expressed continuously irrespective of seasonal changes to hydrology. **Inundation frequency:** Seasonal inundation (annual or near annual inundation) **Duration of waterlogging:** > 6 months **Duration of inundation:** < 6 months **Inundation depth:** Shallow (< 30 cm)	Management should be primarily about replicating patterns of natural flooding events, in conjunction with maintaining the water-table. It is important to allow natural drainage. If inundation is too sustained, the trees can be at risk of drowning Frood, and Papas (2016).	Frood, and Papas (2016), Carr and Muir (1994)
Damp-sands Herb Rich Woodland	A low, grassy or bracken-dominated eucalypt open forest or woodland to 15 m tall with a large shrub layer and ground layer rich in herbs, grasses, and orchids. Often presents as a somewhat intermediate between Heathy Woodland and other EVCs such as Herb-rich Foothill Forest. Frequently associated with a sand horizon deposited over older, more fertile soil/geology. Trees are able to access the deeper material via their root systems while smaller plants are confined to the less fertile upper layer, promoting heathy elements.	In higher rainfall areas of the Otways region grows in association with Messmate *E. obliqua* and Swamp Gum *E. ovata*. A few scattered shrubs may be present including Coast Beard-heath *Leucopogon parviflorus*, Prickly Moses *Acacia verticillata*, Sweet Bursaria *Bursaria spinosa*, Prickly Tea-tree *Leptospermum continentale*. The ground stratum is dominated by dense Austral Bracken *Pteridium esculentum* above a diversity of forbs, grasses and other graminoids.	Within the Midlands and Otways region Damp Sands Herb-rich Woodland occurs on deep sandy loams, usually associated with adjacent creeks or seasonal lakes and swamps. Effective rainfall is increased by the shallow water tables associated with the creeks that provide adequate moisture to support a rich ground layer of forbs and grasses, including many weed species. Due to its position in the landscape, on terraces above creeks or alluvial flats, aspect and rainfall are of little significance and the community is often ground water dependant. Inundation is not considered a driver for this community.	Maintenance of water tables is required to ensure damp soil conditions are maintained to support canopy species. Drying of surface layers can be tolerated by seasonal waterlogging is required to maintain species diversity in the long-term.	NRE (1999), Tumino and Roberts (1998)

Table 4-2. Water requirements of dominant species identified within Big Swamp

Species	Habitat	Waterlogging[1]			Inundation[1]				GW dependence[2] (Jacobs 2015)	Moisture dependence[3] (SKM 2009)	Summary of water requirements	EVC / vegetation association	References
		<1 month	1-6 months	>6 months	<1 month	1-6 months	>6 months	Permanent					
Acacia verticillata	Moist sandy or clay soils, foothill forests, damp woodlands and forests.	✓	✓		✓				2	3/4	Prefers moist, well-drained soil. Withstands periods of waterlogging and drying in summer. Will not tolerate periods of prolonged inundation.	Damp Sands Herb-rich Woodlands (EVC3)	Bull 2014, Yarra Ranges plant directory,
Blechnum minus	Forested areas, occurring in stream beds, along creek banks and on swamp margins, occasionally growing epiphytically on tree-fern trunks or fallen logs. Juvenile or sterile, suppressed adult plants are commonly found in swampy Tea-tree thickets and along heavily shaded stream margins.	✓	✓	✓					3	2	Moist to wet humus rich soil, tolerates inundation, full sun to semi shade. Roots must remain moist. Tolerates flood events but not inundation.	Riparian Fern Scrub (EVC 191) where inundation is largely absent, Swampy Riparian Woodland (EVC 83)	Vicflora 2019, Bull 2014
Blechnum nudum	Forested stream banks, in deeply shaded gullies and alluvial flats, occasionally in more exposed situations in poorly drained areas.	✓	✓	✓					3	2	Moist to wet humus rich soil, full sun to semi shade. Tolerates flood events but not inundation.	Riparian Fern Scrub (EVC 191) where inundation is largely absent, Swampy Riparian Woodland (EVC 83)	Vicflora 2019, Bull 2014, Yarra Ranges plant directory,
Carex appressa	Riparian, swamps, watercourses, and occasionally in water. Common along watercourses and in wettish depressions almost throughout the State.	✓	✓	✓	✓	✓			4	2/3	Permanent waterlogging. Seasonal flooding related to streamflow. Tolerates flow and periods of prolonged inundation.	Riparian Fern Scrub (EVC 191) where inundation is common, Swampy Riparian Woodland (EVC 83), Wet Verge Sedgeland (EVC 932)	Bull 2014, Vicflora 2019, Hamilton et al. 2013
Carex fascicularis	Edges of wetlands and creeks that are frequently flooded, bases are sometimes submerged, mostly in cooler lowland areas	✓	✓	✓	✓	✓			4	1/2	Moist soils, semi-shade, tolerating prolonged periods of inundation.	Riparian Fern Scrub (EVC 191) where inundation is common, Swampy Riparian Woodland (EVC 83), Wet Verge Sedgeland (EVC 932)	Romanowski 1998, Bull 2014
Dicksonia antarctica	Occurring mostly in forested areas of high rainfall, particularly in shaded gullies and near streams and waterfalls	✓	✓	✓					4	2/3	Moist humus-rich soils, in humid high rainfall areas, southerly and easterly aspects, semi-shade to full sun. Moist to wet soil, roots must remain moist. Does not tolerate inundation.	Swampy Riparian Woodland (EVC 83)	Bull 2014, Vicflora 2019, Yarra Ranges plant directory
Eucalyptus brookeriana	Occurs infrequently on wet sites in the Otway Ranges, commonly on alluvial deposits adjacent to streams and swamps.	✓			✓				4		Sites with relatively high rainfall and fertile soils. Tolerates infrequent water logging and inundation, however will not tolerate prolonged periods of water stress.	Damp Sands Herb-rich Woodlands (EVC3), Lowland Forest (EVC 16)	Vicflora 2019
Eucalyptus obliqua	Mainly a species of cool, well-watered mountain forests, but also common in sandy damp heaths.								2		Prefers seasonal damp soils tolerating periods of prolong drying. Will not persist under regular inundation patterns.	Damp Sands Herb-rich Woodlands (EVC3), Lowland Forest (EVC 16)	Vicflora 2019
Eucalyptus ovata	A widespread species which occurs in poorly drained infertile and clay which may dry out in summer. Prefers sands and clays of swampy flats and poorly drained slopes and hollows.	✓	✓		✓				4	3-4	Able to withstand flooding for several months, however will also grow on well drained sites.	Riparian Fern Scrub (EVC 191) as an emergent, Swampy Riparian Woodland (EVC 83), Damp Sands Herb-rich Woodlands (EVC3) in areas prone to inundation.	Yarra Ranges plant directory, Vicflora 2019
Eucalyptus viminalis	Deep moist loam soils, in valleys or low-lying areas.								3	4-5	Occurs mostly in wetter or seasonally well-watered areas. Tolerant of dry conditions however often dependant on ground water to meet water needs during periods of low rainfall.	Damp Sands Herb-rich Woodlands (EVC3), Lowland Forest (EVC 16), Swampy Riparian Woodland (EVC 83)	EUCLID
Gahnia sieberiana	Occurs in a wide variety of damp to wet sites from heathlands near sea-level to wet mountain forests, usually on sandy or silty alluvial soils. Often found on fringes of ephemeral creeks or areas which may flood in winter.	✓	✓	✓					3	2	Permanent waterlogging. Intolerant of strong flow; No or shallow (<0.2 m) flooding, however will not tolerate prolonged inundation.	Riparian Fern Scrub (EVC 191), Swampy Riparian Woodland (EVC 83), Damp Sands Herb-rich Woodlands (EVC3)	Hamilton et al. 2013, Romanowski 1998
Gleichenia microphylla	Forming scrambling thickets in sunny areas with ample moisture throughout southern Victoria.	✓	✓	✓					3	2	Permanently moist to wet soils in brightly lit position. Not tolerant of inundation however seasonal, low energy flooding possible.	Riparian Fern Scrub (EVC 191) where inundation is largely absent, Swampy Riparian Woodland (EVC 83)	Romanowski 1998, Vicflora 2019
Histiopteris incisa	Heathy woodland, riparian scrub, swampy riparian woodland	✓	✓	✓						4	Prefers moist, well-drained soil. Not tolerant of inundation.	Riparian Fern Scrub (EVC 191) where inundation is absent, Swampy Riparian Woodland (EVC 83)	Bull 2014

Species	Habitat	Waterlogging[1]			Inundation[1]				GW dependence[2] (Jacobs 2015)	Moisture dependence[3] (SKM 2009)	Summary of water requirements	EVC / vegetation association	References
		<1 month	1-6 months	>6 months	<1 month	1-6 months	>6 months	Permanent					
Isolepis inundata	A variable and adaptable species, occurring from brackish swamps near sea-level to shaded mountain gullies, mostly in the southern half of the State.	✓	✓	✓	✓	✓			5	2/3	Moist to wet soils requiring regular seasonal inundation.	Riparian Fern Scrub (EVC 191)	Bull 2014, VicFlora
Leptospermum continentale	Widespread in heath-lands and woodlands, usually on well-drained sandy soils, but also on swamp and stream margins.	✓	✓	✓	✓				3		Tolerates well-drained, moist to wet soils. Seasonal shallow (<0.5 m) flooding but not prolonged inundation. Tolerates weak or low flows.	Riparian Fern Scrub (EVC 191) Swampy Riparian Woodland (EVC 83)	Bull, 2014, Hamilton et al. 2013
Leptospermum lanigerum	Widespread forming thickets in lowland swamps, fringing watercourses in the foothills.	✓	✓	✓	✓	✓			3	2	Requires moist to wet soil conditions. Flood tolerant under weak or low flows. Tolerates seasonally shallow (<0.5 m) flooding. Prolonged inundation is likely to adversely affect plant health.	Riparian Fern Scrub (EVC 191) Swampy Riparian Woodland (EVC 83)	Bull 2014, Vicflora 2019, Zacks et al 2018, Frood and Papas 2016, Hamilton et al. 2013
Melaleuca squarrosa	Mostly in wet and peaty soils, fringing swamps, streambanks and sometimes shaded gullies	✓	✓	✓					4	2	Moist to wet soil, full sun to semi shade. Will tolerate flooding and inundation but regular cycles will result in a decline in plant health over time.	Riparian Fern Scrub (EVC 191) Swampy Riparian Woodland (EVC 83), Damp Sands Herb-rich Woodlands (EVC3)	Zacks et al 2018, Vicflora 2019
Pomaderris aspera	Common in wet and shaded forests on moist, well-drained humus rich acidic soils, semi-shade to full sun.	✓			✓				3		Prefers moist soils. Tolerant of short-duration seasonal waterlogging and inundation.	Swampy Riparian Woodland (EVC 83)	Bull 2014
Pteridium esculentum	Found everywhere except poorly drained soils and heavily shaded sites	✓	✓		✓				2	4/5	Tolerant of both moist and dry soils, however prefers seasonally wet conditions. Tolerant of short-duration seasonal inundation.	Damp Sands Herb-rich Woodlands (EVC3), Lowland Forest (EVC 16)	Bull 2014, Yarra ranges plant directory
Todea barbara	Fern gullies along watercourses in damp forest and wet forest	✓	✓	✓						2	Moist to wet humus rich soil, full sun to semi shade. Tolerates flood events but not inundation.	Riparian Fern Scrub (EVC 191) where inundation is largely absent, Swampy Riparian Woodland (EVC 83)	Bull 2014,
Cycnogeton procerum	Common in still to slow-flowing fresh water to 2 m deep, mostly in permanent swamps, lagoons and streams, but withstands extensive periods of dryness.							✓		1	A permanent aquatic that will tolerate dry conditions by dying back to tuber and resprout once moist. Requires flooding to flower.	Swampy Riparian Woodland (EVC 83)	Romanowski 1998, VicFlora
Triglochin striata	Annual plants of damp soils in seepage areas, winter-wet depressions, estuarine areas.	✓	✓	✓	✓	✓					Prefers damp, water-logged situations, usually in the margins of ponds and lagoons. Likely to be found in freshwater but moderately tolerant of sailne/brackish water. Tolerant of prolonged shallow inundation.	Riparian Fern Scrub (EVC 191) Swampy Riparian Woodland (EVC 83)	Romanowski 1998

[1] **Arthur Rylah Institute dataset (Sinclair, unpublished)**

Inundation; records the maximum length of time a typical plant naturally endures inundation by water (any depth of water above the substrate surface, fresh or saline); and/or waterlogging near the soil surface (~30cm) and/or encompassing most of the plant's root zone.

[2] **SKM (2009) review of moisture dependence:**

1 - Obligate aquatic (emergent, submergent on floating) or amphibious species

2 - Requires ± constantly moist or saturated root zone; tolerant of periods of moderate inundation

3 - Occurs in situations with seasonally/intermittently wet root zone but substrate may be relatively dry for part of the year

4 - Occurs in relatively moist environments (e.g. lower slopes, southern aspects or drainage lines) but with freely draining substrates; roots may have access to water table at depth

5 - Opportunistically occurring in wet/moist environments (e.g. on small rises or stumps) but normally considered 'dryland' species; note that ecotypes of the species may be more moisture-dependant that others.

[3] **Jacobs (2015) function group definitions:**

0 – Not connected to ground and therefore not linked to groundwater (e.g. epiphytes): No ground water dependency.

1 –Obligate terrestrial species requiring well aerated soils and not tolerant of saturating conditions in root zone. Can include shallow rooted and annual weed species making opportunistic use of seasonal water availability: opportunistic groundwater dependency.

2- Terrestrial species sometimes found in GDEs as an opportunistic user of available water. Common in ecosystems outside the GDEs assessed where availability of groundwater is low or non-existent. Includes ferns such as Bracken, shrubs such as Prickly Moses and trees such as Messmate: opportunistic groundwater dependency.

3 - Terrestrial species only found in riparian ecosystems or GDEs. Species require readily available water but are not tolerant of regular inundation: groundwater dependant.

4 - Species requiring at least periodic inundation of root zone for continuing survival: groundwater dependant.

5 - Species requiring regular inundation of root zone for continuing survival: groundwater dependant.

4.3 Ecohydrological assessment

The following analysis compares the historic relationship between water and vegetation with the current conditions measured and modelled within the swamp. For the purpose of the analysis, the study area has been split into three ecohydrological zones which broadly align with the vegetation communities identified onsite (Figure 4-1). A brief discussion of the potential implications of currently proposed remediation actions is provided at the end.

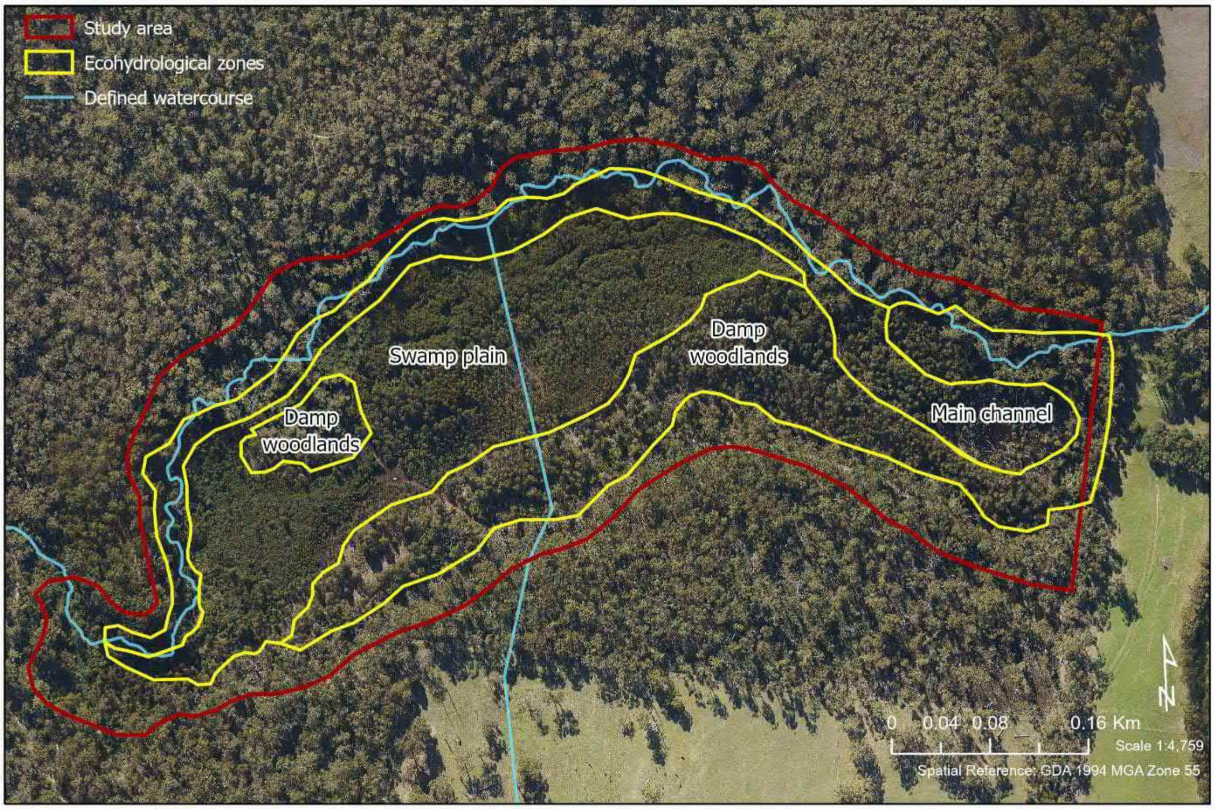


Figure 4-1. Ecohydrolgoical zones within Big Swamp

4.3.1 Swamp Plain

The eastern end of the swamp is dominated by vegetation classified as Riparian Fern Scrub (Figure 3-17). This community requires near-continuous waterlogging of the soil with shallow, often prolonged, periods of inundation (Frood and Papas 2016). Where conditions result in frequent or prolonged inundation, sedges and rushes are likely to become dominant in the understorey. Alternatively, drier conditions would likely see a shift to a fern dominated understorey with emergent trees common.

This correlates with historical evidence indicating that the swamp plain occupied by this vegetation likely consisted of a series of fine, braided channels with substantial inter-channel flow and a broad inundation pattern. The recent development of ASS down to a depth of 2 metres indicates that the soils in this part of the swamp were consistently moist year-round, further aligning with the requirements of this community. The source of historical near-surface waterlogging is difficult to determine with the information available, and therefore may have been a result of water tables at or near the surface, infiltration of surface water or a combination of the two.

Long periods of inundation at the northern end of the swamp, due to the convergence of surface flows (both through the swamp and from the southern tributary) with the main channel, are likely to have contributed to the presence of a low scrub or sedge dominated community in the lowest parts of the swamp plain. Where elevation inhibits prolonged inundation, but provides ample water to maintain waterlogging of the soil, ferns would likely have been present. As elevation increased further to the south and west, and around the small hillock in the north west, vegetation would have dried and graded into a Swamp Gum or Manna Gum woodland fringing the wetland.

In recent years, this part of the swamp has seen significant drying of the substrate, resulting in occasional fires and the loss of vegetation cover. Dominant species such as Prickly Tea-tree and Scented Paperbark have re-colonised the swamp plain post-fire, however this can be attributed to the substantial seed bank likely to have been present and strong post-fire response of these species. Despite the presence of canopy species, understorey species are now virtually absent. A diverse and structurally complex understorey remains only at the west and northern edges of the swamp plain where strong interaction with the main channel likely protected fern and sedge species from the impacts of drying and fires.

The reduced water-table currently present throughout much of the swamp plain is unlikely to support a Riparian Fern Scrub community in the long-term, leading to a gradual shift to a terrestrial damp woodland community over time. Evidence of Swamp Gum encroachment in the form of distinct recruitment cohorts progressively expanding into the swamp plain were observed along the eastern edges and to the east of the small hillock during the field survey (Plate 11). At immediate risk is the Dry Riparian Fern Scrub (RFS120-B) association identified in Figure 3-17.

Plate 11. Swamp Gum regenerating within swamp plain

Whilst there is insufficient information to determine the effects of poor water quality (primarily low pH) on vegetation in this context, the physical influence was visible during field assessments with heavy iron flocculation clinging to all vegetation currently underwater.

4.3.2 Main Channel

Given the narrow and visually discrete nature of the main channel skirting the north of the swamp, there is limited historical information to determine the past condition and nature of this vegetation. Despite this, it can be surmised that this community is likely to have been the least affected by drying of the swamp due to reliable access to surface water during low flow events.

The community observed during field assessments was classified as Swamp Riparian Woodland and exhibited a high level of structural and floristic diversity along the majority of the channel's length. This vegetation type can be highly variable and shares much in common with riparian and swamp scrub communities. Species tolerant of seasonal inundation, such as Swamp Gum and Hazel Pomaderis were present along much of the northern edge of the channel, with the southern side variously alternating between a broad ecotone with the adjacent Riparian Scrub and damp forested sections supporting trees and a range of ferns.

Whilst diverse, this community is likely reliant predominantly on surface flows through the main channel and associated infiltration into the surrounding ground layer. The depth of the channel and variation in elevation along the banks means inundation of this community may have been limited to seasonal floods and localised depressions. Tall forest species less tolerant of inundation, such as Brooker's Gum and Manna Gum, where also present further up the bank as the community shifted into Lowland Forest.

Surface flow modelling undertaken by Jacobs (2019) indicates that even under relatively low flows (e.g. 2ML / day) water persists in the channel. As a result, this community is likely to be more tolerant of long-term reductions in surface flows and the associated reduction in water tables within the swamp. However, should cease-to-flow events continue for extended periods, as has occurred in recent years, this community is to likely to be affected through a reduction in species diversity and encroachment by Lowland Forest species.

4.3.3 Damp woodlands

Historically, woodlands dominated the eastern end of the wetland, small hillock in the north-west and southern edge of the swamp. Whilst this is still the case, this community has been heavily affected by the dry conditions and fire with an absence of mature trees throughout. The community is now a dense stand of Swamp Gum less than 30 years old with a limited understorey.

Historically, the woodlands are likely to have supported several Eucalyptus species, including Manna Gum, Messmate and Brookers Gum, as well as Swamp Gum. The understorey would also have been diverse, with structure and floristics likely to have varied considerably throughout due to changes in elevation, and hence depth to water table, along with proximity to surface flows and inundation.

Based on winter surface flows (20ML/day) modelled by Jacobs (2019), these communities are unlikely to have experienced inundation in normal years. They would still have been heavily dependent on ground water with near-constant access to water between 5 - 10 metres below the surface (Jacobs 2016). These conditions are likely to have been a strong driver of this community and differentiated it from the Lowland Forest EVC on the slopes above.

Currently, this community is in a state of transition, with species tolerant of wet conditions (e.g. Swamp Gum) expanding into the scrub dominated areas of the swamp. Without the restoration of ground water levels, opportunities may be created for Lowland Forest species to colonise this area as the canopy matures and thins. In time this would have the effect of reducing the overall extent of the wetland as the surrounding forests move in.

Measures recommended to protect ecological values are provided below (Section 5.2).

5. Conclusions

5.1 Discussion

The ecology of Big Swamp is complex and intricately linked to the hydrology of the site. The hydrology is in turn informed by a range of factors including soils, topography and climate, as well as surface water use upstream and ground water extraction from the underlying deep aquifer leading to greater rates of surface water infiltration throughout the catchment.

Historically, the swamp is likely to have supported a diverse wetland ecosystem comprised of four distinct vegetation associations:

- A low scrub community through the central and northern sections of the swamp plain. This is likely to be an association of the Riparian Fern Scrub vegetation community which is tolerant of frequent or prolonged inundation and saturated soil conditions, with sedges considered likely to be dominant in the understorey.
- A tall scrub at the western end and fringing the swamp plain, considered to be an association of the Riparian Fern Scrub vegetation community which is differentiated from the above community due to less frequent or prolonged periods of inundation and moist rather than saturated soil conditions. Likely ferns were dominant throughout this association.
- A highly variable, low riparian woodland along the main channels around the northern edge and eastern parts of the swamp. Swamp Gum likely to have been the dominant canopy species, however the community would have included other Eucalypts tolerant of wet conditions as well as a diversity of understorey shrubs, ferns, sedges, rushes and herbs.
- A damp woodland fringing the swamp plain and areas of riparian woodland, primarily along the southern edge and across much of the eastern third of the swamp outside the influence of existing channels. This varied woodland would have supported a range of tall Eucalypts as co-dominants in an open canopy, over a dense understorey tree / shrub layer.

In addition to the dominant associations listed above, there would have also been small pockets of unique vegetation communities throughout the swamp that persisted due to a combination of local conditions. An example of this is the small patch of Wet Verge Sedgeland which was identified at the western end of the swamp during field surveys.

From as early as the 1800s, the swamp has been affected by changing land and water use as vegetation clearance and agricultural practices expanded across the region. This activity has continued to the current day, with the extraction of ground water from the deep Tertiary aquifer, and subsequent reduction in surface flows into the swamp, the most recent pressure on the system. Unfortunately, the cumulative effects have come to a head over the past 20 years with drought conditions triggering intensive ground water extractions and severely limiting surface flows into the swamp. The result was the drying of the swamp through the 1990s and 2000s. While difficult to ascertain, the this drying may have commenced prior to groundwater extraction as the installation of MacDonalds Dam would have changed the flow regime along Boundary Creek from the late 1970s. As the water table dropped and drying occurred, both the vegetation and underlying soil layers rich in organic carbon became susceptible to fire, with two major events occurring in 1998 and 2011. The latter fire resulted in an almost complete loss of vegetation cover across the swamp, substantially altering the structure of the communities throughout. Subsequently, it appears erosion of the swamp plain, likely driven by large rainfall events combined with exposed post-fire soils, has concentrated surface flows into a primary channel that now bisects the plain. The resulting eroded sediment appears to have in part accumulated at the eastern end of the swamp in the form of a plug, leading to the formation of a small pool of standing water which now persists year-round. This chain of events is presented in Figure 5-1.

Whilst there is likely to have been a gradual shift in community structure and composition since European settlement, and even prior due to decadal shifts in climate, the last 30 years has seen significant and potentially irreversible changes to the ecology of the Swamp. The fires have had the greatest direct impact on vegetation, resulting in a reduction of both floristic and structural diversity across the swamp plain and damp woodlands. While a high cover of canopy species has regenerated in both these areas, the understorey is absent in many places and where it has recovered consists almost exclusively of a few common species. Fires are a natural phenomenon in the Australian landscape, even in swamps, and are therefore not necessarily considered a degrading event that would have long term consequences for the Swamp's ecosystem. However, when combined with a distinct shift in the hydrological regime, widespread modification of the under lying substrate due to drying and sub-surface fires and the development of acid sulfate conditions, the consequences are potentially severe in the long term. Two major trends, which can currently be observed in the swamp, will likely continue and result in a shift in the composition of vegetation and associated habitat across the swamp. These include:

- Restriction of flows through the swamp plain to a narrow, central channel, that in the worst-case scenario may only flow intermittingly during seasonal, high rainfall events. Combined with a continuing failure to restore a near-surface water table across much of the plain, the current Riparian Fern Scrub community is likely to reduce in extent to a narrow band limited by proximity to the remaining channels (i.e. one or two through the plain and the main channel along the northern edge). Vegetation outside of this band will in time be replaced by damp woodlands, with Swamp Gum progressively colonising the plain and eventually forming a mature canopy. The resulting consequence will be a significant depletion of the extent of the Riparian Fern Scrub and simplification of the floristic and structural diversity likely to have been present prior to extraction. In a worst-case scenario, the encroachment of woodlands may have a feedback effect, leading to further drying of the swamp plain as species with higher evaporation rates establish and mature. This could theoretically lead to the permanent loss of the Riparian Fern Scrub community from the swamp in the long term. Given climatic trends towards lower average annual rainfall, this scenario cannot be discounted.
- Similar to the Riparian Fern Scrub, a failure to restore ground water levels across the swamp may also see the encroachment of the surrounding Lowland Forest into areas historically dominated by damp woodlands. Whether the overall extent of the damp woodlands will change is difficult to say, however it will have the effect of reducing the extent of the swamp and ecosystem as a whole.

The other unknown factor when predicting the future ecology of the ecosystem is the effects of fires on soil structure and composition, and associated ASS issues, both in-situ and as low pH surface and ground water. While information on the impacts is limited, it is likely these factors will continue to limit the diversity of understorey species within the swamp, either directly due to unsuitable conditions, or indirectly by promoting the establishment of species which may outcompete those indigenous to the site.

5.2 Remediation

Remediation of the swamp recognises that the original, pre-extraction condition cannot be practicably attained, either via an interventionalist or hands-off approach. The aim is therefore to improve ecological values to a satisfactory end-point. In order to provide a definition of this state, the following is proposed as the remediation goal for Big Swamp:

> *"Ensure the long-term persistence of a diverse, functional wetland community across the pre-extraction swamp's full extent"*

While the swamp does not currently meet this goal, it can reasonably be assumed that should suitable hydraulic regimes be returned, communities will re-establish a degree of structural and floristic diversity over time. Supporting this hypothesis is the persistence of floristic elements in the western end of the swamp and along the main channel which currently contain a high diversity of lifeforms and species in sufficient numbers to allow for re-colonisation of the swamp as conditions improve. Complimenting this is the distinct lack of introduced species within the swamp, despite the substantial disturbance that has occurred over the past 20 years. It is also widely recognised that wetland communities are particularly resilient to modification provided suitable conditions are re-established within an acceptable timeframe. Whether this remains the case for Big Swamp, given the multiple issues confronting it, is difficult to say.

To achieve the above goal, the following objectives are proposed to address the negative trends identified within the swamp. These objectives, which can also be considered 'health indicators' or 'success measures', include:

- No further encroachment of terrestrial woodland into the swamp plain over the next 15 years.
- No encroachment of Lowland Forest dominant species into areas of Damp Forest over the next 15 years.
- No loss of structural or floristic diversity along the main channel and western end of the swamp over the next 15 years.
- Increase diversity of understorey species within swamp plain, with a focus on ferns and sedges, over the next 25 years

Monitoring of these objectives can be achieved through repeat transect surveys of those established during the field survey (Appendix B) every two years. To cover all relevant ecological gradients identified in the study and ensure sufficient data is available to assess the objectives listed above, an additional three transects are recommended as follows (Figure B1, Appendix B):

- Transect 6 located at the northern-most point of the swamp crossing the Main channel into swamp plain.
- Transect 7 located in the South-east quadrant intersection Damp Forest and Swampy Riparian Forest immediately to the west of the open-water pool.
- Transect 8 located on the southern side of the swamp, beginning in Lowland forest and moving into areas of Damp Forest.

Figure 5-1. Chain of event flow chart for Big Swamp

Given the significant and fundamental changes that have occurred to the substrate across much of the swamp as a result of sub-surface fires and subsequent erosion and soil collapse, a focus on flow intervention is unlikely to be sufficient to restore ecological function to the site (with the long-term aim of allowing pre-extraction wetland communities to return). Physical works may therefore be required to distribute the flow of water evenly across the swamp plain to mitigate the effects of drying and subsequent colonisation by woodland communities.

Whilst specific quantities are still to be determined, this assessment indicates rehabilitation of the swamp will be more reliant on surface flows than restoration of groundwater levels. Raising groundwater levels also has the unwanted potential to liberate additional acidity from ASS from depth to the surface, further exacerbating the current issue. The wetting of the swamp from the ‘top down’ using surface flows, in association with physical works to distribute flows across the swamp, will help to contain immediate issues associated with ASS whilst preventing the current south-to-north drying of the swamp and transition of the wetland to a woodland community.

Whilst the substantial impacts to the swamp’s substrate cannot be reversed, the restoration of a functional hydrological regime across the swamp will allow for the re-colonization of modified areas with a range of species currently persisting in small pockets throughout the swamp, thus restoring a degree of diversity and function to the wetland overtime.

Active management of the vegetation onsite, either through removal or revegetation, is not recommended until the effects of flow intervention are known. Whilst swamp communities currently exhibit dense cohorts of recruits in many places, this is a symptom of post-fire regeneration, and will naturally self-regulate overtime as the vegetation matures. Limited ‘thinning’ of trees in woodland areas as a complimentary measure may be of benefit to promote and hasten the establishment of large mature trees, which will in-turn suppress dense woody growth. This however is not considered a priority or critical to achieving the stated objectives. Furthermore, removal of trees within the swamp plain will be ineffective without restoration of a suitable hydrological regime and has the potential to further degrade the existing community through disturbance associated with harvesting.

Given suitable canopy species have effectively re-colonised much of the site since the fire, both within scrub and woodland areas, revegetation is not considered a viable management option in this context. Many of the understorey species currently absent from degraded areas are difficult to propagate and will be a challenge to plant-out and maintain given the dense vegetation and issues associated with access. As the wider area supports both diverse native forest, woodlands and high-quality wetland remnants along the main channel and upstream, the priority is ensuring conditions are suitable to facilitate natural re-colonisation of the swamp and damp forests from these existing sources. Given the dynamic nature of wetlands, and assuming appropriate conditions are restored, re-colonisation of disturbed areas will occur relatively quickly, with a measurable increase in species diversity expected over a 20-30 year period.

To achieve the goals and objectives, the following actions are proposed:

A. Ensure surface flows into the swamp are sufficient to maintain year-round waterlogging within the top metre of the swamp plain. Flows however should not resulted in inundation of the swamp plain for a continuous period of more than 6 months, and ideally should be designed to result in continuous seasonal inundation (maximum 30cm depth) of the plain for between 2 – 3 months.

B. Install a limited number of low bund/weirs through sections of the swamp plan. Ideally this would utilise existing tracks and disturbed areas for construction and access. The objective of the bunds would be to block the deeper channels that have formed in the swamp plain and distribute flows across broader area. While it may be unavoidable in places, it is important to avoid the creation of permanently inundated areas of open water. Gradually vegetation and sediment will fill the existing channels and any small areas of open water created by the bunds and over time start to return the profile of the swamp plain to a fine series of braided channels as believed to have originally occurred.

C. Refill/block-off the fire trench (and other unnecessary drains) and re-establish flow of the southern tributary into the swamp along the original alignment. Given the modification of the substrate, small diversion barriers may be required to direct flows into and through the swamp plain.

D. Considered potential use of the recently-formed open water area at the eastern end of the swamp to treat water quality issues created by ASS. Potential options may include the use of specific wetland species (e.g. *Phragmites australis*) as bio-accumulators to treat water quality issues associated with acid-sulphate and heavy metals. However, such an approach would require further investigation as there is the potential for secondary degradation through the introduction of aggressive species into a damaged ecosystem.

E. Undertake continued monitoring of the swamp using the established and proposed transects. Consideration should be given to establishing comparable monitoring transects in wetlands with similar EVCs as a control to monitor broader climatic changes on vegetation.

The indicative locations of remediation actions are shown in Figure 5-2.

A secondary impact, however, of the re-flooding of the swamp plain is the potential for further decreases in surface elevation as voids created in the soil due to the burning of organic material are flooded and collapse. This may further exacerbate issues associated with channelization and drying of parts of the swamp plain and will need to be considered when designing the low bunds.

In addition, further investigations are recommended to inform design of remediation options and long-term management of Big Swamp. These include:

- Condition assessments in high quality Riparian Fern Scrub and Swamp Gum remnants in the region to establish benchmarks against which monitoring data can be assessed. Existing quadrat plots and transects may be suitable for comparison of damp woodland communities however there is currently a lack of monitoring data related to the Riparian Fern Scrub EVC from the local region.

- Assessment of the connectivity between the shallow and deep aquifer systems and relationship to Big Swamp.

- Survey of the swamp plain profile to inform design of proposed weirs/bunds.

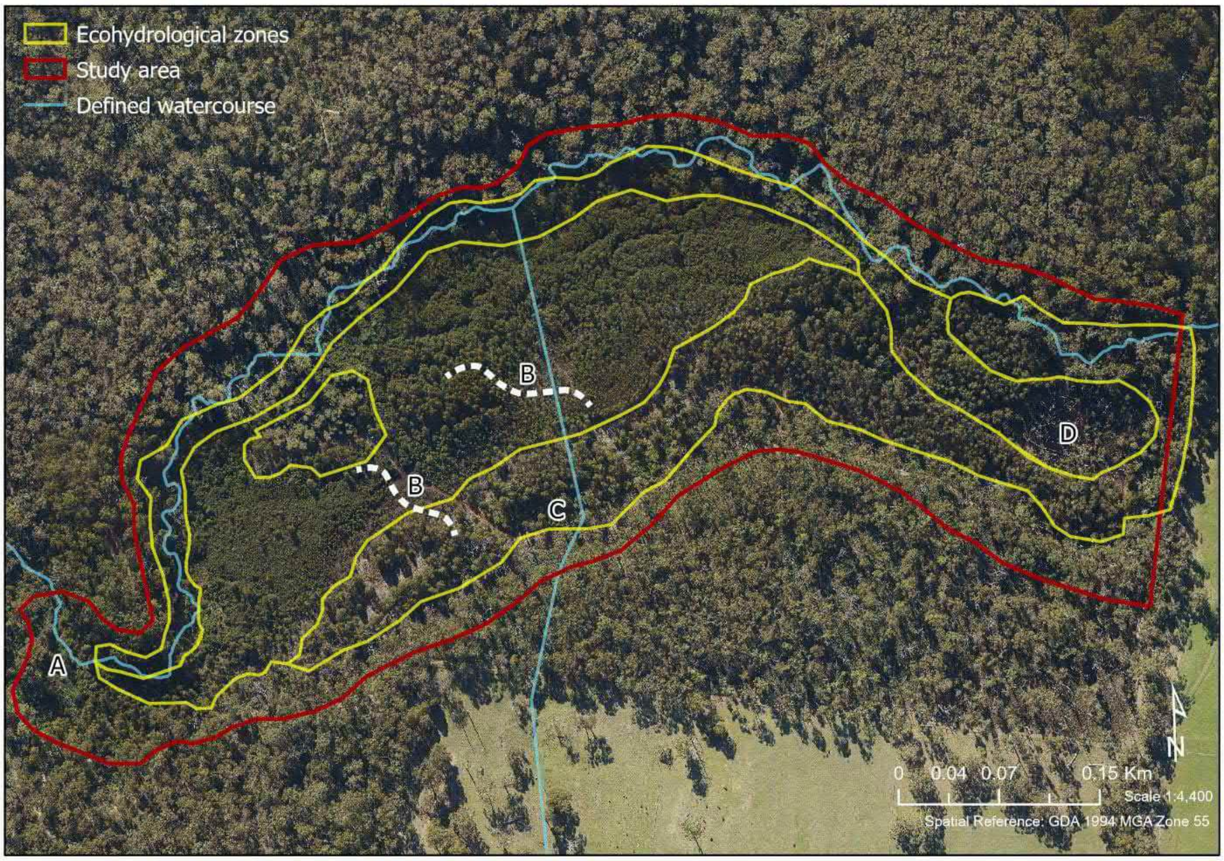


Figure 5-2. Indicative locations of remediation measures within Big Swamp

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Appendix A Species list

Table A1. Flora recorded in Big Swamp

Origin	Scientific name	Common name	Lifeform	VROT	FFG
	Acacia melanoxylon	Blackwood	S		
	Acacia stricta	Hop Wattle	S		
	Acacia verticillata	Prickly Moses	S		
	Acaena novae-zelandiae	Bidgee-widgee	MH		
*	*Acetosella vulgaris*	Sheep Sorrel	H		
*	*Agrostis capillaris*	Brown-top Bent	G		
*	*Agrostis stolonifera*	Creeping Bent			
	Alternanthera denticulata s.s.	Lesser Joyweed	MH		
	Amyema pendula	Drooping Mistletoe			
*	*Anthoxanthum odoratum*	Sweet Vernal-grass			
	Banksia marginata	Silver Banksia	S		
	Blechnum minus				
	Blechnum nudum	Fishbone Water-fern	GF		
	Bursaria spinosa	Sweet Bursaria	S		
	Cardamine tenuifolia				
	Carex appressa	Tall Sedge	Se		
	Carex fascicularis	Tassel Sedge	Se		
	Carex gaudichaudiana	Fen Sedge	MNG		
	Cassinia aculeata	Common Cassinia	S		
*	*Centaurium erythraea*	Common Centaury			
	Centipeda cunninghamii	Common Sneezeweed	MH		
*	*Cerastium glomeratum s.s.*	Sticky Mouse-ear Chickweed			
*	*Cirsium vulgare*	Spear Thistle			
	Clematis aristata	Mountain Clematis	S/C		
	Coprosma quadrifida	Prickly Currant-bush	S		
	Cycnogeton procerum	Common Water-ribbons	Herb		
*	*Cyperus eragrostis*	Drain Flat-sedge			
	Cyperus gunnii subsp. gunnii	Flecked Flat-sedge	Se		
	Dichondra repens	Kidney-weed	SH		
	Dicksonia antarctica	Soft Tree-fern	TF		
	Empodisma minus	Spreading Rope-rush	Se		
	Epacris impressa	Common Heath	S		
	Epilobium billardierianum	Variable Willow-herb	MH		

Origin	Scientific name	Common name	Lifeform	VROT	FFG
	Eucalyptus falciformis	Western Peppermint	T		
	Eucalyptus obliqua	Messmate Stringybark	T		
	Eucalyptus ovata var. ovata	Swamp Gum	T		
	Eucalyptus viminalis subsp. viminalis	Manna Gum	T		
	Euchiton involucratus s.s.	Star Cudweed	MH		
	Euchiton japonicus	Creeping Cudweed	MH		
	Gahnia sieberiana	Red-fruit Saw-sedge	Se		
*	*Galium aparine*	Cleavers			
	Galium leiocarpum	Maori Bedstraw	MH		
	Geranium potentilloides	Soft Crane's-bill	MH		
	Geranium sp. 2	Variable Crane's-bill	MH		
	Gleichenia microphylla	Scrambling Coral-fern	GF		
	Glyceria australis				
	Gratiola peruviana	Austral Brooklime	MH		
	Gynatrix pulchella s.s.	Hemp Bush	S		
	Histiopteris incisa	Bat's Wing Fern	GF		
*	*Holcus lanatus*	Yorkshire Fog			
	Hydrocotyle hirta	Hairy Pennywort	SH		
	Hydrocotyle muscosa				
	Hydrocotyle pterocarpa	Wing Pennywort	SH		
*	*Hypochaeris radicata*	Flatweed			
	Hypolepis ragulosa		GF		
	Isolepis fluitans	Floating Club-sedge	MNG		
	Isolepis inundata	Swamp Club-sedge	MTG		
	Juncus amabilis	Hollow Rush	MTG		
	Juncus pauciflorus	Loose-flower Rush	MTG		
	Juncus procerus	Tall Rush	LTG		
	Juncus sarophorus	Broom Rush	MTG		
	Lachnagrostis filiformis s.s.	Common Blown-grass	MNG		
*	*Leontodon saxatilis*	Hairy Hawkbit			
	Lepidosperma elatius	Tall Sword-sedge	LTG		
	Lepidosperma laterale var. laterale	Variable Sword-sedge	MTG		
	Leptospermum continentale	Prickly Tea-tree	S		
	Leptospermum lanigerum	Woolly Tea-tree	S		
	Leptostigma reptans	Dwarf Nertera	SH		
	Lobelia ?beaugleholei	Showy Lobelia	SH		

Origin	Scientific name	Common name	Lifeform	VROT	FFG
	Lobelia anceps	Angled Lobelia	SH		
	Lomandra filiformis subsp. coriacea	Wattle Mat-rush	MTG		
	Lomandra longifolia subsp. longifolia	Spiny-headed Mat-rush	MTG		
	Luzula meridonalis				
	Lycopus australis	Australian Gipsywort	LH		
	Melaleuca squarrosa	Scented Paperbark	S		
	Microlaena stipoides var. stipoides	Weeping Grass	MNG		
	Monotoca glauca	Currant-wood	S	r	
	Montia australasica	White Purslane	MH		
	Olearia lirata	Snowy Daisy-bush	S		
	Opercularia varia	Variable Stinkweed	SH		
	Ottelia ovalifolia subsp. ovalifolia	Swamp Lily	MH		
	Oxalis exilis	Shady Wood-sorrel	SH		
	Oxalis perennans	Grassland Wood-sorrel	SH		
	Ozothamnus ferrugineus				
	Persicaria decipiens	Slender Knotweed	MH		
*	*Poa annua*	Annual Meadow-grass			
	Poa labillardierei	Common Tussock-grass	MTG		
	Poa sieberiana var. hirtella	Grey Tussock-grass	MNG		
	Poa tenera	Slender Tussock-grass	MNG		
	Pomaderris aspera	Hazel Pomaderris	S		
	Pteridium esculentum	Austral Bracken	GF		
	Pterostylis ?lustra	Small Sickle Greenhood	SH	e	L
	Pterostylis melagramma	Tall Greenhood	SH		
	Pterostylis pedunculata	Maroonhood	SH		
	Ranunculus amphitrichus	Small River Buttercup	MH		
	Ranunculus repens				
*	*Rubus anglocandicans*	Common Blackberry			
	Senecio glomeratus	Annual Fireweed	MH		
	Senecio linearifolius	Fireweed Groundsel	LH		
	Senecio minimus	Shrubby Fireweed	MH		
*	*Sonchus asper s.s.*	Rough Sow-thistle			
*	*Stellaria media*	Chickweed			
	Stellaria pungens	Prickly Starwort	MH		
	Tetrarrhena distichophylla	Hairy Rice-grass	MNG		
	Tetrarrhena juncea	Forest Wire-grass	LNG		

Origin	Scientific name	Common name	Lifeform	VROT	FFG
	Todea barbara	Austral King-fern	GF		
*	*Trifolium subterraneum*	Subterranean Clover			
	Triglochin striata	Streaked Arrowgrass	MH		
	Veronica calycina	Hairy Speedwell	SH		
	Viola hederacea sensu Entwisle (1996)	Ivy-leaf Violet	SH		

Table A2. Fauna recorded in Big Swamp

Origin	Common name	Scientific name	Group	VROT	FFG
	Australian King-Parrot	*Alisterus scapularis*	Bird		
	Australian Magpie	*Cracticus tibicen*	Bird		
	Australian Shelduck	*Tadorna tadornoides*	Bird		
	Australian Wood Duck	*Chenonetta jubata*	Bird		
	Black Kite	*Milvus migrans*	Bird		
	Brown Thornbill	*Acanthiza pusilla*	Bird		
	Common Brush-tail Possum	*Trichosurus vulpecula*	Mammal		
	Common Froglet	*Crinis signifera*	Frog		
*	Common Starling	*Sturnus vulgaris*	Bird		
	Crescent Honeyeater	*Phylidonyris pyrrhopterus*	Bird		
	Crested Shrike-tit	*Falcunculus frontatus*	Bird		
	Crimson Rosella	*Platycercus elegans*	Bird		
*	Dog	*Canis familiaris*	Mammal		
	Eastern Grey Kangaroo	*Macropus giganteus*	Mammal		
	Eastern Rosella	*Platycercus eximius*	Bird		
	Eastern Spinebill	*Acanthorhynchus tenuirostris*	Bird		
	Eastern Yellow Robin	*Eopsaltria australis*	Bird		
	Freshwater Cray	*Engaeus sp.*	Crustacean		
	Galah	*Eolophus roseicapillus*	Bird		
	Golden Whistler	*Pachycephala pectoralis*	Bird		
	Grey Butcherbird	*Cracticus torquatus*	Bird		
	Grey Fantail	*Rhipidura albiscapa*	Bird		
	Grey Shrike-thrush	*Colluricincla harmonica*	Bird		
	Laughing Kookaburra	*Dacelo novaeguineae*	Bird		
	Little Raven	*Corvus mellori*	Bird		
	Long-billed Corella	*Cacatua tenuirostris*	Bird		
	Mistletoebird	*Dicaeum hirundinaceum*	Bird		

Origin	Common name	Scientific name	Group	VROT	FFG
	New Holland Honeyeater	*Phylidonyris novaehollandiae*	Bird		
	Noisy Miner	*Manorina melanocephala*	Bird		
	Olive Whistler	*Pachycephala olivacea*	Bird		
	Pacific Black Duck	*Anas superciliosa*	Bird		
	Pied Currawong	*Strepera graculina*	Bird		
*	Pig	*Sus scrofa*	Mammal		
*	Red Fox	*Vulpes vulpes*	Mammal		
	Red Wattlebird	*Anthochaera carunculata*	Bird		
	Rufous Bristlebird (Otways Subspecies)	*Dasyornis broadbenti caryochrous*	Bird	nt	L
	Satin Bowerbird	*Ptilonorhynchus violaceus*	Bird		
	Silvereye	*Zosterops lateralis*	Bird		
	Southern Brown Tree-frog	*Litoria ewingii*	Frog		
	Spotted Pardalote	*Pardalotus punctatus*	Bird		
	Striated Pardalote	*Pardalotus striatus*	Bird		
	Sulphur-crested Cockatoo	*Cacatua galerita*	Bird		
	Superb Fairy-wren	*Malurus cyaneus*	Bird		
	Wedgetail eagle	*Aquila audax*	Bird		
	Welcome swallow	*Hirundo neoxena*	Bird		
	White-browed Scrubwren	*Sericornis frontalis*	Bird		
	White-eared Honeyeater	*Lichenostomus leucotis*	Bird		
	White-naped Honeyeater	*Melithreptus lunatus*	Bird		
	White-throated Treecreeper	*Cormobates leucophaea*	Bird		
	Willie Wagtail	*Rhipidura leucophrys*	Bird		
	Yellow-faced Honeyeater	*Lichenostomus chrysops*	Bird		

Appendix B Transect data

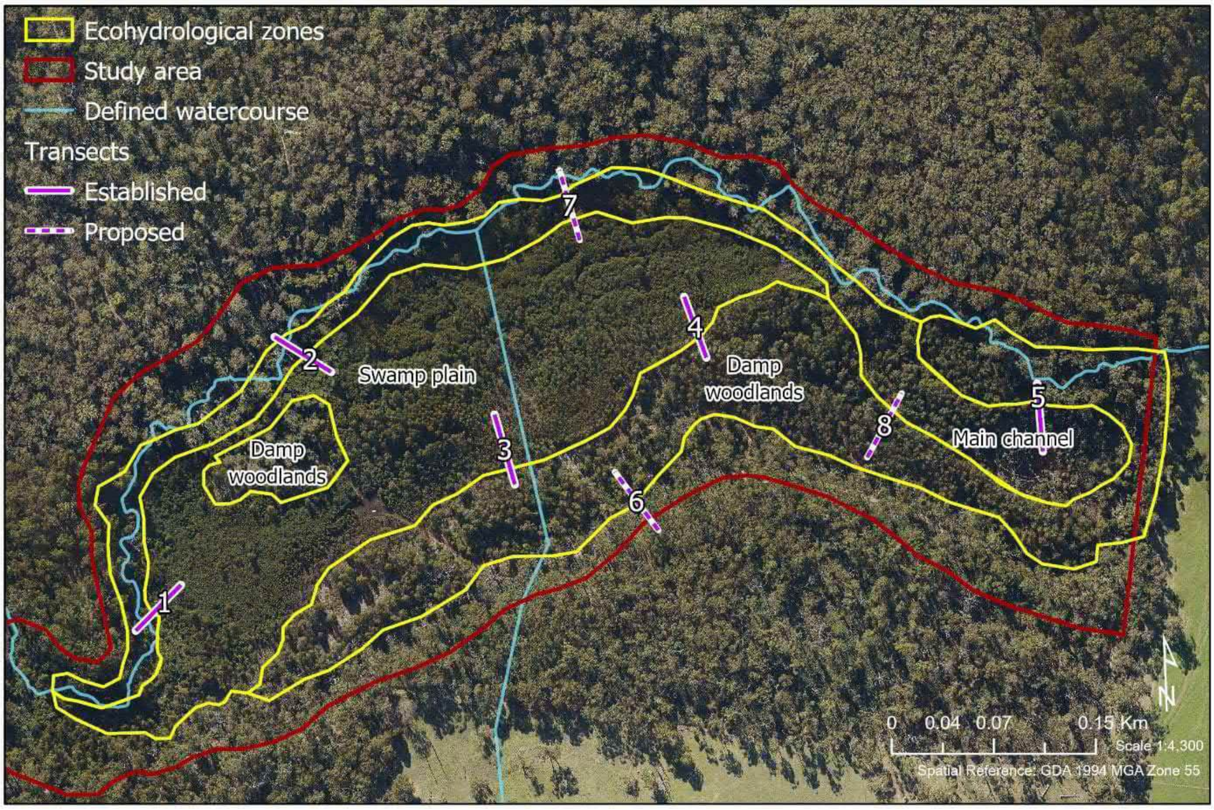

Figure B1. Locations of established and proposed transects in Big Swamp

Table B1. Results of vegetation transects undertaken in Big Swamp in September 2019

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
0.25	*Carex appressa, Lepidosperma elatius*	Litter	*Gahnia sieberiana, Holcus lanatus*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter	*Lepidosperma elatius*	Litter
0.5	*Lepidosperma elatius*	Litter	*Tetrarrhena juncea, Lepidosperma elatius*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata, Microlaena stipoides var. stipoides*	Litter	*Lepidosperma elatius*	Litter
0.75	*Lepidosperma elatius*	Litter	*Lepidosperma elatius*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter	*Lepidosperma elatius*	Litter
1	*Lepidosperma elatius, Pteridium esculentum subsp. esculentum*	Litter	*Tetrarrhena juncea, Lepidosperma elatius*	Litter	*Eucalyptus ovata*	Bare ground	*Pteridium esculentum subsp. esculentum*	Litter		Litter
1.25	*Lepidosperma elatius*	Litter	*Tetrarrhena juncea, Lepidosperma elatius, Pteridium esculentum subsp. esculentum*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Lepidosperma elatius*	Litter
1.5	*Lepidosperma elatius*	Litter	*Tetrarrhena juncea, Pteridium esculentum subsp. esculentum*	Bryophytes	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter		Litter
1.75	*Lepidosperma elatius, Tetrarrhena juncea*	Litter	*Tetrarrhena juncea, Lepidosperma elatius*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata, Anthoxanthum odoratum*	Litter	*Holcus lanatus*	Litter
2	*Lepidosperma elatius, Pteridium esculentum subsp. esculentum*	Litter	*Tetrarrhena juncea*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Logs		Bryophytes

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
2.25	*Lepidosperma elatius, Pteridium esculentum subsp. esculentum, Olearia lirata*	Litter	*Tetrarrhena juncea*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter	*Tetrarrhena juncea*	Litter
2.5	*Lepidosperma elatius, Pteridium esculentum subsp. esculentum, Tetrarrhena juncea*	Litter		Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Holcus lanatus*	Litter
2.75	*Lepidosperma elatius, Tetrarrhena juncea*	Litter	*Tetrarrhena juncea*	Logs		Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Pomaderris aspera, Tetrarrhena juncea, Senecio minimus*	Litter
3	*Lepidosperma elatius, Olearia lirata, Tetrarrhena juncea, Pteridium esculentum subsp. esculentum*	Litter	*Tetrarrhena juncea*	Litter		Litter	*Eucalyptus ovata*	Litter	*Pomaderris aspera*	Litter
3.25	*Lepidosperma elatius, Tetrarrhena juncea*	Bryophytes	*Tetrarrhena juncea, Pteridium esculentum subsp. esculentum*	Litter		Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Pomaderris aspera*	Litter
3.5	*Olearia lirata, Tetrarrhena juncea*	Litter	*Tetrarrhena juncea, Pteridium esculentum subsp. esculentum*	Litter		Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Pomaderris aspera, Tetrarrhena juncea*	Litter
3.75	*Tetrarrhena juncea*	Bryophytes	*Senecio minimus, Pteridium esculentum subsp. esculentum*	Litter		Litter	*Eucalyptus ovata*	Litter	*Lepidosperma elatius*	Litter

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
4	*Tetrarrhena juncea*	Bryophytes		Litter		Litter	*Eucalyptus ovata*	Litter	*Lepidosperma elatius*	Litter
4.25		Litter	*Holcus lanatus*	Litter		Bryophytes	*Eucalyptus ovata*	Litter	*Lepidosperma elatius*	Litter
4.5	*Prostanthera lasianthos*	Litter	*Holcus lanatus, Lepidosperma elatius*	Litter		Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Lepidosperma elatius*	Litter
4.75	*Prostanthera lasianthos, Pomaderris aspera*	Litter	*Holcus lanatus, Lepidosperma elatius*	Litter		Litter	*Eucalyptus ovata*	Litter	*Tetrarrhena juncea*	Litter
5	*Prostanthera lasianthos, Pomaderris aspera*	Litter	*Lepidosperma elatius*	Litter		Litter	*Eucalyptus ovata*	Litter	*Pteridium esculentum subsp. esculentum*	Litter
5.25	*Prostanthera lasianthos, Pomaderris aspera*	Litter	*Holcus lanatus*	Litter		Litter	*Eucalyptus ovata*	Litter	*Pteridium esculentum subsp. esculentum, Tetrarrhena juncea*	Litter
5.5	*Prostanthera lasianthos, Pomaderris aspera*	Litter	*Holcus lanatus*	Litter		Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Tetrarrhena juncea*	Litter
5.75	*Pomaderris aspera*	Litter	*Gynatrix pulchella s.l., Holcus lanatus*	Litter		Bare ground	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Tetrarrhena juncea*	Litter
6	*Pomaderris aspera*	Litter	*Gynatrix pulchella s.l., Cerastium glomeratum s.l., Acacia melanoxylon*	Bryophytes		Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Tetrarrhena juncea*	Litter

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
6.25	*Holcus lanatus, Pomaderris aspera, Tetrarrhena juncea*	Litter	*Gynatrix pulchella s.l., Cerastium glomeratum s.l., Acacia melanoxylon*	Bare ground		Bare ground	*Eucalyptus ovata, Tetrarrhena juncea*	Litter	*Tetrarrhena juncea*	Litter
6.5	*Pomaderris aspera*	Litter	*Gynatrix pulchella s.l.*	Water		Litter	*Tetrarrhena juncea*	Litter	*Tetrarrhena juncea*	Bryophytes
6.75	*Rubus anglocandicans, Pomaderris aspera*	Litter	*Gynatrix pulchella s.l.*	Water	*Pteridium esculentum subsp. esculentum*	Bare ground	*Tetrarrhena juncea, Gahnia sieberiana*	Litter		Litter
7	*Pomaderris aspera*	Litter	*Gynatrix pulchella s.l.*	Water		Litter	*Anthoxanthum odoratum, Acacia verticillata, Gahnia sieberiana*	Litter	*Tetrarrhena juncea*	Bryophytes
7.25	*Pomaderris aspera*	Litter	*Gynatrix pulchella s.l.*	Water		Litter	*Acacia verticillata*	Bryophytes		Litter
7.5	*Holcus lanatus*	Litter	*Gynatrix pulchella s.l.*	Water		Bryophytes	*Tetrarrhena juncea*	Litter	*Pteridium esculentum subsp. esculentum*	Bryophytes
7.75		Litter	*Gynatrix pulchella s.l.*	Water		Bryophytes	*Pteridium esculentum subsp. esculentum*	Litter	*Pteridium esculentum subsp. esculentum, Holcus lanatus*	Litter
8	*Holcus lanatus*	Litter	*Gynatrix pulchella s.l.*	Water		Litter	*Acacia verticillata*	Litter	*Pteridium esculentum subsp. esculentum, Holcus lanatus*	Litter

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
8.25	*Lepidosperma elatius, Holcus lanatus*	Litter	*Gynatrix pulchella s.l.*	Water		Litter	*Acacia verticillata*	Bare ground	*Pteridium esculentum subsp. esculentum, Holcus lanatus*	Litter
8.5	*Holcus lanatus*	Litter	*Gynatrix pulchella s.l.*	Water		Litter	*Acacia verticillata*	Litter	*Galium aparine, Pteridium esculentum subsp. esculentum, Holcus lanatus*	Litter
8.75	*Pomaderris aspera, Lepidosperma elatius, Carex appressa*	Litter	*Gynatrix pulchella s.l.*	Water		Litter		Litter	*Eucalyptus brookeriana, Holcus lanatus*	Litter
9	*Pomaderris aspera, Lepidosperma elatius, Carex appressa*	Litter	*Gynatrix pulchella s.l., Carex appressa*	Bare ground		Litter	*Pteridium esculentum subsp. esculentum*	Litter	*Eucalyptus brookeriana, Holcus lanatus, Tetrarrhena juncea*	Litter
9.25	*Pomaderris aspera, Lepidosperma elatius*	Litter	*Gynatrix pulchella s.l., Carex appressa*	Litter		Litter	*Tetrarrhena juncea*	Litter	*Tetrarrhena juncea*	Litter
9.5	*Pomaderris aspera, Lepidosperma elatius*	Litter	*Gynatrix pulchella s.l., Carex appressa*	Bryophytes		Bryophytes		Litter	*Eucalyptus brookeriana, Tetrarrhena juncea*	Litter
9.75	*Pomaderris aspera, Lepidosperma elatius*	Litter	*Gynatrix pulchella s.l., Poa tenera, Cerastium glomeratum s.l.*	Litter		Litter		Litter	*Eucalyptus brookeriana, Tetrarrhena juncea*	Litter

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
10	*Pomaderris aspera, Lepidosperma elatius, Rubus anglocandicans*	Litter	*Gynatrix pulchella s.l., Poa tenera, Senecio minimus*	Litter		Litter		Litter	*Eucalyptus brookeriana, Tetrarrhena juncea, Holcus lanatus*	Litter
10.25	*Pomaderris aspera, Lepidosperma elatius, Carex appressa*	Litter	*Gynatrix pulchella s.l., Galium aparine, Poa tenera*	Litter		Litter		Litter	*Holcus lanatus*	Litter
10.5	*Pomaderris aspera, Lepidosperma elatius*	Litter	*Gynatrix pulchella s.l., Acacia verticillata*	Litter	*Pteridium esculentum subsp. esculentum*	Litter		Litter	*Pteridium esculentum subsp. esculentum, Holcus lanatus*	Litter
10.75	*Pomaderris aspera, Lepidosperma elatius*	Litter	*Gynatrix pulchella s.l., Acacia verticillata*	Litter		Litter	*Pteridium esculentum subsp. esculentum*	Litter	*Holcus lanatus*	Bryophytes
11	*Pomaderris aspera, Lepidosperma elatius*	Litter	*Gynatrix pulchella s.l., Acacia verticillata, Cerastium glomeratum s.l.*	Litter		Litter		Litter	*Tetrarrhena juncea*	Litter
11.25	*Leptospermum continentale, Lepidosperma elatius*	Litter	*Acacia verticillata*	Litter	*Pteridium esculentum subsp. esculentum*	Bare ground	*Eucalyptus ovata*	Logs		Logs
11.5	*Leptospermum continentale, Lepidosperma elatius*	Litter	*Pomaderris aspera, Lepidosperma elatius, Carex appressa*	Litter		Litter	*Eucalyptus ovata*	Logs	*Tetrarrhena juncea*	Logs

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
11.75	*Leptospermum continentale, Lepidosperma elatius*	Litter	*Pomaderris aspera*	Litter		Bryophytes	*Eucalyptus ovata*	Litter		Logs
12	*Pomaderris aspera*	Litter	*Pomaderris aspera*	Logs		Litter	*Eucalyptus ovata*	Litter	*Tetrarrhena juncea*	Litter
12.25	*Pomaderris aspera*	Litter	*Leptospermum continentale*	Logs		Bryophytes	*Eucalyptus ovata*	Logs	*Tetrarrhena juncea*	Litter
12.5	*Pomaderris aspera, Carex appressa*	Litter	*Carex appressa*	Litter	*Eucalyptus ovata*	Bryophytes	*Eucalyptus ovata*	Logs	*Tetrarrhena juncea*	Litter
12.75	*Pomaderris aspera*	Litter	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter		Litter
13	*Pomaderris aspera, Carex appressa, Leptospermum continentale*	Litter	*Leptospermum continentale, Carex appressa*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata, Senecio glomeratus*	Litter		Water
13.25	*Pomaderris aspera, Lycopus australis, Carex appressa, Leptospermum continentale*	Water	*Leptospermum continentale, Carex appressa*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter		Water
13.5	*Carex fascicularis*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Water
13.75	*Carex fascicularis*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Water
14	*Carex fascicularis*	Water	*Leptospermum continentale, Holcus lanatus*	Litter	*Eucalyptus ovata*	Bare ground	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
14.25	*Cycnogeton procerum s.s.*	Water	*Leptospermum continentale, Hydrocotyle hirta*	Bryophytes	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter
14.5	*Cycnogeton procerum s.s.*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter
14.75	*Cycnogeton procerum s.s.*	Water	*Tetrarrhena juncea*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter
15	*Cycnogeton procerum s.s., Leptospermum continentale, Leptospermum lanigerum*	Water	*Holcus lanatus*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter
15.25	*Cycnogeton procerum s.s., Leptospermum continentale, Leptospermum lanigerum*	Water	*Holcus lanatus*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter
15.5	*Cycnogeton procerum s.s., Leptospermum continentale, Leptospermum lanigerum*	Water	*Holcus lanatus, Pteridium esculentum subsp. esculentum*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter
15.75	*Cycnogeton procerum s.s., Leptospermum continentale,*	Water	*Leptospermum continentale,*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
	Leptospermum lanigerum		*Pteridium esculentum subsp. esculentum*							
16	*Leptospermum continentale, Leptospermum lanigerum*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter
16.25	*Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Litter		Litter
16.5	*Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Logs		Water
16.75	*Leptospermum lanigerum*	Water	*Leptospermum continentale, Hydrocotyle pterocarpa*	Water	*Eucalyptus ovata, Melaleuca squarrosa*	Litter	*Eucalyptus ovata*	Logs		Water
17	*Lobelia beaugleholei, Leptospermum lanigerum*	Water		Water	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Eucalyptus ovata*	Logs		Water
17.25	*Leptospermum lanigerum*	Water	*Leptospermum continentale, Hydrocotyle pterocarpa*	Water	*Pteridium esculentum subsp. esculentum*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus brookeriana*	Litter
17.5	*Leptospermum lanigerum*	Water	*Leptospermum continentale, Acacia melanoxylon*	Water		Litter	*Eucalyptus ovata*	Litter		Litter
17.75	*Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water		Litter	*Eucalyptus ovata*	Litter		Litter

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
18	*Leptospermum lanigerum*	Water	*Leptospermum continentale, Acacia melanoxylon*	Water		Litter	*Eucalyptus ovata*	Litter		Water
18.25	*Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water		Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter		Water
18.5	*Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water		Litter	*Eucalyptus ovata*	Litter		Water
18.75	*Leptospermum lanigerum*	Water	*Leptospermum continentale, Lobelia beaugleholei*	Water		Litter	*Eucalyptus ovata*	Litter		Water
19	*Leptospermum lanigerum*	Water	*Leptospermum continentale, Carex appressa*	Water		Bryophytes	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter		Water
19.25	*Leptospermum lanigerum*	Water	*Leptospermum continentale, Carex appressa*	Water	*Pteridium esculentum subsp. esculentum*	Bryophytes	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter		Water
19.5	*Leptospermum lanigerum*	Water	*Leptospermum continentale, Carex appressa*	Water	*Pteridium esculentum subsp. esculentum*	Litter	*Eucalyptus ovata*	Litter		Water
19.75	*Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata*	Litter		Water
20	*Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata*	Litter		Water
20.25	*Leptospermum lanigerum*	Water	*Leptospermum continentale, Carex appressa*	Litter	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata*	Litter		Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
20.5	*Leptospermum lanigerum*	Water	*Leptospermum continentale, Carex appressa*	Water	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata*	Litter		Water
20.75	*Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata*	Litter		Water
21	*Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata*	Logs		Water
21.25	*Alternanthera denticulata s.l., Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Litter	*Eucalyptus ovata*	Logs		Water
21.5	*Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata, Melaleuca squarrosa*	Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter		Water
21.75	*Lycopus australis, Carex appressa, Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata, Melaleuca squarrosa*	Litter	*Eucalyptus ovata*	Litter	*Juncus procerus*	Water
22	*Carex appressa, Leptospermum lanigerum*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata, Melaleuca squarrosa*	Litter	*Eucalyptus ovata*	Litter	*Juncus procerus*	Water
22.25	*Carex appressa, Leptospermum lanigerum*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata, Melaleuca squarrosa, Pteridium esculentum subsp. esculentum*	Litter	*Eucalyptus ovata*	Litter	*Juncus procerus*	Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
22.5	*Carex appressa*	Water	*Leptospermum continentale, Galium ciliare subsp. Terminale*	Litter	*Eucalyptus ovata, Melaleuca squarrosa, Pteridium esculentum subsp. esculentum*	Litter	*Eucalyptus ovata*	Bryophytes	*Juncus procerus*	Water
22.75	*Todea barbera, Carex appressa*	Water	*Leptospermum continentale, Galium ciliare subsp. Terminale*	Litter	*Eucalyptus ovata*	Litter	*Pteridium esculentum subsp. esculentum*	Litter	*Juncus procerus*	Water
23		Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter		Bryophytes		Water
23.25	*Holcus lanatus, Carex appressa*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Litter		Litter		Water
23.5	*Leptospermum continentale, Ranunculus amphitrichus, Alternanthera denticulata s.l., Carex appressa*	Water	*Leptospermum continentale, Carex appressa*	Water	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Pteridium esculentum subsp. esculentum*	Bryophytes		Water
23.75	*Leptospermum continentale*	Water	*Leptospermum continentale, Carex appressa*	Water	*Eucalyptus ovata*	Litter	*Pteridium esculentum subsp. esculentum*	Bryophytes		Water
24	*Leptospermum continentale*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata, Leptospermum continentale*	Litter		Litter		Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
24.25	*Leptospermum continentale, Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata, Leptospermum continentale*	Litter	*Gahnia sieberiana*	Litter		Water
24.5	*Leptospermum continentale, Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata, Leptospermum continentale*	Logs	*Gahnia sieberiana*	Litter		Logs
24.75	*Leptospermum continentale, Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata, Leptospermum continentale*	Litter	*Gahnia sieberiana*	Litter		Water
25	*Carex fascicularis*	Water	*Leptospermum continentale, Carex appressa*	Litter	*Eucalyptus ovata, Leptospermum continentale*	Litter	*Gahnia sieberiana*	Litter		Water
25.25	*Carex fascicularis*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata, Leptospermum continentale*	Litter		Bryophytes		Water
25.5	*Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Gahnia sieberiana*	Litter		Litter		Water
25.75	*Carex fascicularis*	Water	*Leptospermum continentale, Carex appressa*	Water	*Gahnia sieberiana*	Litter		Litter		Water
26	*Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Gahnia sieberiana*	Bryophytes		Litter		Water
26.25	*Carex appressa, Cyperus gunnii*	Water	*Leptospermum continentale*	Water	*Gahnia sieberiana*	Litter		Litter		Water
26.5	*Carex appressa, Cyperus gunnii*	Water	*Leptospermum continentale*	Water		Litter		Litter		Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
26.75	*Carex appressa, Cyperus gunnii*	Water	*Leptospermum continentale*	Water	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata*	Litter		Water
27	*Carex appressa, Cyperus gunnii*	Water	*Leptospermum continentale*	Water		Litter	*Eucalyptus ovata*	Litter		Water
27.25	*Cyperus gunnii*	Water	*Leptospermum continentale*	Water	*Melaleuca squarrosa*	Bare ground	*Eucalyptus ovata*	Litter		Water
27.5	*Cyperus gunnii*	Water	*Leptospermum continentale*	Litter	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter		Water
27.75	*Carex fascicularis, Cyperus gunnii*	Water	*Leptospermum continentale*	Litter	*Leptospermum continentale, Pteridium esculentum subsp. esculentum*	Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter		Water
28	*Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum, Gahnia sieberiana*	Litter		Water
28.25	*Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter		Water
28.5	*Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata, Melaleuca squarrosa*	Logs	*Gahnia sieberiana*	Litter		Logs
28.75		Water	*Leptospermum continentale*	Water	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum*	Litter	*Gahnia sieberiana*	Litter		Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
29	*Melaleuca squarrosa, Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter		Water
29.25		Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter		Water
29.5	*Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Bryophytes	*Gahnia sieberiana*	Litter		Water
29.75	*Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Bryophytes	*Gahnia sieberiana*	Litter		Water
30	*Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata, Leptospermum continentale*	Litter	*Gahnia sieberiana*	Litter		Water
30.25	*Carex appressa*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata, Leptospermum continentale*	Bryophytes	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
30.5	*Carex appressa*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
30.75	*Carex appressa*	Water	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
31	*Carex appressa*	Water	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
31.25	*Carex appressa*	Water	*Leptospermum continentale*	Water	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
31.5	*Carex appressa*	Water	*Leptospermum continentale*	Litter	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
31.75		Water	*Leptospermum continentale*	Litter	*Melaleuca squarrosa*	Litter	*Gahnia sieberiana*	Litter		Water
32	*Carex appressa*	Water	*Leptospermum continentale*	Litter	*Melaleuca squarrosa*	Litter	*Gahnia sieberiana*	Litter		Water
32.25		Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Litter	*Gahnia sieberiana*	Litter		Water
32.5	*Carex fascicularis*	Water	*Leptospermum continentale*	Logs	*Pteridium esculentum subsp. esculentum*	Bryophytes	*Gahnia sieberiana*	Litter		Water
32.75	*Carex fascicularis*	Water	*Leptospermum continentale*	Water		Bryophytes	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum, Gahnia sieberiana*	Litter		Logs
33	*Carex fascicularis*	Water	*Leptospermum continentale*	Water		Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum, Gahnia sieberiana*	Litter		Water
33.25	*Carex fascicularis*	Water	*Leptospermum continentale*	Water		Bryophytes	*Eucalyptus ovata, Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
33.5	*Carex fascicularis*	Water	*Leptospermum continentale*	Water		Bryophytes	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
33.75	*Leptospermum continentale, Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata, Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
34	*Leptospermum continentale*	Water	*Leptospermum continentale*	Water	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
34.25	*Leptospermum continentale*	Water	*Leptospermum continentale*	Water		Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
34.5	*Leptospermum continentale*	Water	*Leptospermum continentale*	Water		Logs	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Logs
34.75	*Carex fascicularis, Carex appressa*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
35	*Leptospermum continentale, Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum, Gahnia sieberiana*	Litter		Water
35.25	*Leptospermum continentale, Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Bare ground	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
35.5	*Leptospermum continentale, Carex fascicularis*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Bryophytes	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
35.75	*Leptospermum continentale, Carex appressa*	Water	*Leptospermum continentale*	Water	*Eucalyptus ovata*	Bryophytes	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
36	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
36.25		Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
36.5		Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Bryophytes	*Gahnia sieberiana*	Litter		Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
36.75	*Leptospermum continentale, Carex appressa*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
37	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
37.25	*Leptospermum continentale, Cyperus eragrostis*	Water	*Leptospermum continentale*	Litter		Litter	*Eucalyptus ovata, Pteridium esculentum subsp. esculentum, Gahnia sieberiana*	Litter		Water
37.5	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Leptospermum continentale*	Litter	*Gahnia sieberiana*	Litter		Water
37.75	*Leptospermum continentale*	Water	*Leptospermum continentale*	Water		Litter	*Leptospermum continentale, Gahnia sieberiana*	Litter		Water
38	*Leptospermum continentale, Persicaria decipiens*	Water	*Leptospermum continentale*	Water	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata, Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
38.25	*Leptospermum continentale*	Water	*Leptospermum continentale*	Water	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata, Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
38.5	*Leptospermum continentale, Acacia melanoxylon, Alternanthera denticulata s.l.*	Water	*Leptospermum continentale*	Water	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
38.75	*Leptospermum continentale, Acacia melanoxylon*	Water	*Leptospermum continentale*	Bare ground	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
39	*Leptospermum continentale, Acacia melanoxylon*	Water	*Leptospermum continentale*	Bare ground	*Melaleuca squarrosa*	Bryophytes	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
39.25	*Leptospermum continentale, Acacia melanoxylon*	Water	*Leptospermum continentale*	Litter	*Melaleuca squarrosa*	Litter	*Eucalyptus ovata, Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
39.5	*Leptospermum continentale, Acacia melanoxylon*	Water	*Leptospermum continentale*	Litter	*Melaleuca squarrosa*	Litter	*Leptospermum continentale, Eucalyptus ovata, Gahnia sieberiana, Gahnia sieberiana*	Litter		Water
39.75	*Leptospermum continentale, Acacia melanoxylon*	Water	*Leptospermum continentale*	Bare ground	*Eucalyptus ovata, Melaleuca squarrosa*	Litter	*Leptospermum continentale, Pteridium esculentum subsp. esculentum, Gahnia sieberiana, Eucalyptus ovata*	Litter		Water
40	*Leptospermum continentale, Acacia melanoxylon*	Water	*Leptospermum continentale*	Bare ground	*Melaleuca squarrosa*	Litter	*Leptospermum continentale, Eucalyptus ovata, Gahnia sieberiana*	Litter		Water
40.25	*Leptospermum continentale*	Water	*Leptospermum continentale*	Bare ground	*Melaleuca squarrosa*	Litter	*Gahnia sieberiana*	Litter		Water
40.5	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Leptospermum continentale*	Litter	*Eucalyptus ovata, Gahnia sieberiana*	Litter		Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
40.75	*Leptospermum continentale*	Water	*Leptospermum continentale*	Bare ground		Litter	*Pteridium esculentum subsp. esculentum, Gahnia sieberiana*	Litter		Water
41	*Leptospermum continentale*	Water	*Leptospermum continentale*	Bare ground	*Melaleuca squarrosa*	Litter	*Gahnia sieberiana*	Litter		Water
41.25	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Melaleuca squarrosa*	Litter	*Leptospermum continentale, Gahnia sieberiana*	Litter		Water
41.5	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Melaleuca squarrosa*	Litter	*Leptospermum continentale, Gahnia sieberiana*	Litter		Water
41.75	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Melaleuca squarrosa*	Litter	*Leptospermum continentale, Gahnia sieberiana*	Litter		Water
42	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Melaleuca squarrosa*	Bryophytes	*Gahnia sieberiana*	Litter		Water
42.25	*Leptospermum continentale*	Litter	*Leptospermum continentale*	Litter	*Melaleuca squarrosa*	Litter	*Gahnia sieberiana*	Litter		Water
42.5	*Leptospermum continentale*	Litter	*Leptospermum continentale*	Litter	*Melaleuca squarrosa*	Litter	*Leptospermum continentale, Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
42.75	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Bryophytes	*Gahnia sieberiana*	Litter		Water
43	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Litter	*Leptospermum continentale, Gahnia sieberiana*	Litter		Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	**Ground cover**	**Species**	**Ground cover**	**Species**	**Ground cover**	**Species**	**Ground cover**	**Species**	**Ground cover**
43.25	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Bryophytes	*Pteridium esculentum subsp. esculentum, Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
43.5	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Melaleuca squarrosa*	Litter	*Pteridium esculentum subsp. esculentum, Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
43.75	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata, Melaleuca squarrosa*	Litter	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
44	*Leptospermum continentale*	Litter	*Leptospermum continentale*	Litter	*Eucalyptus ovata, Melaleuca squarrosa*	Litter	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
44.25	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata, Melaleuca squarrosa*	Litter	*Leptospermum continentale, Gahnia sieberiana*	Litter		Water
44.5	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata, Melaleuca squarrosa*	Litter	*Gahnia sieberiana*	Litter		Water
44.75	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Leptospermum continentale, Gahnia sieberiana*	Litter		Water
45	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Leptospermum continentale, Gahnia sieberiana*	Litter		Water
45.25	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Leptospermum continentale, Gahnia sieberiana*	Litter		Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
45.5	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Leptospermum continentale, Gahnia sieberiana*	Litter		Water
45.75	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Bare ground	*Leptospermum continentale, Gahnia sieberiana*	Litter		Water
46	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Leptospermum continentale, Gahnia sieberiana*	Litter		Water
46.25	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter	*Eucalyptus ovata*	Litter	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
46.5	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Litter	*Gahnia sieberiana*	Litter		Water
46.75	*Leptospermum continentale*	Litter	*Leptospermum continentale*	Litter		Litter	*Gahnia sieberiana*	Litter		Logs
47	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Bryophytes	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
47.25	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Litter	*Gahnia sieberiana*	Litter		Water
47.5	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Litter	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
47.75	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Litter	*Gahnia sieberiana*	Litter		Water
48	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Litter	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water

Point	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5	
	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover	Species	Ground cover
48.25	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Litter	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
48.5	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Litter	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
48.75	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Bryophytes	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
49	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Bryophytes	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
49.25	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Litter	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
49.5	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Litter	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
49.75	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Litter	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water
50	*Leptospermum continentale*	Water	*Leptospermum continentale*	Litter		Bare ground	*Melaleuca squarrosa, Gahnia sieberiana*	Litter		Water

Appendix C Condition assessment results

Table C1. General information

Wetland Name	Big Swamp
Bioregion	Otway Plain
Projection/Datum	UTM S
Zone	54
Eastings	735394
Northings	5743969
Area (hectares)	6.95
Was the whole wetland assessed?	Yes
Assessors	Karl Just and James Garden
Date Assessed	7/09/2019
Agency	Barwon Water

Inundation Status of Wetland	
Water Cover	
Dry or moist soil	20%
Saturated soil	70%
Water Cover	10%
Unknown	0
Wetland Phase	Full
If dry, number of years dry	0

Table C2. Index of wetland condition results

Bioregion	Otway Plain			
Sub-index	**Score**	**Condition Category**	**Weight**	**Adjusted score**
Wetland catchment	18	Excellent	0.26	4.68
Physical form	8.75	Poor	0.08	0.70
Hydrology	0	Very Poor	0.31	0.00
Water properties	7	Poor	0.47	3.29
Soils	6	Poor	0.07	0.42
Biota	12.48	Poor	0.73	9.11
Total				**18.20**
Overall IWC Score		**Moderate**		**5**

Table C3. Wetland catchment index

Wetland Buffer Assessment		
	Description	**Score**
Average buffer width (metres)	>50	2
% of wetland perimeter with buffer	>95	5
	Wetland buffer assessment score	10
Percentage of land in different land use intensity classes adjacent to the wetland		
Land Use Intensity Class	**% of adjacent land in each land use intensity class**	**Result**
Very High	0	0
High	0	0
Medium	20	40
Low	10	30
Very Low	60	240
	Sum of results	**310**
	Adjacent Land use Score	**8**
Wetland catchment sub-index score (wetland buffer score + adjacent land use score)		**18**

Table C4. Physical form index

Reduction in Wetland Area		
	% reduction in wetland area	**Score**
Percentage of reduction in wetland area	25 to 50	6
Does the shape of the wetland boundary differ from Wetland 1994 layer or more recent mapping?	n/a	
Activities leading to a change in wetland bathymetry		
Excavation of the wetland bed (e.g. channels, dams, dredging)	Yes	
Land forming (e.g. raised-bed cropping, laser-levelling, building mounds, aqueducts, tracks)	No	
Severity of bathymetry changes		
Severity rating	**% of wetland area**	**Score**
High	60	0
Medium	20	1
Low	10	0.75
None	10	1
	Change in bathymetry score	**2.75**
Physical form sub-index score (reduction in wetland area score + change in bathymetry score)		**8.75**

Table C5. Hydrology index

Water Source	River or stream	✓
	Surface runoff	
	Ground Water	✓
	Artificial Channel	
Activities that change the flow regime of the water source	River regulation	
	Activities that change surface drainage patterns	✓
	Activities that change groundwater levels	✓
	Regulation not associated with maintaining or restoring reference condition	
Activities that change the wetland water regime	Activity that changes the flow regime of the water source	
	Obstruction or regulation of natural water flow to wetland	
	Obstruction or regulation of natural water outlets	✓
	Drainage of water from the wetland	
	Disposal of water into the wetland	
	Extraction of water directly from the wetland	
	Activities that permanently raise the water level (e.g. damming the wetland or constructing levees to restrict the spread of water)	
	Activities leading to an increase in groundwater height	
	Activities leading to a decrease in groundwater height	✓
Severity of change on water regime components		
	Severity of Change	**Score**
Timing	Change to another season	0
Water Regime Category	Change in Category	0
	Sum of Severity Score	0
	Hydrology sub-index score	**0**

Table C6. Water properties and soil index

WATER PROPERTIES - Extant	
Activities leading to nutrient enrichment	
Point source inputs (channel or pipe of urban/industrial/ agricultural nutrient-rich water to the wetland)	
Application of fertilizer to wetland	
Runoff of nutrients to wetland (e.g. from fertilizer application or grazing)	✓
Grazing of wetland by livestock and feral animals	✓
Aquaculture	

Nutrient Enrichment Score (If there are activities, is the likelihood of an increase in nutrients in the wetland low (score = 7), moderate (score = 5) or high (score = 0). If there are no activities, score = 10.)	7	
Water quality observations		
Evidence of a change in Salinity		
		Score
Is there evidence that the wetland has increased in salinity? (AS)	No	0
Is there evidence of saline water intrusions from the marine environment via groundwater and/or storm surges?	No	0
Is the brackish or fresh wetland within 250 m of a salinity discharge site?	No	0
Is saline water delivered to a fresh or brackish wetland or is (unnatural) freshwater delivered to a saline wetland?	No	0
	Salinity Score	**0**
	Water properties sub-index score (Nutrient Enrichment Score + Salinity Score)	**7**

SOILS - Extant		
Activities that causes soil disturbances		
Pugging by livestock		
Disturbance/pugging by feral animals (e.g. pigs, rabbits, deer, horses)	✓	
Carp mumbling		
Trampling by humans		
Cultivation		
Driving of vehicles in the wetland	✓	
Soil disturbance severity	**% of soil**	**Score**
High	60	0
Medium	10	1
Low	20	3
None (100% of soil)	10	2
	Soil Sub-index Score	**6**

Table C7. Wetland biota index

Vegetation association		Riparian Fern Scrub (RFS120-A)	Riparian Scrub (RFS120-B)	Riparian Scrub (RFS120-C)	Wet-verge Sedgeland (WVS932-A)
	Max. Score	*Score*	*Score*	*Score*	*Score*
Critical Life form groupings	25	21.90	21.90	6.25	19.37
Weeds	25	22	22	22	25
Indicators of altered processes	25	20	10	5	25
Vegetation structure and health	25	25	20	0	25
EVC Sub-total	100	88.90	73.90	33.25	94.37
Adjusted EVC Score (EVC/5)	20	17.78	14.78	6.65	18.90
Area of wetland covered by EVC (%)		6%	62%	31%	1%
Wetland EVC Score		1.07	9.16	2.06	0.19
	Total Wetland Biota Score			**12.48**	

[1] Zones shown in Figure 3

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