

Merrifield North Employment and Beveridge
South West PSP Pre-European Wetland
Investigation

July 2024

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Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for Country and the waterways within.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for Melbourne Water under the contract titled 'Merrifield North Employment and Beveridge South West PSP Pre-European Wetland Investigation.'

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Glossary

Annual exceedance probability	The probability of a flow rate (or rainfall depth) being equalled or exceeded in any one year.
Ecological Vegetation Class (EVC)	The standard unit for classifying vegetation types in Victoria. EVCs are described through a combination of floristics, lifeforms and ecological characteristics, and through an inferred association to particular environmental attributes
Groundwater dependent ecosystem (GDE)	Ecosystems that are supported by groundwater, including springs and wetlands
Ground truth	The task of validating modelled results by conducting site visits and documenting conditions or the absence/presence of some modelled state
Pre-European	The time period prior to European arrival and settlement in Victoria
Wetland	Areas of land covered or saturated with fresh, brackish or salt water that's generally still or slow moving.
Wetland expression	Period in which intermittent wetlands become partially or completely saturated, triggering the expression particular flora at the ground surface

1 Introduction

The objective of this study is to identify the extent of pre-European wetlands within the combined Merrifield North Employment and Beveridge South West PSP areas (referred to herein as the combined PSP area). This study forms part of broader background investigations to support the Proposed Merrifield North Employment and Beveridge South West Precincts component of the Kalkallo Creek DSS.

The term pre-European distinguished the wetland from those that have been mapped as part of the supporting PSP background investigations, recognising that land use changes in the catchment since European settlement are likely to have had an impact on the process that control wetland extent and the values they can support, and therefore on the extent and quality of the wetlands themselves.

Although this pre-European wetland investigation may be used to inform cultural heritage assessments and in identifying culturally sensitive sites, those aspects have not been addressed in this study. This study focuses on the biophysical aspects of wetlands rather than the social or cultural aspects.

The combined PSP area is known to host, or have hosted, seasonal wetlands. Those wetlands (and their contemporary remnants) lie within a broad, flat and low gradient alluvial plain that formed in a low energy and depositional environment. A combination of shallow groundwater and water flowing through shallow and discontinuous waterways fed the wetlands with freshwater. Annual changes in rainfall and larger climate conditions in the surrounding landscape cause variation in the standing water within the wetland, resulting in annual variation in the quantity and visual presence of wetland flora.

This assessment does not attempt to fully reconstruct the pre-European environment that hosted the wetlands. Instead, this report draws upon geomorphology and ecological field investigations¹ and flood modelling².

1.1 Wetland Definitions

Wetland definitions according to Index of Wetland Conditions literature

The Index of Wetland Condition (IWC) Conceptual framework produced by the Department of Sustainability and Environment (2005) defines wetland as "*naturally occurring, waterbodies with static water and without a marine hydrological influence*".

Vegetation within wetlands can be highly spatially and temporally variable with different vegetation types presenting across different parts of a wetland and at different times. Temporal variability can be expressed within a day for tidal impacted wetlands, seasonally, annually, or intermittent depending on the water regime and source of inundation for the wetland. To help with the assessment of wetland vegetation quality and extent, vegetation types (EVCs) present across all temporal and spatial scales of Victorian wetlands have been identified (ARI, 2016). The EVC wetland guide outlines the water regimes (including frequency of inundation, duration of inundation and depth of inundation) and the salinity range for all wetland EVCs. It also outlines which phase of drying or wetting the EVCs are likely to present in.

Wetland EVC definition: "*An EVC is regarded as relevant to wetlands if the ecological effects of at least intermittent inundation or extreme waterlogging are expressed in the floristic composition. This determination has been based on the ecological attributes and habitat preferences of the component species. Presently, 158 wetland EVCs have been described*" (DELWP 2022a).

¹ Alluvium 2023, Merrifield North Employment and Beveridge South West Precinct Structure Plans geomorphology and vegetation assessments

² Alluvium 2023 Merrifield North Employment and Beveridge South West Precinct Structure Plans flood assessment modelling report

Although the extent and observable vegetation of a wetland is highly variable both spatially and temporally, the IWC assessment allows for the identification and assessment of biota health and an overall wetland score regardless of the wetting/ drying phase it is in during the time of assessment.

Because this study is based on modelling and topographical information, wetlands are mostly according to the IWC literature. The resulting interpretations are informed by field investigations and spatial information pertaining to EVCs and other markers of water in the landscape.

1.2 Approach

The extent of the pre-European wetland(s) and flow paths that feed the wetland(s) were reconstructed using multiple lines of evidence, including:

1. Current surface water observations
2. Analyses of current and modelled spatial mapping of wetland features and the broader landscape
3. Analysis of historic maps, surveys and accounts
4. Modelling of pre-European wetlands via the following steps
 - Reconstruction of surface terrain to remove post-European features
 - historic rainfall data captured in relevant intensity Frequency Duration curves
 - Hydraulic modelling to estimate the extent of inundation under a limited number of rainfall scenarios

Together this evidence enables us to infer the potential extent of wetlands in the landscape prior to European colonisation.

2 Current surface water observations

2.1 Current surface waters (spatial)

Several watercourses traverse the combined PSP area (Figure 1). Kalkallo Creek is the predominant watercourse, which flows in a southerly direction, through the Kalkallo retarding basin and off site towards its confluence with the Merri Creek. Most watercourses in the combined PSP area, including Kalkallo Creek, consist of straight channels that vary in width, depth and degree of incision³. It is presumed that the current locations of the straight channels differ from those of pre-European watercourses. Sinuous reaches are assumed to have formed through natural processes, although it is possible that upstream anthropogenic activity and the clearing of vegetation together with the sodic nature of soils may have exacerbated channel erosion and incision since colonisation.

Numerous instream dams have been excavated which impact the way water moves through the landscape. Furthermore, the Kalkallo retarding basin (constructed in 1984) plays a significant role in the management of stormwater and flooding within the PSP area.

³ Alluvium 2023, Merrifield North Employment and Beveridge South West Precinct Structure Plans geomorphology and vegetation assessments

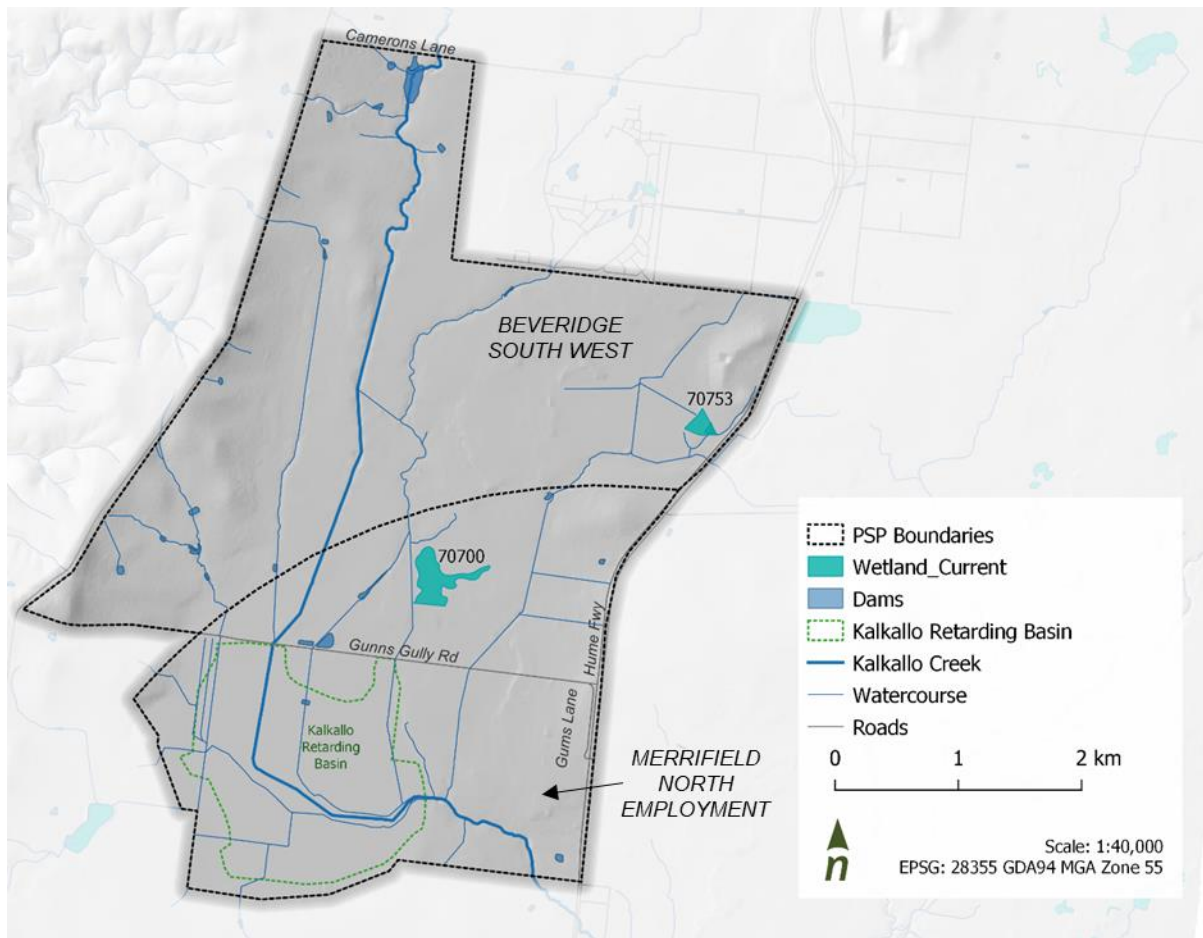


Figure 1. Mapped current wetlands, waterways and dams in the Merrifield North Employment and Beveridge South West PSP areas.

According to the Department of Energy, Environment and Climate Action (DEECA) Victorian Wetland Inventory dataset (Wetland_Current), two wetlands are located within the combined PSP area (Figure 1, Figure 2). Wetland_Current was created in 2013, and updated in 2014, 2017 and 2021. The spatial extent of wetland 70700 in the 2021 spatial layer has significantly decreased compared to earlier versions of the Wetland_Current and Wetland_1994 spatial layers (not shown). It is noted that wetland 70753 was not included in DEECA's Wetland_1994 spatial dataset. Inconsistencies in these spatial datasets are therefore acknowledged. None-the-less, these suggest where wetlands may be supported in the landscape. Field assessments were conducted in 2023 to ground truth the accuracy of spatial layers and assess the condition of existing wetland vegetation.

2.2 Field observations of wetlands and wetland EVCs

Summary of IWC condition assessment for 70700 based on observable site conditions (17/02/2023)

In field assessments conducted in February/March 2023, the area marked as wetland 70700 was dry and being used for cropping. The area, although clearly waterlogged in the extremely wet spring, looks to have only experienced shallow inundation, and was no longer functioning as a wetland. The water source for Wetland 70700 was determined to be a combination of river/ stream flows delivered via in channel or over bank flows, local surface run off and to a lesser extent, groundwater.

100% of the soil conditions were assessed as dry unsaturated soil with a 95% reduction in the wetland area. The reason for the reduction was identified as a combination of barriers to filling and the development of channelisation/ drains within the wetland however it is unclear from the site assessment when the reduction in the wetland area took place. Due to the now cropped nature of the wetland area, the nutrient enrichment score

was assessed as high and 100% of the soil in/around the wetland were categorised as disturbed due to cultivation.



70700



70753



Figure 2. Current wetlands in the PSP area.

The only EVC listed for the extent of the wetland was **Unclassified (Crop) EVC 999** which covered 100% of the area. The historic EVC (listed as Plains Grassy Wetland) was scored as completely displaced with no species that define the Plains Grassy Wetland EVC currently present in the landscape. The overall condition of the mapped wetland 70700 is assessed at the very low end of Poor, with the biota component achieving a score of 'Very Poor' due to its total conversion to cropping and lack of species characteristic of the prior EVC and dependant on at least periodic inundation. The only evidence of a wetland influence could be seen in the areas of canola crop failure across the site. These patches likely represent patches of inundation beyond the tolerance of the canola crop.

Conclusion for Wetland 70700

Due to the lack of remnant wetland vegetation (Unclassified EVC 999), it is not possible to determine the number of years the wetland has been dry for or the variability of the system. The impact of waterlogging on the Canola crop across the area mapped as wetland 70700 indicates that the area still has some water holding capacity however it has ceased to support plant species that are characteristic of wetland vegetation. However, if the wetland did not fill in the recent wet years, future inundation is considered highly unlikely.

Summary IWC condition assessment for 70753 based on observable site conditions (12/07/2023)

Wetland 70753 is an excavated dam structure surrounded by soil mounds. In July 2023, extensive sections of a low-lying area to the immediate west of the mapped wetland 70753 were inundated and are estimated to comprise part of the original extent of this wetland.

The water sources for Wetland 70753 were identified as a combination of local surface run off and groundwater. The reduction in the effective wetland area was scored between 25-50% indicating a minimum of 50% effective wetland area persists on site. The primary reason for reduction in wetland area can be attributed to infilling of areas of the wetland, barriers to wider filling and channelisation/ drains within the wetland (see description in section 3.2) . The depth of the wetland has undergone changes due to excavation and land forming (building of mounds derived from the excavated soil) which were clearly visible during the site inspection (see Figure 3 below). Nutrient runoff from the adjacent cropped areas and grazing of livestock within and adjacent to the wetland resulted in high levels of nutrient enrichment within the defined wetland area.

Brackish Wetland Aggregate EVC 656, made up 100% of the vegetation area cover within the wetland.

Disturbed/weedy areas were not distinguished as a separate zone due to patchiness of distribution of native species across the wetland. Despite the presence of native flora within the wetland, the low cover and density of native obligate wetland flora and high cover of weeds (due to disturbance) resulted in a biota score of 'Very Poor' for the wetland. Despite the low overall score, two patches of FFG Act listed endangered *Ranunculus diminutus* (Brackish Plains Buttercup) were noted adjacent to one of the dammed walls of the wetland. The overall condition of the mapped wetland 70753 was assessed as 'Poor'.



Figure 3. Left- Wetland 70753 with mounds dumped highlighted, right - *Ranunculus diminutus* (Brackish Plains Buttercup) patch.

To the northwest of the mapped 70753 wetland is a further wetland area, estimated to encompass the original wetland extent (Figure 4). The wetland contains patches of Brackish Sedgeland EVC 13. No formal IWC assessment has been done on this patch however due to the relatively minimal amount of excavation within the wetland, it should be considered in future planning.



Figure 4. Left- Image Wetland extension to the northwest of the mapped Wetland 70753. Easting 0319611; Northing 5848720, right- Mapped extent of estimated wetland area including inundated patch.

Conclusion for Wetland 70753

The presence of Brackish Wetland vegetation in the mapped wetland 70753 and the patches of Brackish Sedgeland in the inundated patch to the north of the wetland indicate that despite low IWC health scores, the wetland is still retaining some floristic and likely fauna habitat functionality.

Current wetland conclusion

Taken together field assessments suggest that the wetlands have changed markedly since European colonisation. For example, wetland 70700 no longer functions as a wetland, although evidence of surface waterlogging and poor crop performance are consistent with this area being intermittently or seasonally wet despite the land use change and lack of wetland EVCs. Although wetland 70753 contains regions of excavation (which would not have existed prior to colonisation), adjoining areas were inundated at the time of the assessment and consistent with this area being at least seasonally wet. Wetland 70753 could not be assessed during summer months, thus the extent of the wetland during dry months remains unknown.

2.3 Comparison between modelled Wetlands 70700 and 70753 and Burrung Buluk (Hanna Swamp)

Burrung Buluk (Hanna Swamp) is a 70ha wetland located south of the township of Wallan and straddles the Wallan South and Beveridge North West PSP areas (Figure 5). The swamp sits approximately 5.7km north from wetland 70753 and 7km north of Wetland 70700. Hanna Swamp is outside the study area of this project but provides a useful comparison to wetlands 70753 and 70700 due to the scope of earlier investigations, its potential for rehabilitation and its cultural significance.

Surveys of Burrung Buluk (Hanna Swamp) indicate that the southern portion of the swamp contains significant biodiversity values. Field surveys conducted by Alluvium (October 2020) confirmed the presence of EVC 125 / Seasonal Herbaceous Wetlands (SHW) at Burrung Buluk (Hanna Swamp) in the southern portion, and degraded EVC 125 vegetation in the northern portion. These earlier investigations (Alluvium, 2020) assessed Burrung Buluk (Hanna Swamp) as having a high potential for rehabilitation if appropriate interventions are taken.

Compared with Burrung Buluk (Hanna Swamp), wetland 70700 within Merrifield North Employment PSP is of low quality with no evidence of SHW flora.

The mapped wetland 70753 and the associated inundated patch to the northwest of the mapped area have a higher cover remnant vegetation (compared with Wetland 70700), however they have also experienced a high level of soil disturbance (in the form of mounding and pugging), a high cover of weed invasion and they did not indicate the presence of SHW flora as was found at Burrung Buluk (Hanna Swamp).

Neither wetland 70700 or wetland 70753 therefore can be compared in quality or floristically to Burrung Buluk (Hanna Swamp). Despite this, there is high possibility for rehabilitation of both wetlands (but particularly 70753 with remnant attributes). As they are the only remnant wetland patches within the development footprint and due to the presence of FFG listed *Ranunculus diminutus* in wetland 70753, both the wetlands, a buffer area around the wetlands and a suitable water supply need to be protected and rehabilitated during and after the PSP development. Recent excavation in wetland 70753 may have limited the possibility of rehabilitation, but to what extent is unknown. Much of the excavation appears to have been undertaken in the portion of the wetland that was already a permanent pool (potentially due to past excavations). A more detailed investigation, essentially a site visit by a suitably qualified wetland ecologist, as to the potential for rehabilitation and the impact that the recent excavation has had on the potential for rehabilitation is required.

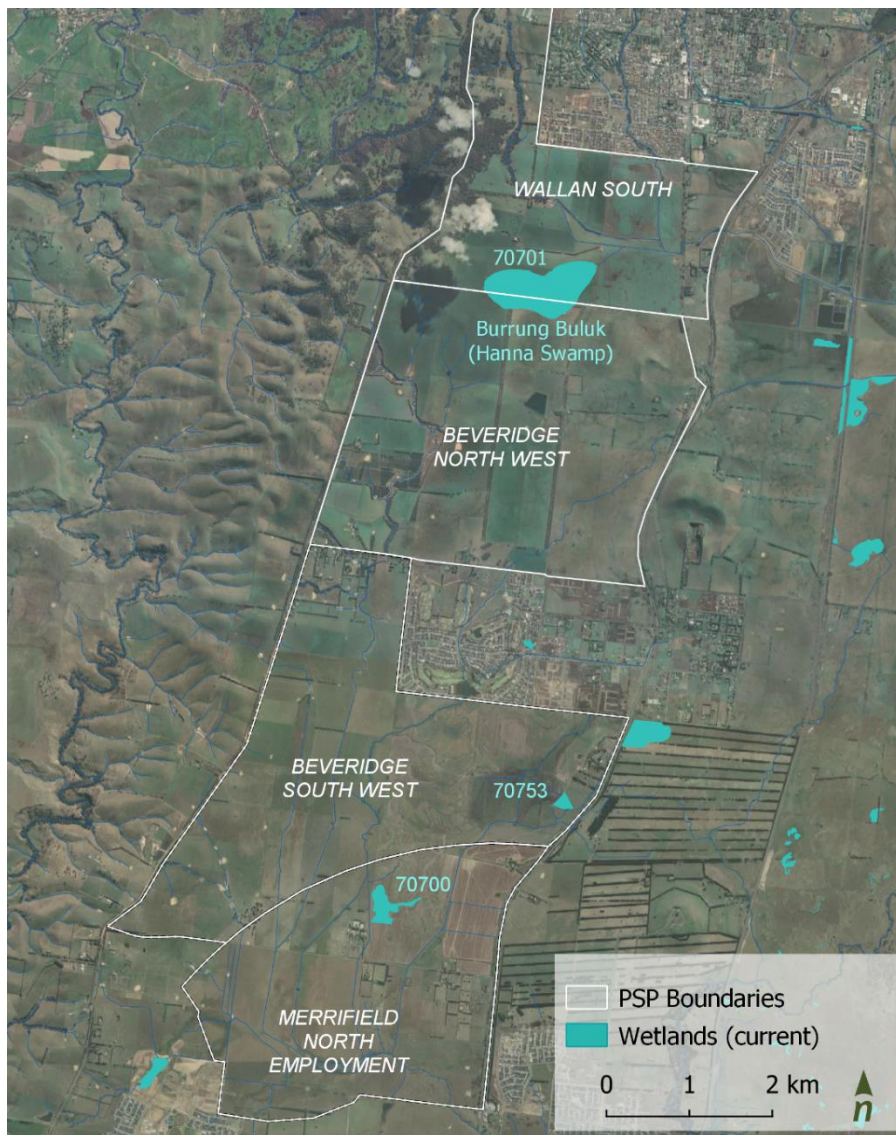


Figure 5. Location of Burrung Buluk (Hanna Swamp) relative to wetlands 70700 and 70753.

3 Analyses of modelled and current spatial data

3.1 Current and modelled wetlands in the PSP area

As noted above, two current wetlands are mapped in the PSP area:

- (1) wetland 70700 which is located in the centre of the combined PSP areas, and
- (2) wetland 70753, which is a small wetland in the east of the Beveridge SW PSP area.

Modelled pre-European wetlands

The Victorian Wetland Inventory Pre-European wetland spatial layer contains modelled wetland extents before European colonisation. The layer was most-recently updated in 2021 and is shown Figure 6, together with the current wetland spatial layer. The large pre-European wetland (70700) has a considerably larger spatial extent than current wetland 70700. Pre-European wetland 70753 shares the same extent as current wetland 70753, although according to the available spatial attribute table, pre-European wetland 70753 was approximately 3 times larger than the mapped area (consistent with field assessments).

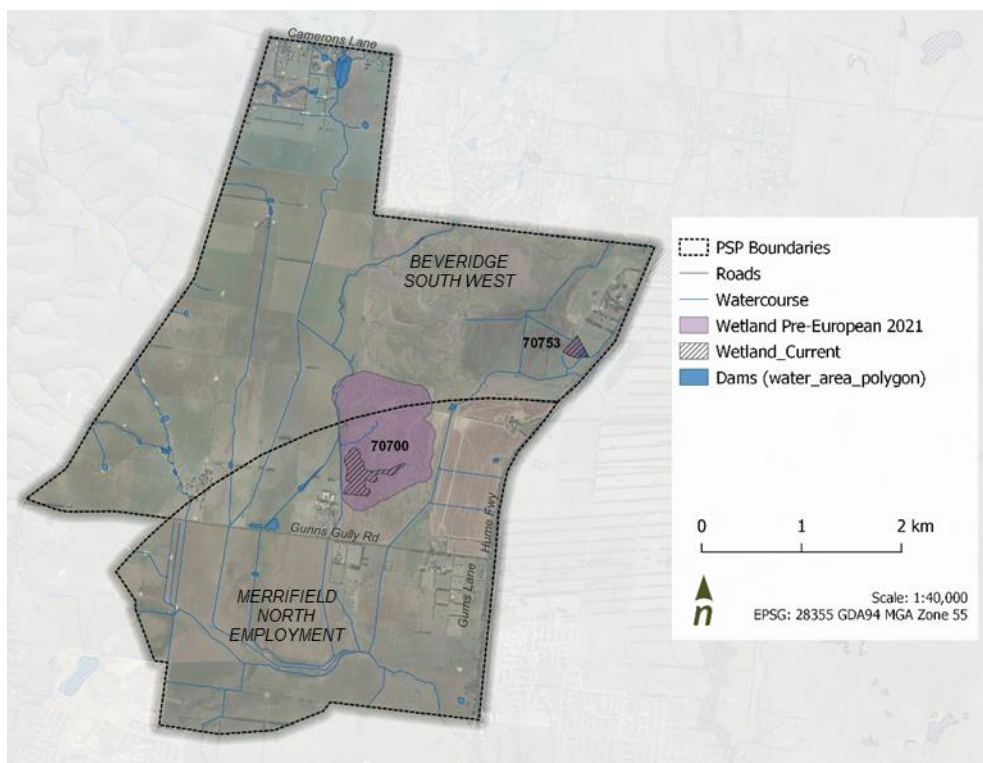


Figure 6. DEECA's Victorian Wetland Inventory Pre-European Wetland spatial layer (2021).

It is unclear how the Pre-European Wetland spatial layer was generated, nor the data on which pre-European wetland location and extent are based.

Therefore this report explored other spatial dataset related to topography, ecology and groundwater to inform our understanding of the broader PSP landscape and its ability to support wetlands.

3.2 Elevation and topography

Site elevation, as determined by 1 m resolution LiDAR data, is shown in Figure 7. Note, no LiDAR data was available for the southeastern corner of the site (intense red colouring). The lowest parts of the landscape occur at the site of the existing Kalkallo Retarding Basin, but also extend northwards into the central region of the

Beveridge SW PSP area. Note that the modelled pre-European Wetland 70700 is not located in the lowest parts of the landscape, nor is it located in a visible local depression.

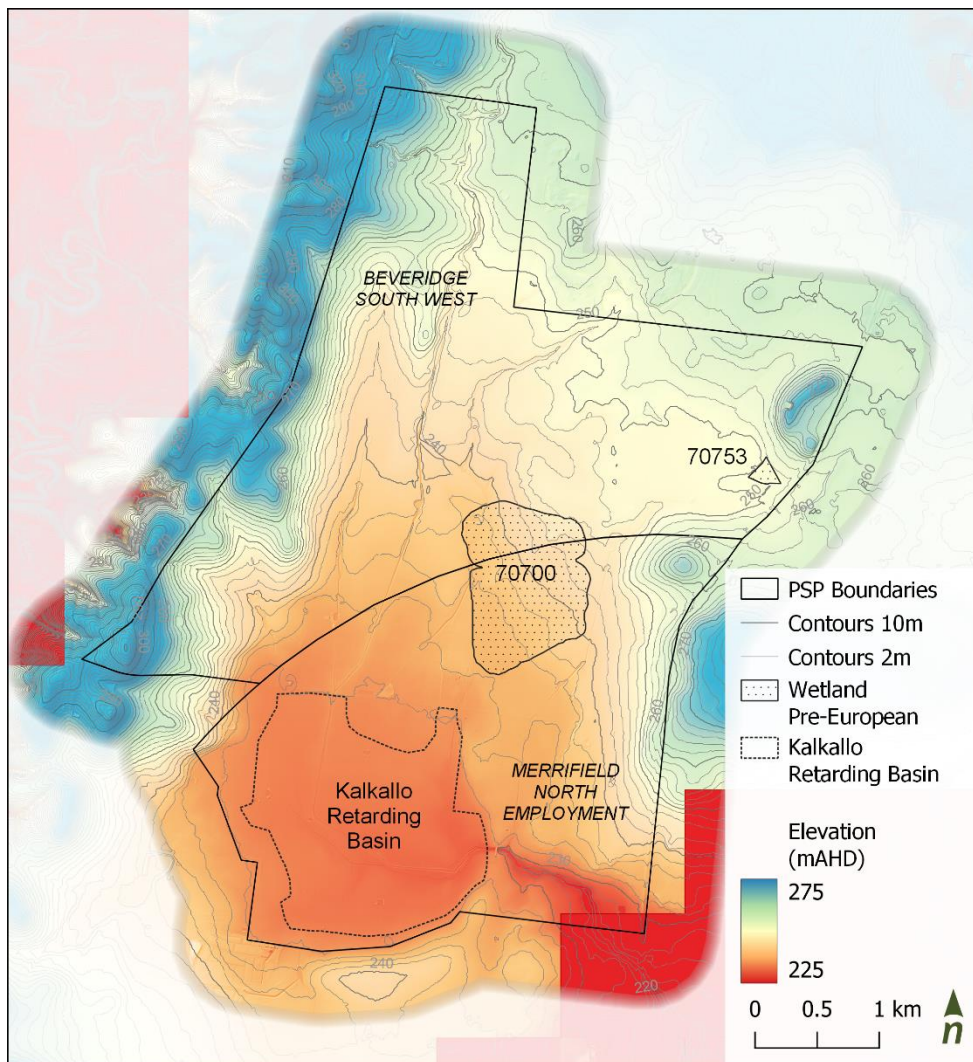


Figure 7. Site Elevation (mAHD).

Recent topographic change

Inspection of aerial imagery revealed that drainage lines have been to the north of wetland 70753 (Figure 9), along the approximate natural flow path that feeds surface water towards the area surrounding the wetland (see Figure 28 for an overview of these flow paths). The excavation and mounding of material from within the mapped footprint of the wetland observed in the field (see section 2.2) is also evident in the 2023 aerial image in Figure 8.

I've looked at Google Earth and there has been major work through the middle of the extended wetland (beyond the extent of 70753) - installation of a channel, road and other mounding and other work...along the course of what would have been the Spring Street Swamp. - I've put a folder of photos from google earth on the SharePoint. The image is shown in the modelling images, but not earlier in the report. Worth adding as an extra section in the report. To note further anthropogenic channels beyond that captured by LiDAR. Sp



Figure 8. Aerial images of wetland 70753 from 2015 (left) and 2023 (right) with recent drainage line and wetland excavation annotated.

3.3 Soils

Soil colour indicates the redox status of soil, and the soil's drainage qualities. Grey soils have low redox potential, are associated with areas of poor drainage and prolonged saturation⁴. Black soils may be due to high levels of organic matter, but black colouring may also indicate waterlogging or drainage issues⁵.

As shown in Figure 9, both pre-European wetlands are located on land modelled as grey Sodosols. Sodosols are texture contrast soils that have sodic subsoils. The grey colouring suggests that the entire area (over geological time) is prone to waterlogging and poor drainage.

Note that field-based soils assessment at the site concur that soils are strongly sodic⁶. Geotechnical assessments⁷ also noted the presence of grey surface and subsoils, and mottled soils (another hallmark of waterlogging) at the site.

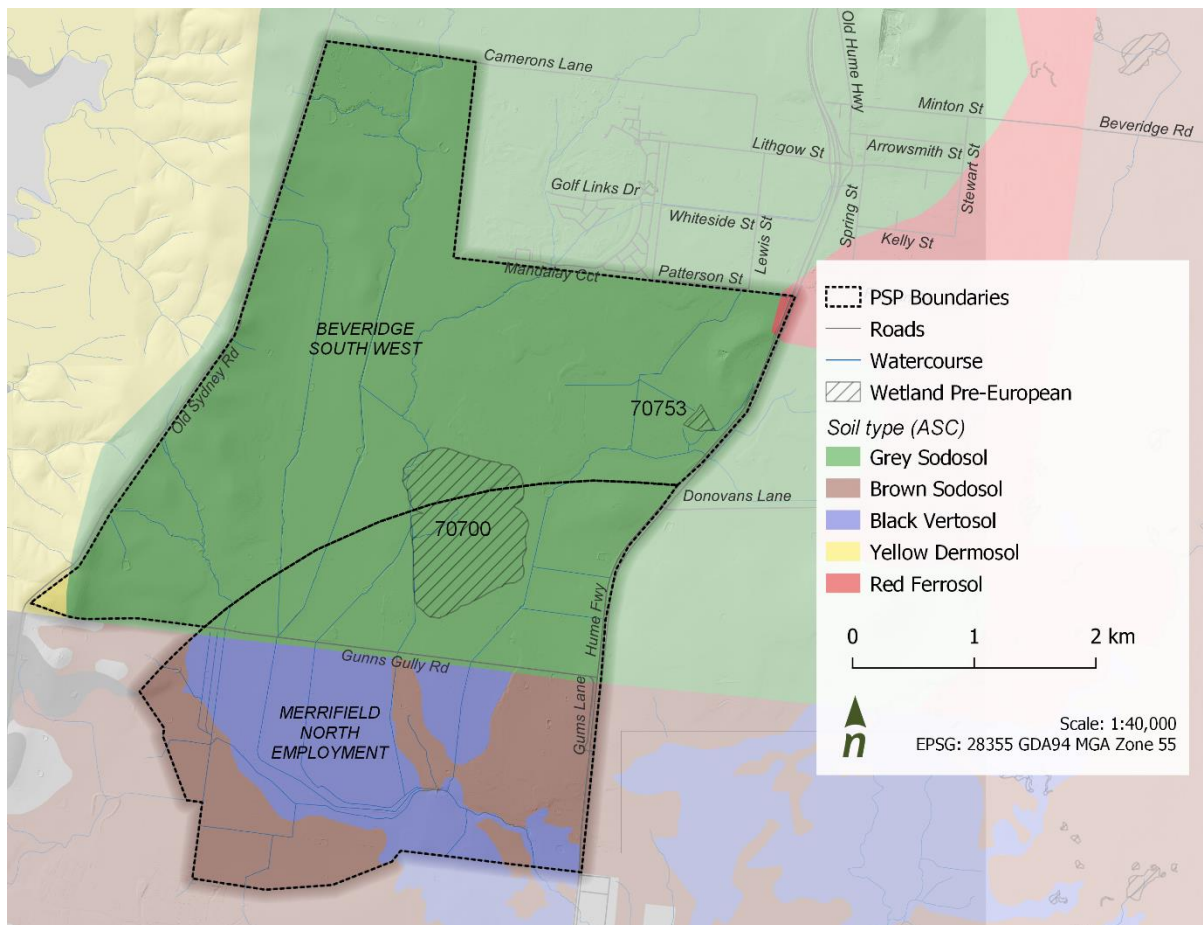


Figure 9. Soils in the PSP area (Source: DEECA Soil Type, Australian Soil Classification).

⁴ https://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soilhealth_interpret_colour

⁵ <https://www.qld.gov.au/environment/land/management/soil/soil-properties/colour#:~:text=Soil%20colour%20is%20usually%20due,white%E2%80%94from%20silicates%20and%20salt.>

⁶ Regen Soils 2023 Beveridge PSP Sodic Soil Investigation

⁷ Ground Science 2023, Preliminary geotechnical site investigation Beveridge Southwest PSP. Kalkallo Creek DSS, prepared for Alluvium Consulting Australia Pty Ltd

3.4 Groundwater Interactions

Several regions of the combined PSP area have very shallow water tables (0-2.5 m, Figure 10). This is particularly evident in the retarding basin, along watercourses and in the north east of the Beveridge SW PSP area, near wetland 70753, where the water table is modelled to sit just below the surface.

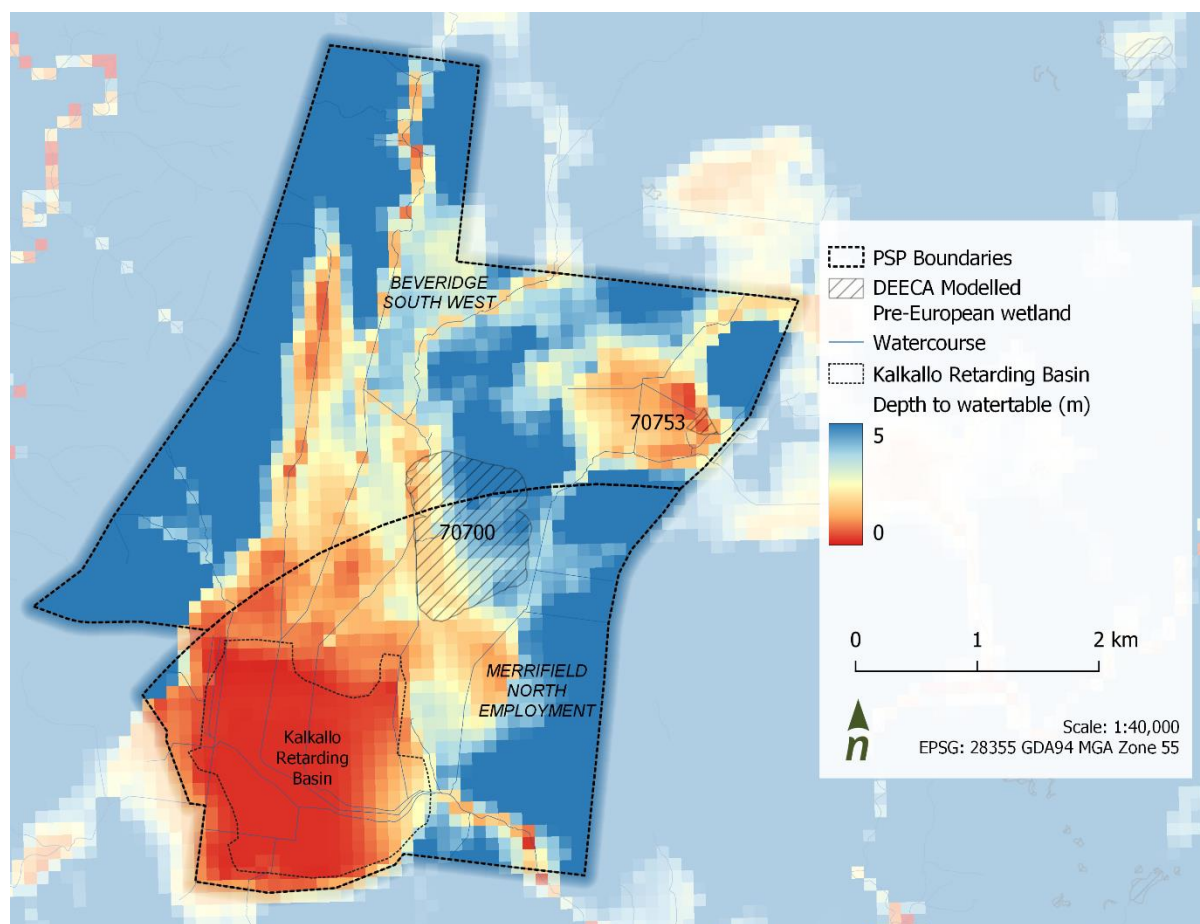


Figure 10. Depth to water table (Source: DEECA, Water table depth layer swl100 f).

The accompanying Groundwater Investigation report by CDM Smith (Dec 2022)⁸ suggest that groundwater in the study area flows towards Kalkallo Creek, and that Kalkallo Creek is likely a ‘gaining stream’ (a stream that receives groundwater inflows, which add to the stream’s overall flows).

Groundwater modelling was beyond the scope of the current investigation. Groundwater may play a significant role in driving the expression (timing, duration of flooding/soil saturation and the presence of wetland vegetation) and extent of the wetlands, and is supported by other spatial datasets, as discussed below.

Groundwater dependent ecosystems (GDE)

According to the Groundwater Dependent Ecosystems Atlas⁹, wetlands 70700 and 70753 are both predicted aquatic groundwater dependent ecosystems (Figure 11). The extents of the GDE and modelled pre-European wetland polygons overlay perfectly (with the potential caveat that the layers may not have been independently generated, and one may be based on the other). Note that Kalkallo Creek is also identified as an aquatic groundwater-dependent ecosystem in the atlas, which is consistent with the CDM Smith report⁸ that the water

⁸ CDM Smith 2022. Merrifield PSP Development Groundwater Impact Assessment. Report Prepared for Alluvium Consulting Australia, Pty Ltd.

⁹ <http://www.bom.gov.au/water/groundwater/gde/>

table slopes towards Kalkallo Creek and the creek seems to be a gaining stream (i.e. a stream that gains water from groundwater).

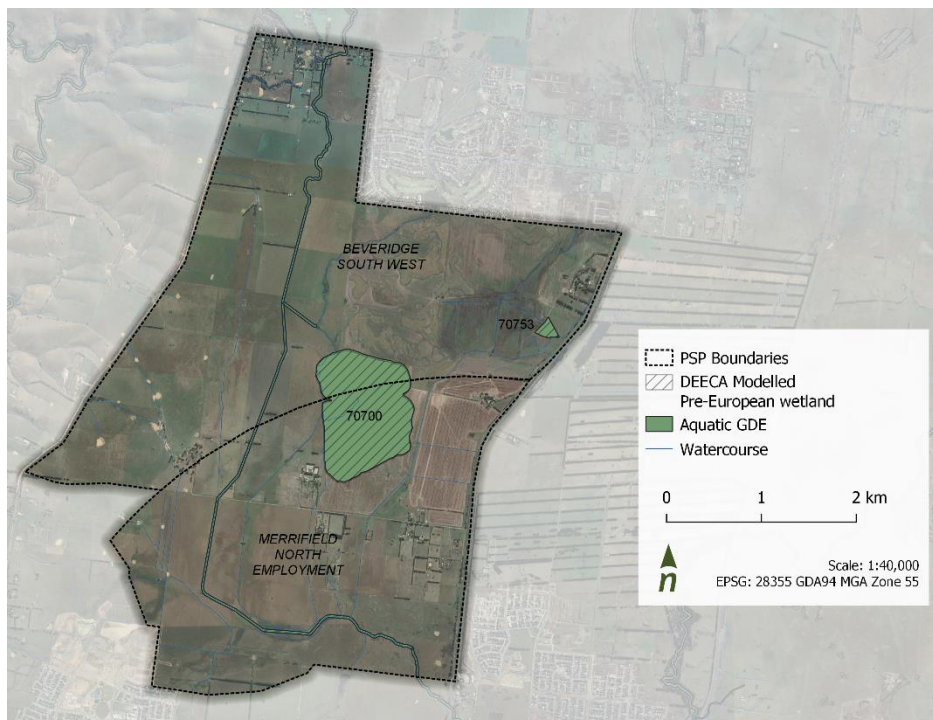


Figure 11. Groundwater dependent ecosystems (Source: GDE Atlas, Bureau of Meteorology)

3.5 1750 Modelled EVCs

DEECA's 1750 modelled ecological vegetation class (EVC) layer shows the Plains Grassy Wetland EVC (EVC 125) occupying most of the Merrifield North Employment PSP area, extending from pre-European wetland 70700 southwards to the Kalkallo retarding basin (Figure 12). The EVC layer model reportedly incorporates field data, environmental spatial data (soils, rainfall, topography), satellite imagery and historical records. This spatial layer does not predict wetland EVCs for wetland 70753.

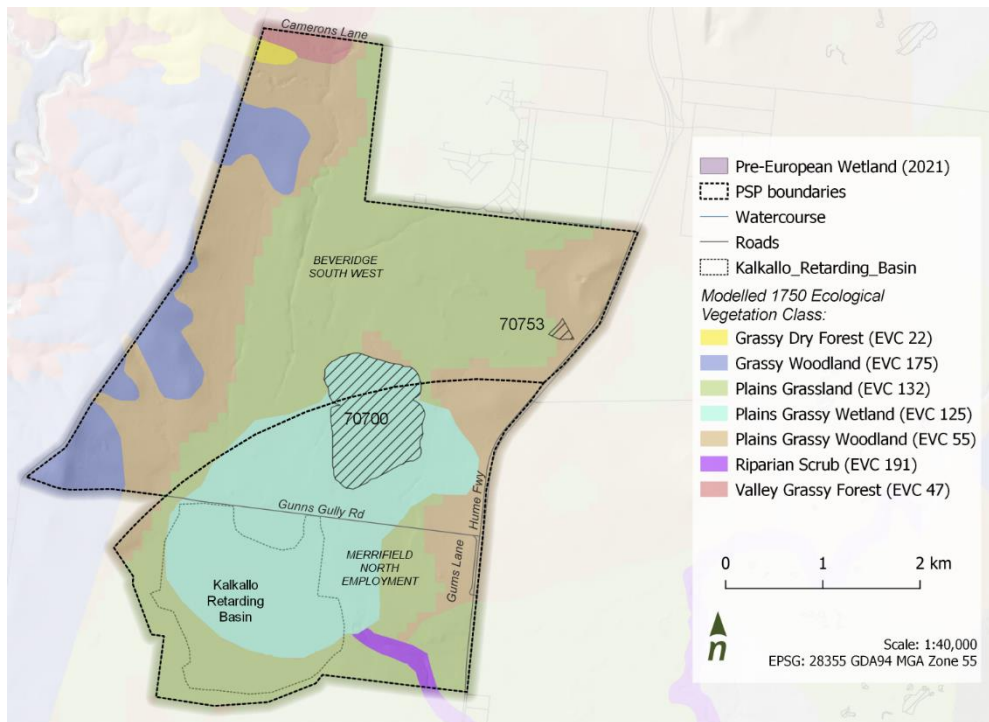


Figure 12. 1750 Modelled Ecological Vegetation Classes.

Changes in modelled EVC classes (1750 modelled vs 2012 vs. 2023 field observations)

The relatively low cover of native vegetation patches in the 2012 EVC map (Figure 13) compared with the 1750 EVC map (Figure 12) highlights the significant changes in vegetation cover that have occurred since colonisation.

According to the 2012 EVC map (compiled as a part of the Melbourne Strategic Assessment Growth Areas) the only patches which represent wetland communities are Plains Grassy Wetland (EVC 125) and Plains Swampy Woodland (EVC 651). Both patches are modelled communities which were not ground truthed by DEECA with site surveys during the time of modelling (according to the data set titled Native Vegetation Time Stamping Dataset - Melbourne Growth Areas (VC68) as provided by DSE, 2012 via data.vic).

The 2023 site assessments of the patch modelled as Plains Swamp Woodland (as mapped in Figure 13) in the SW corner of Beveridge South West did not indicate the presence of a wetland community. During the site assessment the patch was classified as Modified Plains Grassy Woodland due to the presence of old growth River Red-Gums (*Eucalyptus camaldulensis*) and a primarily exotic ground layer. The lack of groundwater fed indicator species indicates that the River Red Gums are likely fed from run off rainwater collecting within a low point in the landscape.

The patch of Plains Grassy Wetland on the 2012 EVC map could not be accessed during the 2023 field surveys due to land holder constraints so the presence of EVC 125 has still not been verified.

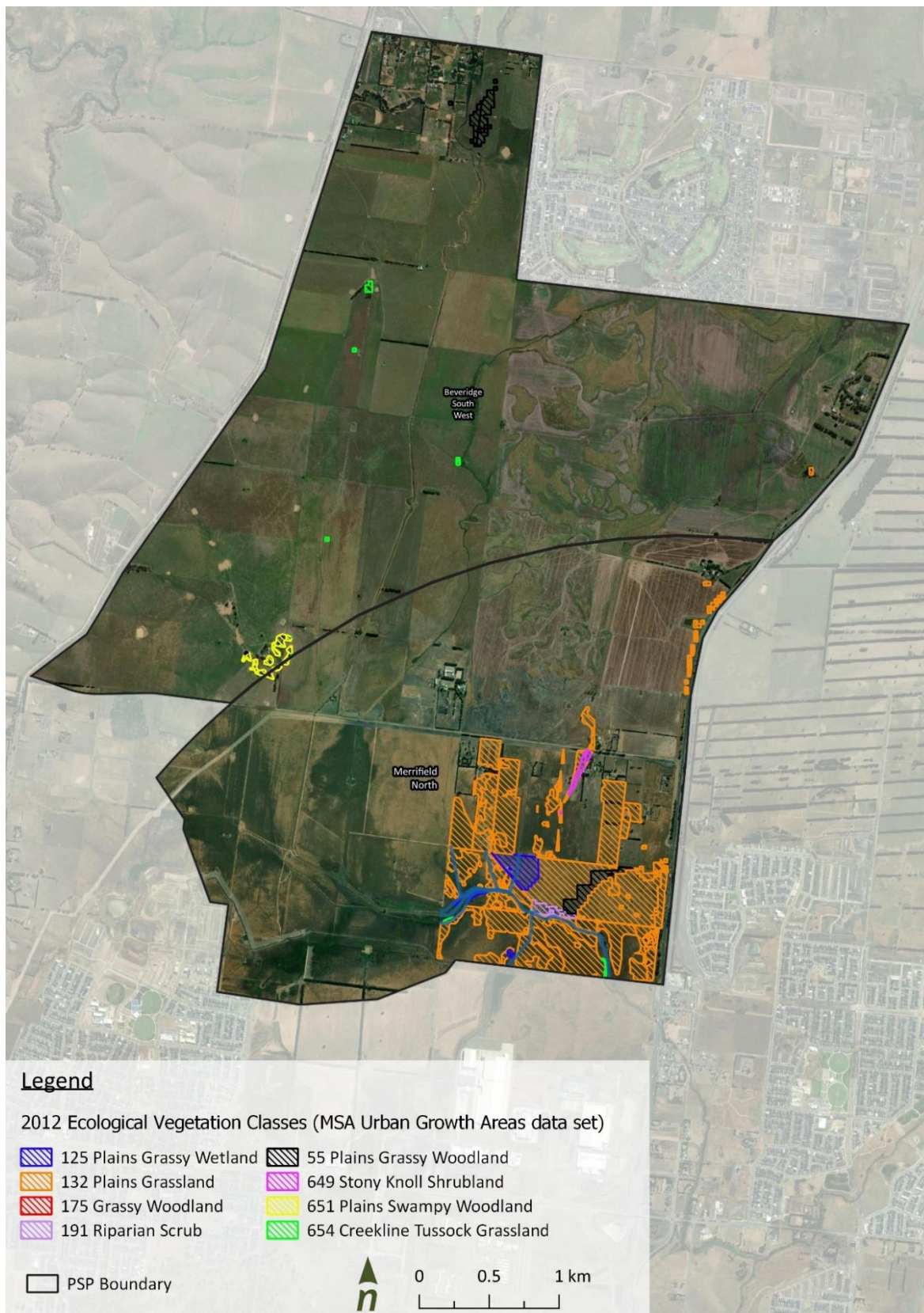


Figure 13: The 2012 Ecological Vegetation Classes data was provided via data.vic. The data set is titled *Native Vegetation Time Stamping Dataset – Melbourne Growth Areas (VC68)*. It was developed in 2012 as part of the Melbourne Growth Area (MSA) Strategic Assessment.

The extensive patch of Plains Grassy Wetland (EVC 125) in the modelled 1750 EVC layer (Figure 12) was only observed in a patch of low lying Seasonal Herbaceous Wetland (SHW) flora within the Retarding Basin in the south central area of Merrifield North. Due to the time of surveying, the extent of the SHW could not be quantified however it has been estimated in Figure 14 below. Other notable example of wetland vegetation within the site were found within and adjacent to modelled wetland 70753 and in the southwest of Merrifield North (within the Melbourne Water retarding basin footprint).

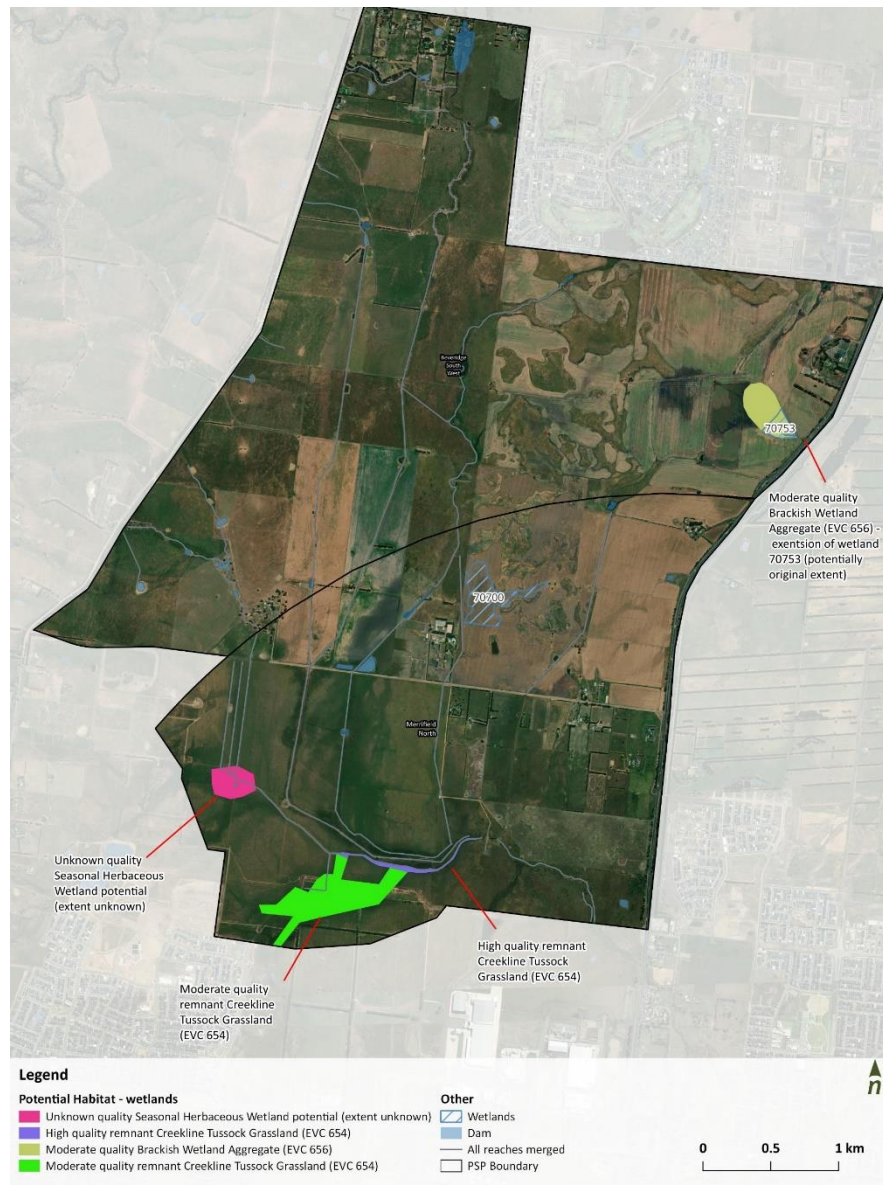


Figure 14. Extant wetland habitat within both PSPs.

3.6 Summary of spatial data

This section (Section 3) summarises analyses of spatial datasets that inform the extent of pre-European wetlands at the Merrifield North Employment and Beveridge South West PSP areas. The modelled spatial data support the possibility of a large pre-European wetland in the centre of the site, whose extent potentially have extended south into the now Kalkallo retarding basin. Wetland 70753 persists today. It is likely that both wetlands have groundwater connections that influence their extent and expression (timing, duration of flooding/soil saturation and the presence of wetland vegetation).

The form and extent of these wetlands have likely significantly changed since European colonisation. A significant caveat to these analyses is that they are reliant upon large scale modelled pre-European datasets - little information is available regarding the quality and accuracy of model inputs, nor the confidence that can be placed in model outputs. As it is not possible to ground truth the modelled pre-European data (as the modelled data is aiming to represent a conditions that were present over 100 years ago), existing reports on historic swamps in the area and district maps from the 1800s – 1900s were examined, to identify surveyed and mapped locations of watercourses and swamps in the PSP area.

4 Analyses of historic survey data and anecdotal evidence

4.1 Historic swamps in the PSP area

In 2018, the Merri Creek Management Committee (MCMC) compiled a map of the historical swamps and wetlands in the upper Merri Creek (Figure 15, MCMC 2018). MCMC report two historic swamps are located within the combined PSP area:

1. Spring Street Swamp
2. Inverlochy Swamp

The MCMC report does not describe how the spatial extents of swamps in Figure 15 were generated.

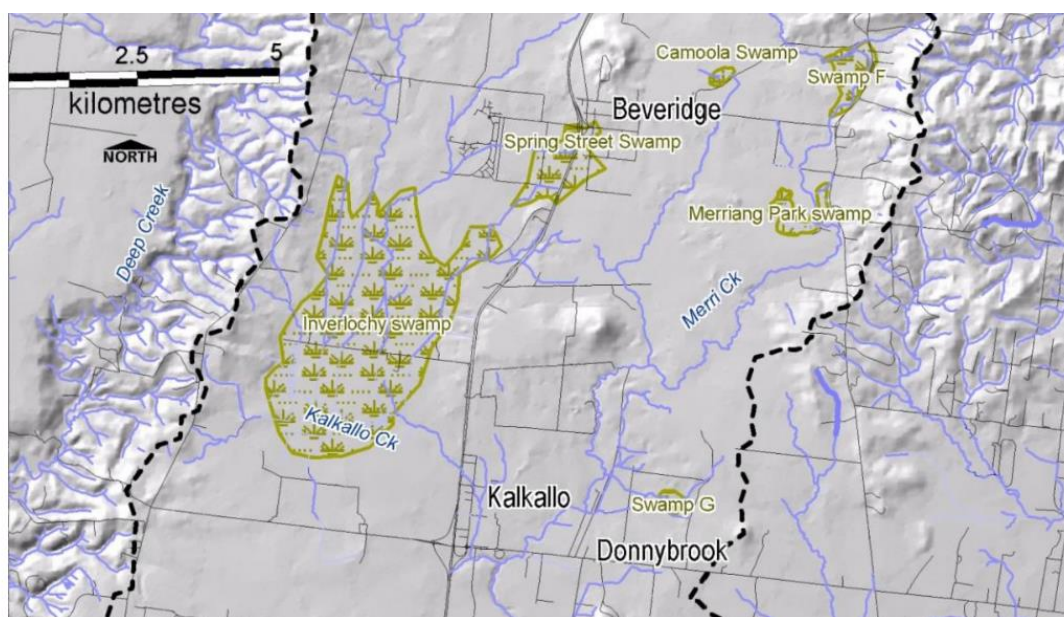


Figure 15 MCMC Historic swamps and wetlands near the Merrifield North Employment and Beveridge South West PSP areas (Source: MCMC 2018¹⁰).

Spring Street Swamp

The Spring Street Swamp is a permanent, spring-fed wetland, which is consistent with the shallow water table in this area. The spring rises in the southwestern foot of Mt Fraser. The Spring Street Swamp is reported by MCMC to be a remnant of the Inverlochy swamp, and today occupies 1-2 ha at the Beveridge Recreation Reserve (Beardsell 1997¹¹), although the swamps are depicted as geographically separate in the MCMC report. The extent of historical spring Street Swamp included the northeastern corner of the Beveridge SW PSP area, and

¹⁰ Merri Creek Management Committee 2018. Swamps and wetlands of the Upper Merri Creek Catchment. Original report 2012. Updated 2018.

¹¹ Beardsell, C 1997. Sites of Faunal and Habitat Significance in North East Melbourne, Volume 1. Report prepared by Dunmoochin Biological Surveys for the North East Regional Organisation of Councils.

the swamp extended northwards into what is now the Beveridge Central PSP area (Beveridge Central Precinct Structure Plan 2018, VPA) (Figure 16). The Spring Street Swamp area could not be accessed during the 2023 geomorphology or ecology assessments to confirm the presence or persistence of wetland EVCs.

The Spring Street Swamp is visible as an alluvial deposit on an 1862 Geological Survey of Victoria map L3SW (Attachment 1). The PSP boundaries, overlaid on a georeferenced image of map L3SW are shown in Figure 16. Spring Street Swamp is located in the northeastern corner of the Beveridge SW PSP area. Of note, the pre-European Spring Street swamp appears geographically distinct from current and modelled pre-European wetland 70753, which is located further to the south and on the opposite side of a topographical rise. No other swampy areas were marked within the PSP area on map L3SW (see attachment 1).

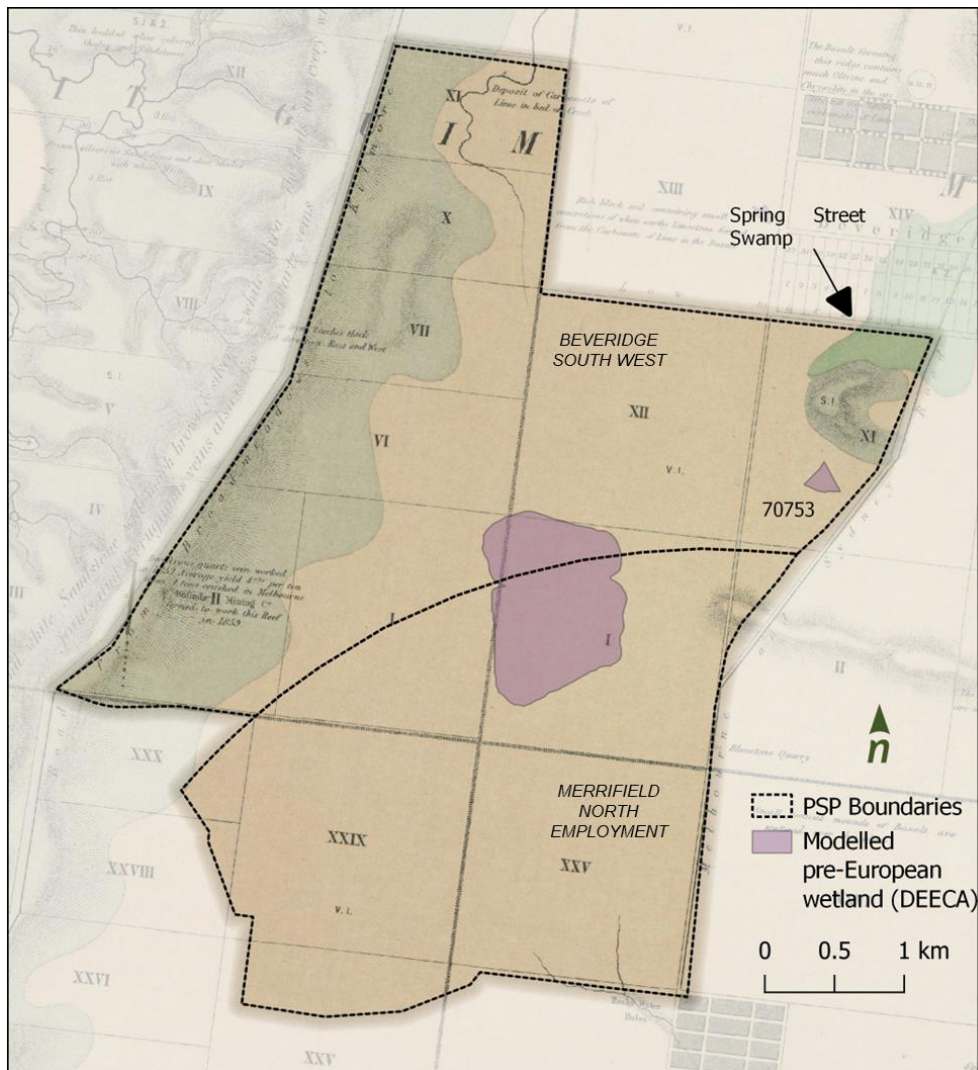


Figure 16. PSP Boundaries overlaid on georeferenced Geological Survey of Victoria map L3SW of Darraweit Guim. Area surveyed 1856, published 1862. Georeferenced lithograph obtained from Public Records of Victoria Map Warper. Arrow indicates the alluvial deposit (green) of Spring Street Swamp.

Inverlochy Swamp

Inverlochy swamp is described as a mostly drained swamp, which before draining reportedly covered 600 ha¹². It is assumed that the pre-European Inverlochy swamp was an ephemeral wetland, and it is unclear how often the swamp was wet, nor how its extent varied with climatic conditions.

The location of Inverlochy Swamp corresponds to the existing Kalkallo Retarding Basin and pre-European Wetland 70700, and extends north to encompass the channelised watercourses of combined PSP areas (Figure 17). In the MCMC map, Inverlochy swamp also extends in a northeasterly direction along an unnamed existing watercourse towards Spring Street Swamp.

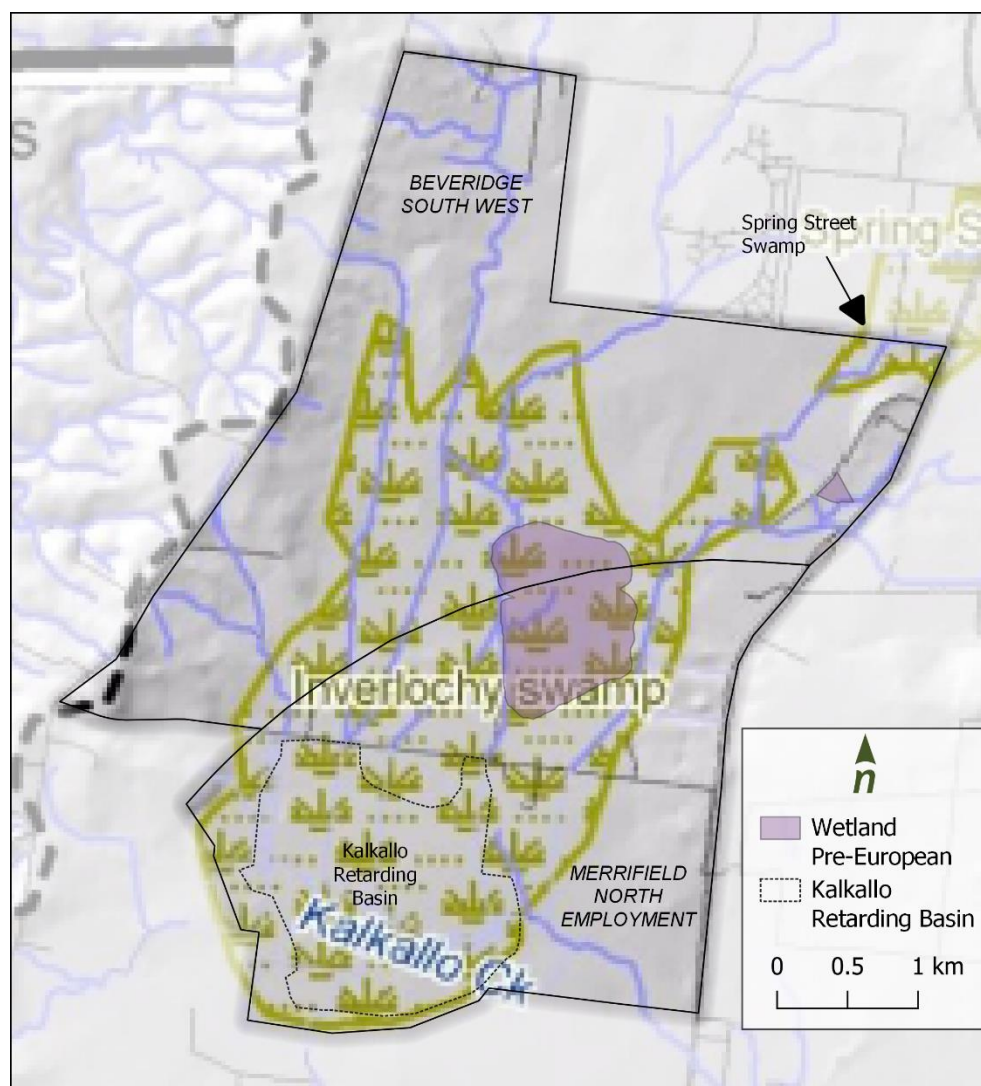


Figure 17. MCMC map of Inverlochy Swamp overlaid on map of PSP boundaries. DEECA Victorian Wetland Inventory modelled pre-European wetlands, and the Kalkallo Retarding Basin are shown. Spring Street Swamp is indicated with an arrow.

The MCMC report does not describe how the spatial extent of Inverlochy Swamp was determined, but the Inverlochy Swamp's extent largely follows topographical contours and areas of low local elevation (Figure 18).

¹² Beardsell, C 1997. Sites of Faunal and Habitat Significance in North East Melbourne, Volume 1. Report prepared by Dunmoochin Biological Surveys for the North East Regional Organisation of Councils.

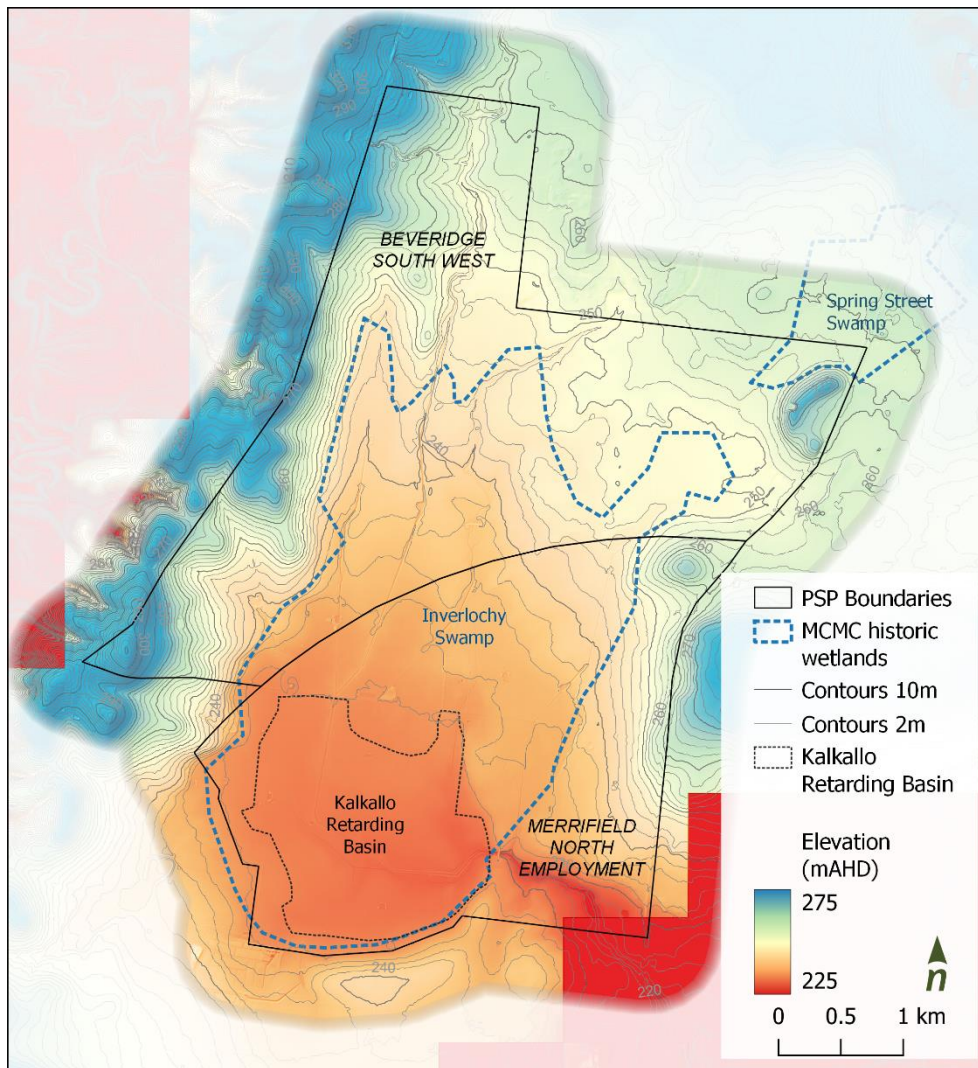


Figure 18. MCMC historic swamps and wetlands overlaid on map showing local elevation and PSP boundaries

A search of the Public Records of Victoria (PROV) Map Warper website¹³ identified a 1913 sketch map of Wallan and Donnybrook districts (DEF127, Appendix 1, Plate A2) that also shows a swampy area in the region of Inverlochy swamp. A combined map was generated showing the location of the 1913 swampy area, MCMC Inverlochy Swamp extent and DEECA Victorian Wetland Inventory modelled pre-European wetlands (Figure 19).

¹³ <https://mapwarper.prov.vic.gov.au/>

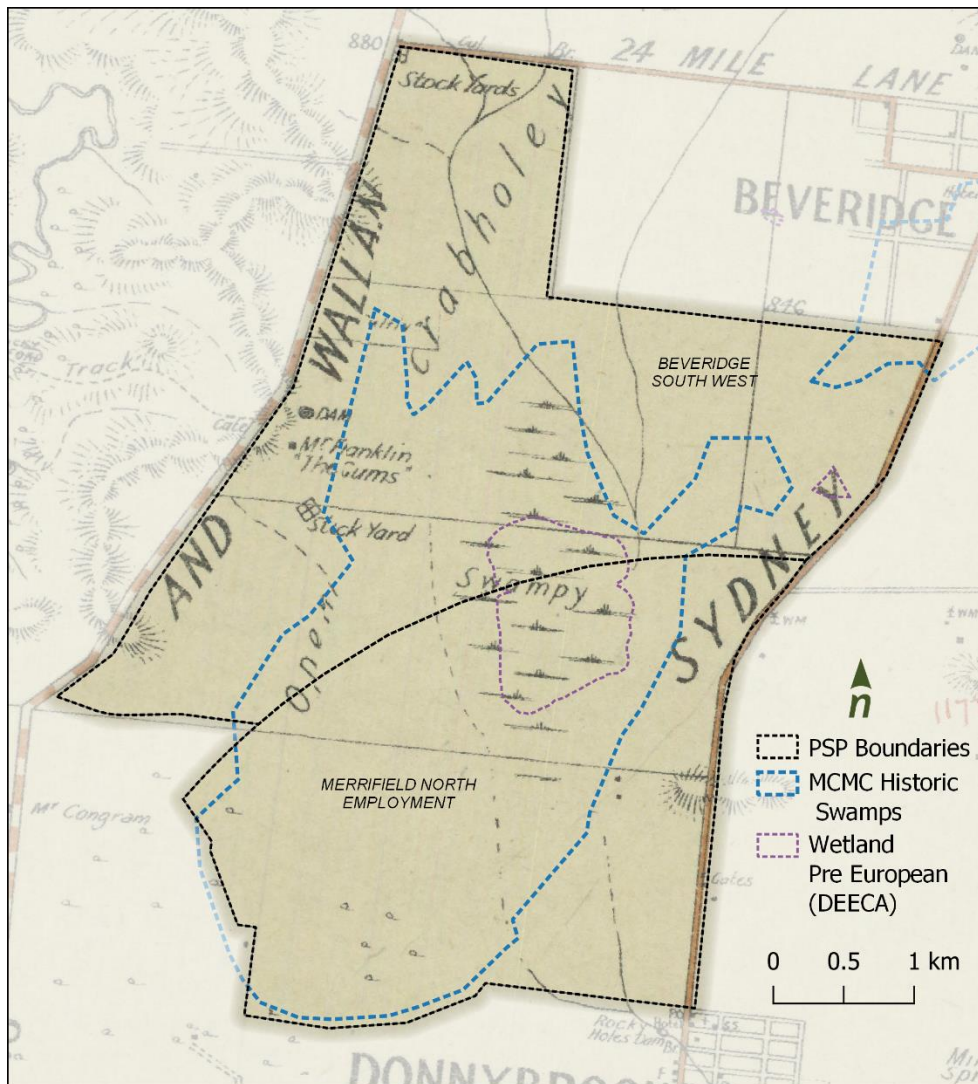


Figure 19. 1913 sketch map of Wallan and Donnybrook districts overlaid with PSP boundaries, the MCMC report extent of Inverlochy Swamp and the DEECA Victorian Wetland Inventory modelled pre-European wetlands. Sketch map sourced from PROV Map Warper

As shown in Figure 19, the 1913 swampy area is larger than the modelled pre-European wetland 70700. Unlike the MCMC Inverlochy swamp boundary, the 1913 swampy area extends northwards into the Beveridge South West PSP area and does not appear to extend south into the Kalkallo retarding basin.

The accuracy of the extent of the swampy area in the 1913 sketch map is not clear, however the major roads and nearby watercourses (Deep Creek and Merri Creek) on the 1913 map align with meanders of the current day watercourses, providing confidence that the swampy area existed in the depicted location on the 1913 sketch map. Also note that the Kalkallo Creek watercourse on the 1913 sketch map differs markedly from the location of day watercourses. This is explored below in Section 4.2.

4.2 Historic Watercourses

Parish and other maps obtained from PROV Map Warper were examined for the historic locations of watercourses (Figure 20 - Figure 23). It is noted that minor watercourses within the PSP were often incompletely surveyed, or at least not fully mapped across the site. Today, the watercourses that traverse the PSP areas consist of natural low sinuosity boulder beds, shallow swales and drainage depressions, and straightened channels of varied depth and extent of erosion.

The 1851 plan of the Parish of Darraweit Guim shows a watercourse entering the Beveridge SWS PSP area from the north, and traversing the PSP area in the area in a SSW direction. Presumably this watercourse corresponds to the original Kalkallo Creek. A tributary is shown entering the Beveridge SW PSP area from the west. The watercourse exits the map near the border of the two PSP areas. It is noted that the 1851 mapped area stops at the southernmost border of the Beveridge SW PSP area.

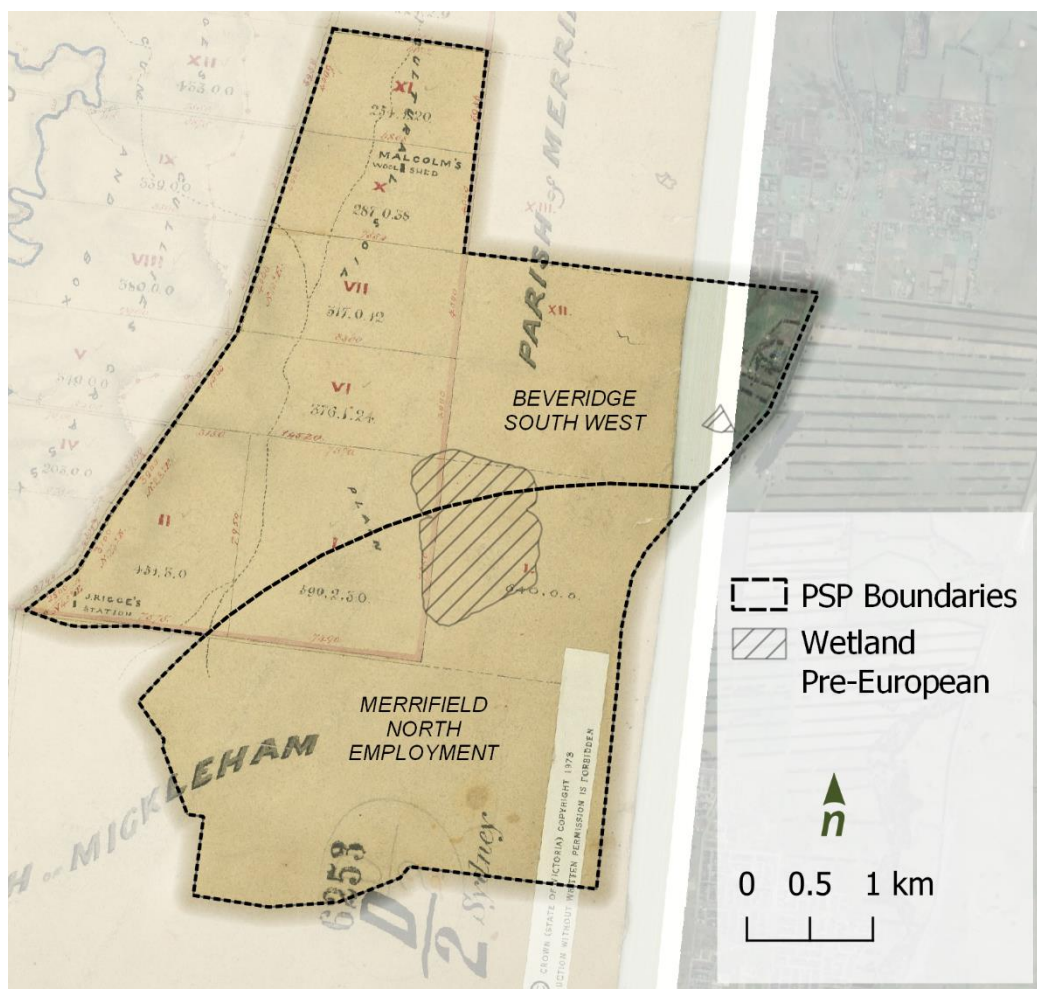


Figure 20. 1851 Plan of Parish of Darraweit Guim showing watercourses overlaid with the PSP boundaries and DEECA Victorian Wetland Inventory modelled pre-European wetlands. Parish map sourced from PROV Map Warper

An 1862 Geological Survey map lacks internal watercourses but shows a sinuous watercourse in the vicinity of the Kalkallo creek in both the north and south of the PSP area (Figure 21). Two watercourses converge in the south east of the PSP area.

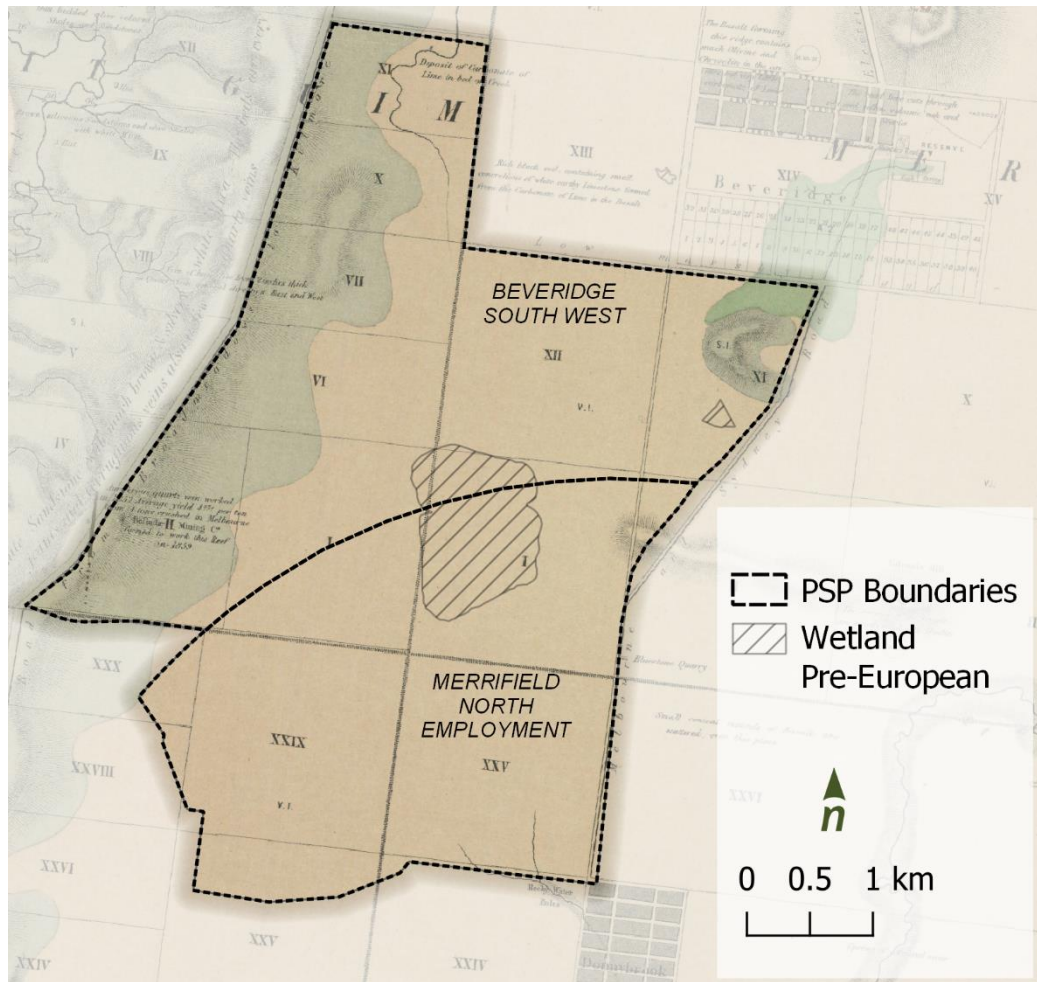


Figure 21. 1962 Geological Survey of Victoria Map showing watercourses in the north and south overlaid with the PSP boundaries and DEECA Victorian Wetland Inventory modelled pre-European wetlands. Geological survey map sourced from PROV Map Warper. The full map is shown in Attachment 1 Plate A1.

A 1904 map shows a dam on the PSP border that was constructed on a now-channelised section of the Kalkallo Creek (Figure 22). The map describes the reach upstream of the dam as an 'open drain' and labelled as 'fair portion impassable', which is consistent with the eroded nature of the current channel. Downstream of the dam, the watercourse extends in a south easterly direction and converges with a reach of the Kalkallo creek that persists today. These southerly watercourses overlay those on the 1962 map. Note, the inverted triangle in the 1904 map represents an instream dam, with the upstream watercourse labelled as 'open drain'.

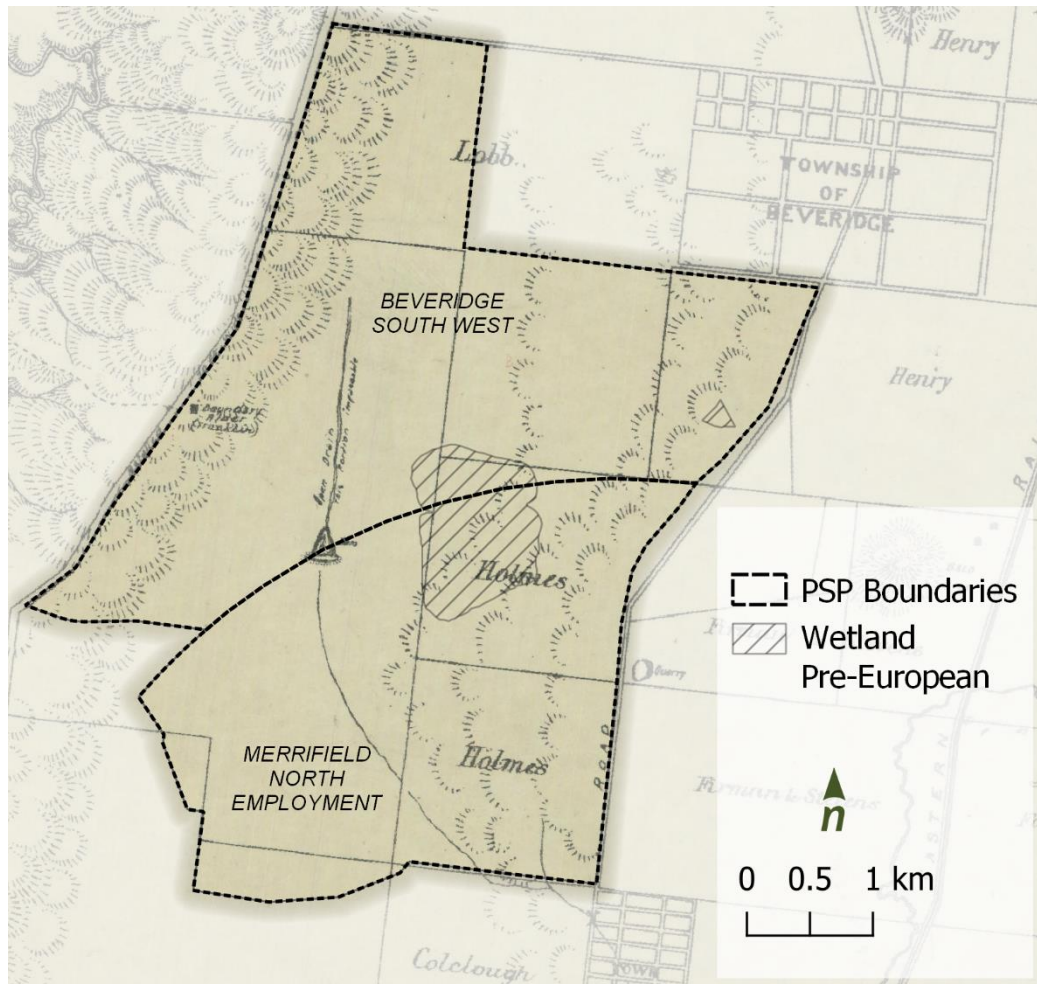


Figure 22. 1904 Australian Light Horse Camp Lancefield Junction map showing a watercourse overlaid with the PSP boundaries and DEECA Victorian Wetland Inventory modelled pre-European wetlands. The 1904 basemap was sourced from PROV Map Warper.

The 1913 map shows Kalkallo Creek taking a southeasterly course that runs north and east of the swampy area (Figure 23). A tributary northeast of the swampy area joins Kalkallo Creek. It is unclear how these watercourses transverse the swampy area. Watercourses rise to the west, and southeast, of the swampy area, which converge near the modern-day Kalkallo creek in the south of the PSP area (consistent with the 1862 and 1904 maps). The 1913 watercourse map best aligns with the location of the DEECA modelled pre-European wetland 70700. It is curious that the pre-European wetland 70700 is not located in the lowest part of the landscape, and that pre 1900 maps do not depict wetlands or swampy areas. It is possible that those surveys took place at times when the landscape was dry and the swamps not expressing.

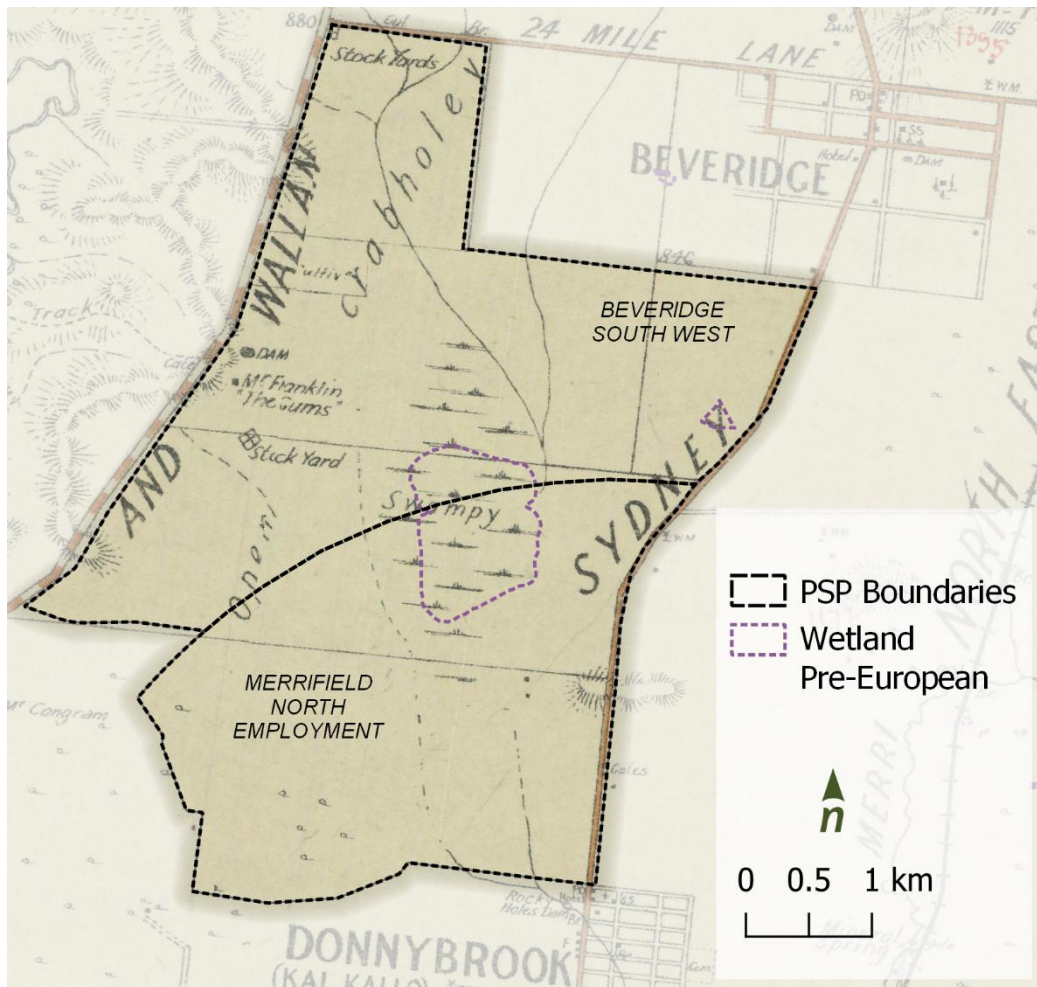


Figure 23. 1913 Map of Wallan and Donnybrook District showing watercourses overlaid with the PSP boundaries and DEECA Victorian Wetland Inventory modelled pre-European wetlands. 1913 basemap was sourced from PROV Map Warper. The full map is shown in Attachment 1, Plate A2.

4.3 Summary

Taken together the historic maps and data presented in Section 4 support the presence of two pre-European wetlands within the boundary (Figure 24). There are some significant differences to the modelled spatial data.

1. The historic northeastern wetland (Spring Street Swamp) is in a different location to wetland 70753. It is unclear whether they were ever connected on the surface. None-the-less, it is likely that they are at least partly groundwater fed.

2. A large swampy area was located in the centre of the combined PSP area, although in the historic maps this wetland did not extend into the retarding basin area (Figure 24), nor did it extent as far as DEECA's modelled 1750 grassy wetland EVC area.

Inconsistencies were also noted between historic maps, for example the 1913 map shows a watercourse that ran north east of wetland 70700, whereas the 1851 map has Kalkallo Creek taking an entirely westerly course. The 1904 map shows the waterway as an open drain that is 'impassable', which is consistent with the field observations. This 'drain' is not marked on the 1913 map. In general, watercourses are not mapped within the combined PSP area. It is unknown whether waterways were not surveyed, if the terrain was impassable (albeit not recorded in the survey), or if the watercourses were generally considered insignificant, or indiscernible.

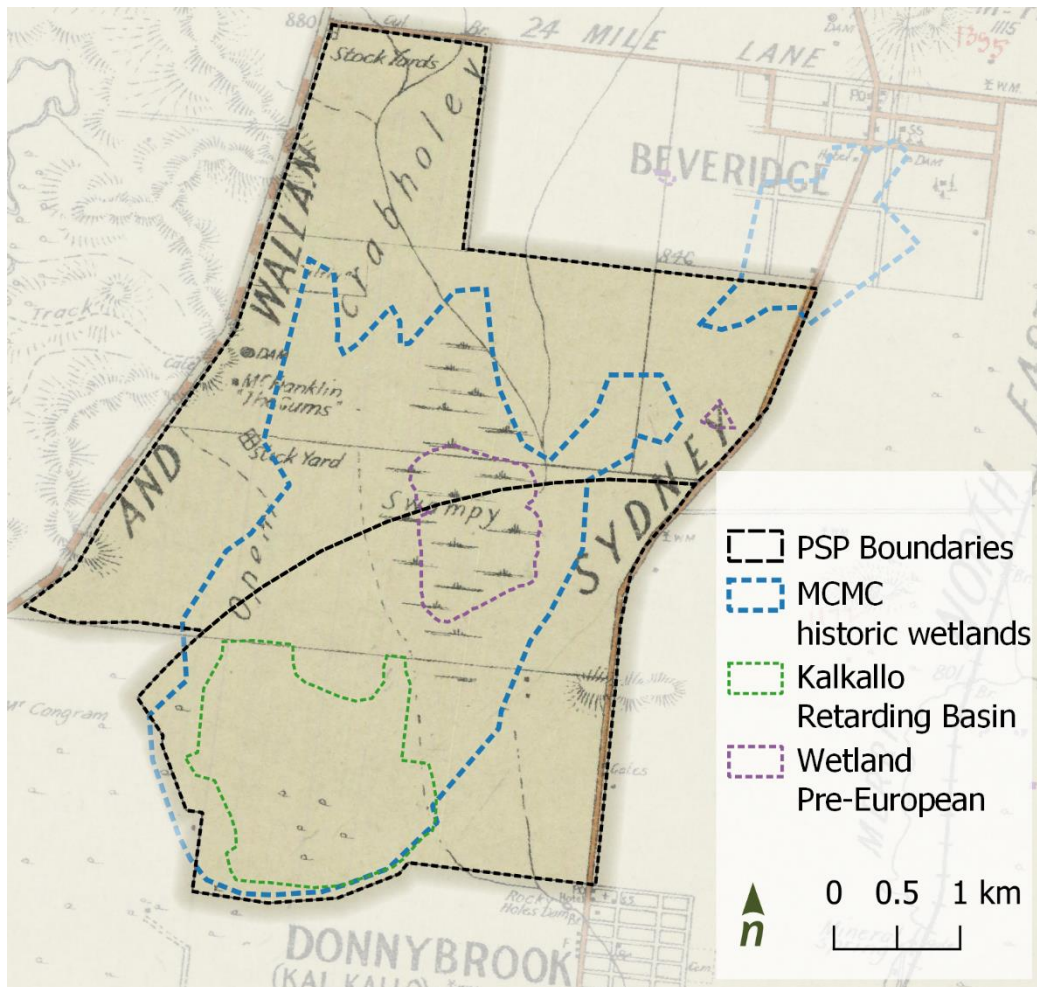


Figure 24. All wetlands and swamps in the study area plus the current Kalkallo Retarding Basin overlaid on the base 1913 Map of Wallan and Donnybrook District. 1913 basemap was sourced from PROV Map Warper.

5 Cultural Values

A preliminary report on Cultural Values within the Merri Creek (McConachie and McAlister, 2019¹⁴) stated that Merri Creek was a potential ancestral route on Wurundjeri Country. Several sites of cultural sensitivity have been identified within the Merrifield North Employment and Beveridge South West PSP areas (Figure 25). Note that the current Kalkallo Creek watercourse takes a different route to the pre-European watercourse. It is unclear whether a full cultural values survey has been conducted at the site, due to much of the site now being under private ownership. Several food species, scarred tree records, hearth and mound sites have been found on the nearby Cloverton development. Archaeological surveys at the Cloverton site identified “*stone artefact scatters on every stony rise*” (McConachie and McAlister, 2019). Given the proximity of the PSP areas to Merri Creek and location of Kalkallo creek within the site, the presence of spring-fed wetlands, and the presence of stony rises, it is expected that several additional sites of cultural significance would occur within the PSP areas.¹⁵

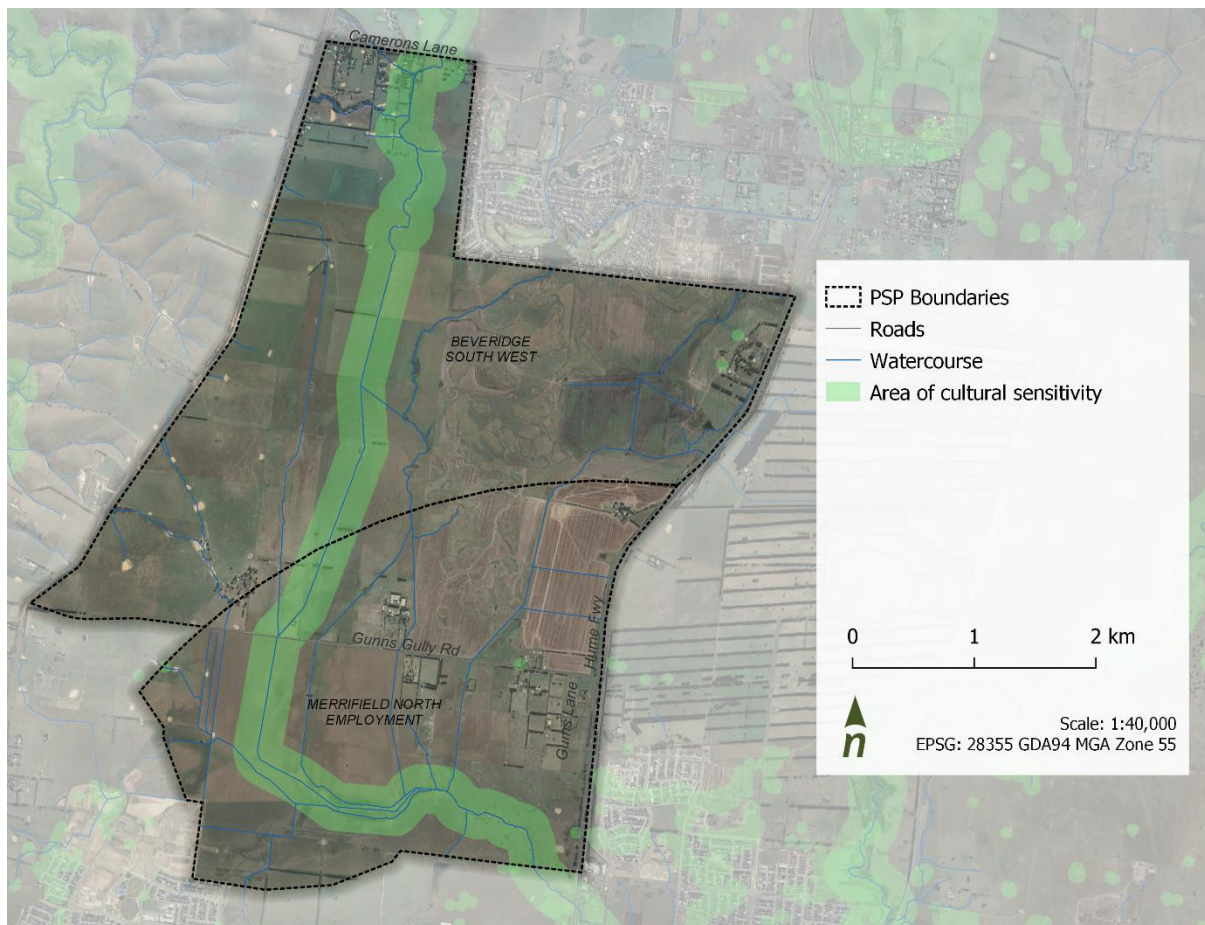


Figure 25. Areas of cultural sensitivity

¹⁴ McConachie and McAlister, 2019 Mapping cultural values: A case study from Kalkallo, Melbourne Metropolitan Area

¹⁵ A cultural heritage assessment is understood to have been commissioned by the VPA for the Merrifield North PSP area. The findings for this report were not available at the time of writing.

6 Modelling of Pre-European Wetland Extent

The historic mapping/surveys and the available spatial data were collated for the study area generated for different purposes and employ a variety of simplifying assumptions. None of those data sources directly addresses the inundation of wetlands due to surface water delivery. This project modified a two-dimensional hydraulic model, and an event based hydrologic model (RORB) to estimate the change in wetland extent that has occurred since European settlement.

The models were originally created to estimate the depth and extent of floodwaters across the Merrifield and Beveridge South West PSP areas to inform PSPS planning. By modelling surface water connection between flow paths and wetlands, the impact of landscape changes post-European settlement on the wetland extent and frequency of inundation can be assessed. The key changes to the study area that will directly impact surface water are:

- Construction of linear drainage channels in low lying areas, to de-water swampy areas and more efficiently convey flows from upstream.
- A change in land use from open grassland/woodland to agricultural land that is (or was until recently) grazed by stock.
- Increases in the peak flow rate for a given event (e.g. an event with an annual exceedance probability of 20 %) due to changes in land use (such as urbanisation) upstream of the study site.
- Construction of roads, which include culverts, perpendicular to the dominant flow direction.

The methods used to generate the models and account for the changes above are described in more detail below and the resulting changes inundation extent and frequency are presented in section 6.2.

6.1 Method

Assessment of flow paths under pre-European conditions were undertaken through hydrologic and hydraulic modelling of the study area. Detailed hydrologic and hydraulic analysis conducted for the PSP areas are presented in a separate flood modelling report (Alluvium, 2023) Our approach involved updating existing RORB model to include pre-European fraction impervious values and updating hydraulic model terrain to represent pre-European conditions (this was achieved by removing impervious vales in areas which are currently developed). The design parameters and inputs used in the assessment are presented in the modelling report.

Pre-European topography was constructed by removing human-made features from the terrain data such as road embankments, culverts, drainage lines and farm dams. These features were first identified using latest aerial and LiDAR of the area (presented in Figure 26). Then these areas were cut out from the existing terrain and reconstructed the surface by retriangulating the surface in 12d.

The modelled 1750 Ecological Vegetation Classes (NV1750_EVCBCS) layer (DEWLP, 2018) was used to to define hydraulic roughness (Manning's n) under pre-European conditions. Corresponding Manning's n values for different EVCs were adapted from Asante et al., 2008.¹⁶

Terrain was further refined by looking at existing historic mapping of swamps and wetland features, to ensure these areas are not occupied by straight waterways or any other man-made infrastructure. After removing straight channels, sinuous channel cross sections and levees were extracted to see if those have been modified

¹⁶ Asante, K.O., Artan, G.A., Pervez, S., Bandaragoda, C. and Verdin, J.P., 2008, Technical Manual for the Geospatial Stream Flow Model (GeoSFM): U.S. Geological Survey Open-File Report 2007–1441, 65 p. (https://www.researchgate.net/figure/Mannings-roughness-values-used-for-various-land-cover-classes-in-GeoSFM_tbl2_264934494)

compared to their pre-European state. Example cross sections at several locations throughout the study area is provided in Figure 27. Creek depth is more deepened (more than 4m) at some locations as shown. A trapezoidal shape channel with depth ranging from 1m to 2m was constructed in 12d where channel depth is largely modified compared to pre-European state. Example new cross sections are also shown in Figure 27.

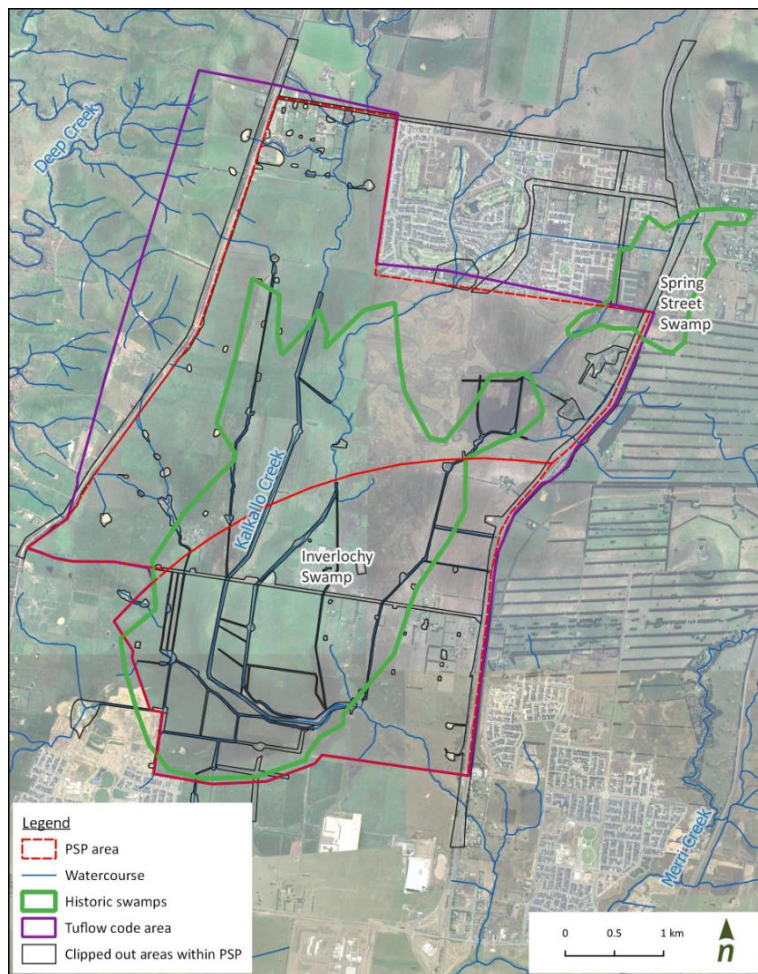


Figure 26. Pre-European terrain modification - clipped out areas within the PSP.

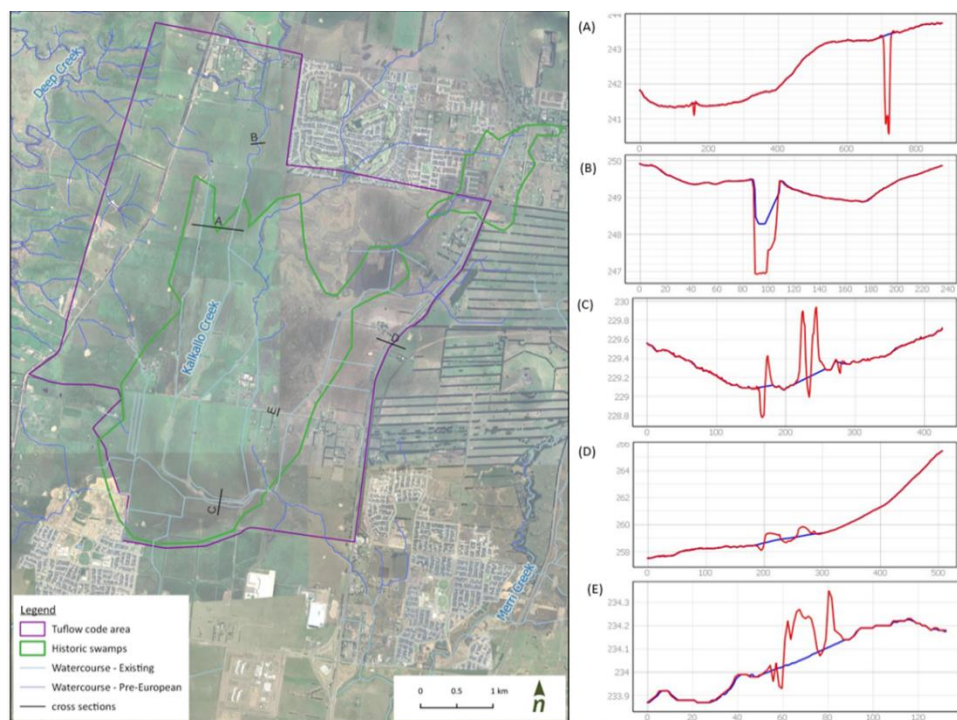


Figure 27. Existing channel cross section (red) vs reconstructed pre-European channel cross sections (blue).

6.2 Results

Hydrological changes

Changes in catchment land use, first conversion to agriculture and more recently urban development, are associated with increase in peak flow magnitudes for all events modelled (Table 1). While the absolute change in peak flow rate decreases as the annual likelihood of an event increases, the percentage change in peak flow rate has the opposite trend – increasing as event likelihood increases. The change in peak flow rate in Kalkallo Creek is proportionally greatest for the smaller, more frequent events. Some, but not all, of the critical storm durations and temporal rainfall patterns associated with the storms that generate the peak flow rate change too (Table 1).¹⁷ The changes are small and the critical durations are not consistently longer or shorter between the pre-European and existing conditions. In summary, catchment changes since European settlement have led to increased peak flow rates and those increases are proportionally greater for smaller, more frequent events.

¹⁷ Recall that several storm durations and temporal rainfall patterns were modelled for each flow event. See Alluvium (2023) flood modelling report for a detailed description of the hydrologic modelling approach adopted in this study.

Table 1. Change in peak flow rates and critical duration of flow that produces the maximum inundation extent between pre-European and existing conditions for modelled flow events.

	Peak flow rate			Critical duration (hours) (temporal pattern)	
	Pre-European conditions (m ³ /s)	Existing condition (m ³ /s)	Change in peak flow rate (m ³ /s) (%)	Pre-European conditions	Existing conditions
AEP 1%	119	134	14 (+ 12 %)	9h (25tp)	6h (30tp)
AEP 2%	95	104	9 (+ 10 %)	12h (28tp)	9h (30tp)
AEP 5%	65	74	9 (+ 14 %)	9h (11tp)	9h (11tp)
AEP 10%	44	52	7 (+ 17 %)	9h (11tp)	9h (11tp)
AEP 20%	24	30	6 (+ 23 %)	9h (8tp)	12h (9tp)
AEP 50%	8	11	3 (+ 42 %)	9h (10tp)	9h (10tp)
AEP 63.2%	4	6	2 (+ 50 %)	9h (10tp)	9h (10tp)

Changes in inundation extent

Although peak flow rates have increased for all modelled events, the total area inundated has *decreased* for all events (Table 2). This suggests that flow is more efficiently conveyed through the study area and that the increased flow is accommodated in-channel, rather than spilling across the floodplain.

Table 2. Change in maximum inundation extent between pre-European and existing conditions for modelled flow events.

Event	Maximum area inundated (ha)		
	Pre-European condition	Existing conditions	Decrease in inundation area
AEP 1%	961	901	61
AEP 2%	932	889	43
AEP 5%	893	838	55
AEP 10%	852	790	62
AEP 20%	797	729	67
AEP 50%	641	538	103
AEP 63.2%	579	457	122

The total area inundated under the modelled 1% AEP event for pre-European and existing conditions is shown in Figure 28. The change in inundation extent – showing areas that were inundated under pre-European conditions but dry under existing conditions – are shown in Figure 29. In the case of the 1% AEP event, the decrease in inundation extent occurs almost entirely in the area surrounding the channelised section of Kalkallo Creek, to the west of wetland 70700 (Figure 29).

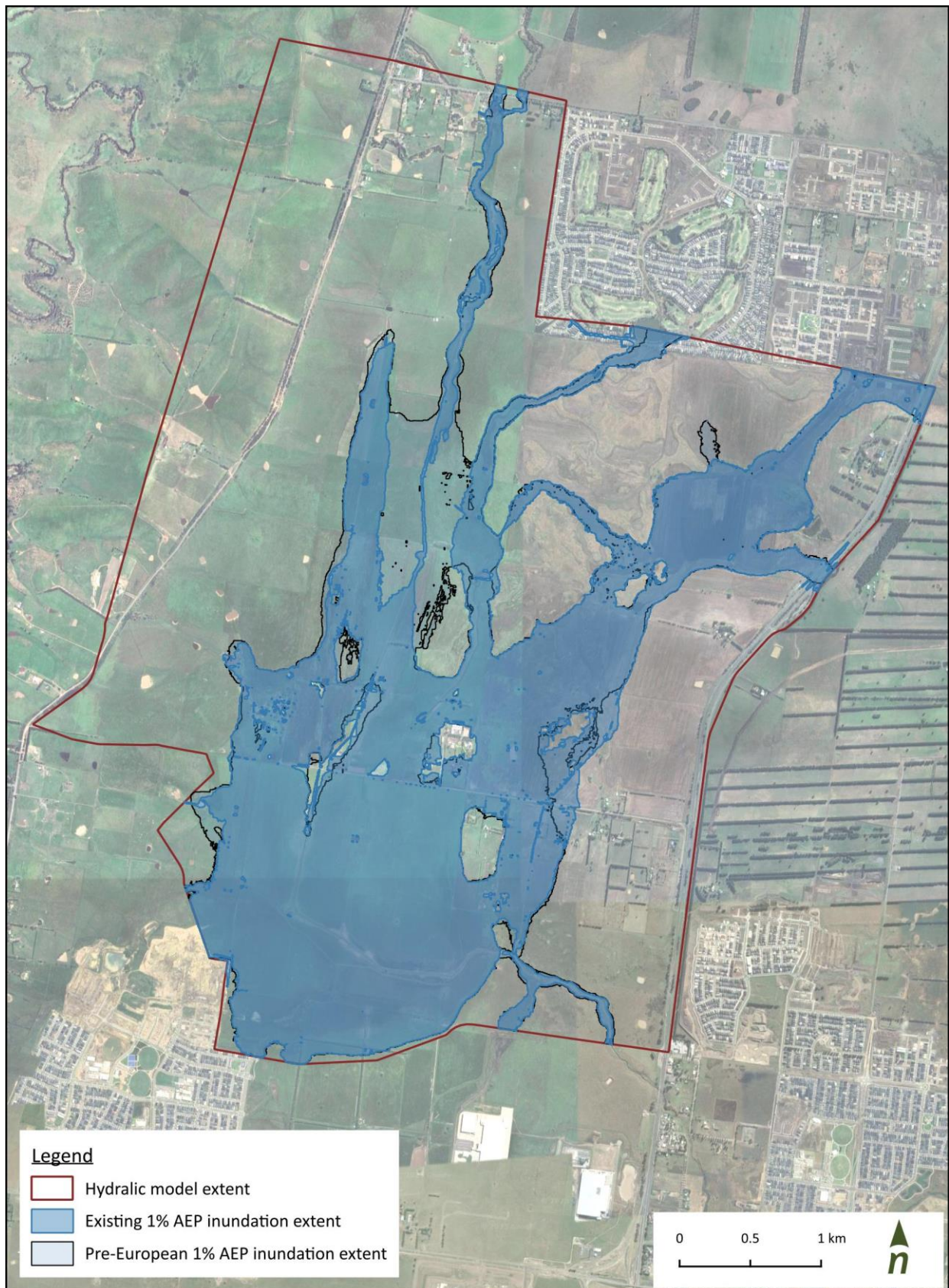


Figure 28. Total modelled inundated area under pre-European and existing conditions for a 1 % AEP event.

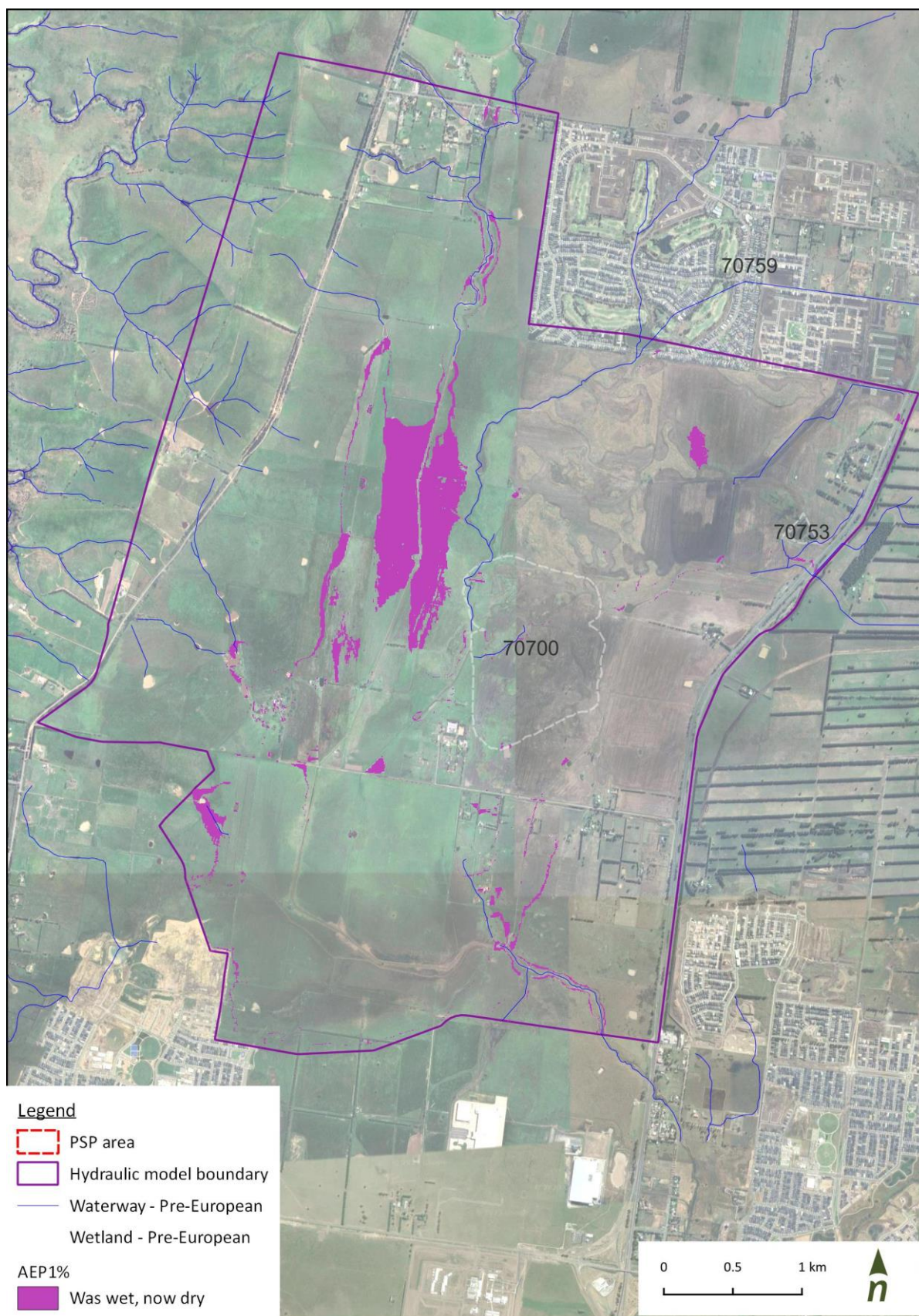


Figure 29. Change in inundation extent between modelled pre-European and existing conditions for a 1 % AEP event.

Overall, as smaller more frequent events are considered the area of floodplain that was wet but is now dry expands along Kalkallo Creek in a downstream direction (Figure 30). Similarly, as smaller more frequent events are examined the areas within wetlands 70700 and the flow path to the west of wetland 70753 become progressively drier (Figure 31).

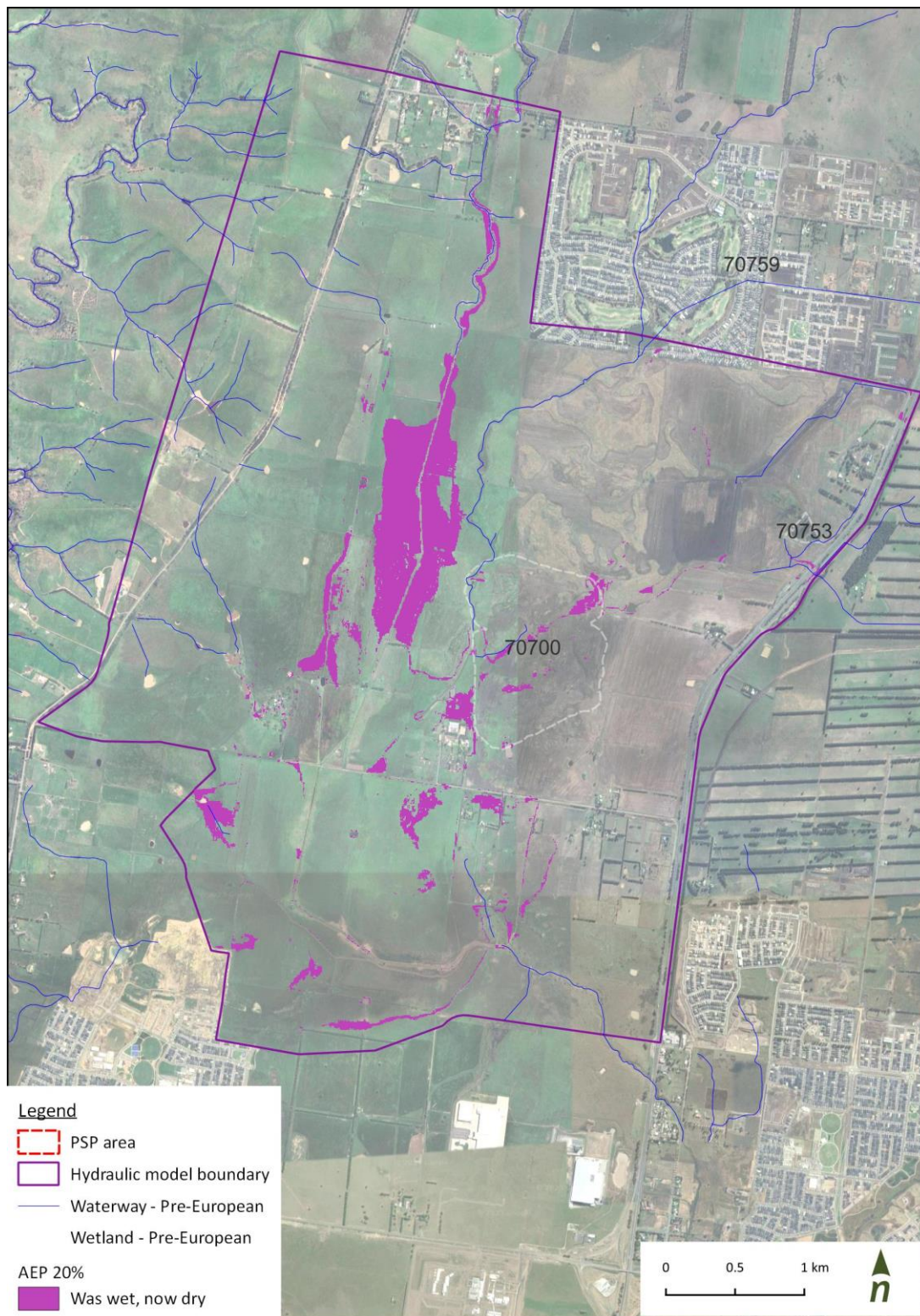


Figure 30. Change in inundation extent between modelled pre-European and existing conditions for a 20 % AEP event.

There is some decrease in inundation extent within the Kalkallo retarding basin, but these areas are aligned along existing artificial channels and are small compared to the size of the retarding basin (Figure 31).

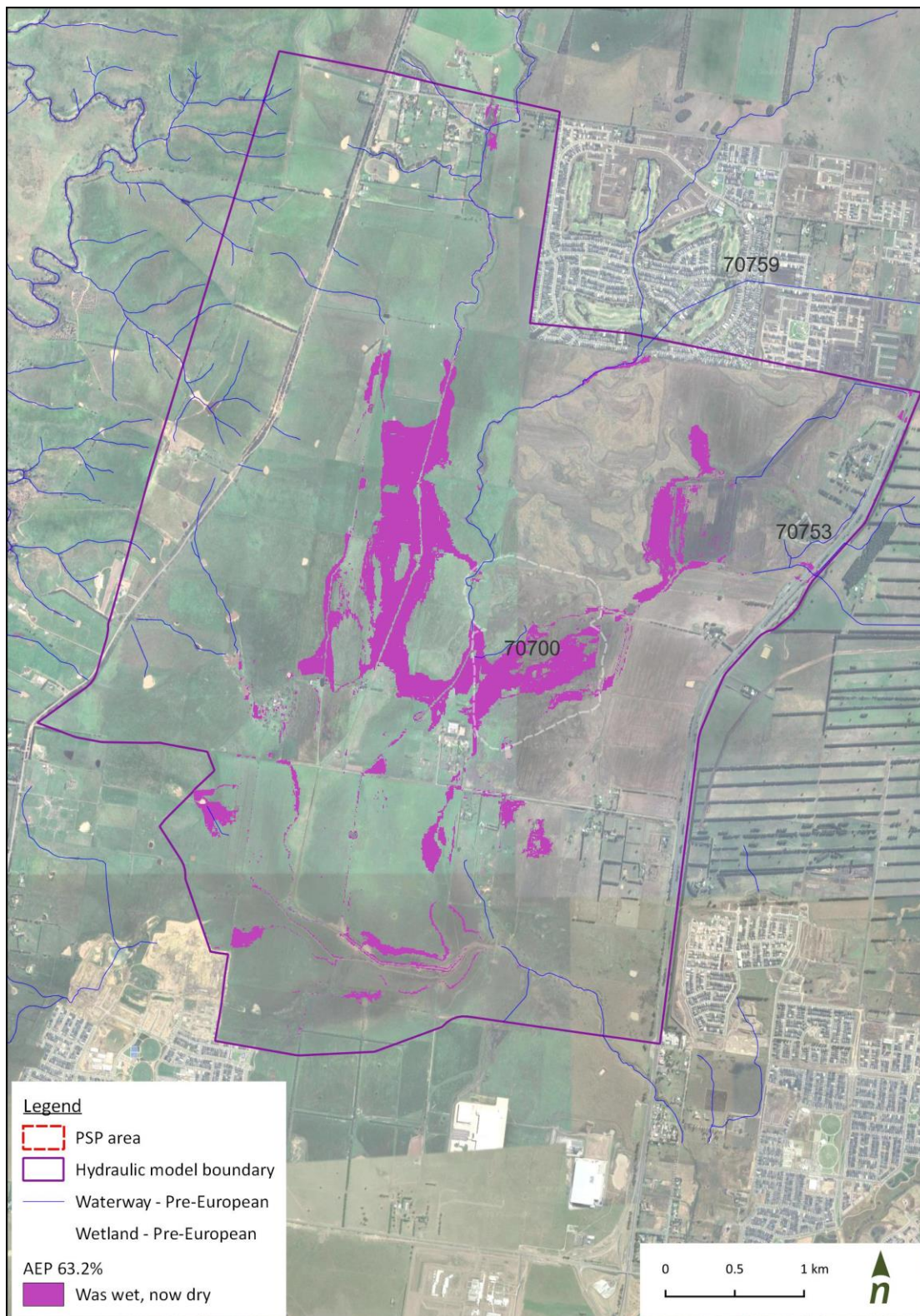


Figure 31. Change in inundation extent between modelled pre-European and existing conditions for a 63 % AEP event.

7 Discussion and conclusion

This section presents an overall discussion, the key findings of this investigation into pre-European wetland extent and then identifies the future investigations that have the potential to reduce (but buy no means eliminate) the uncertainty in pre-European wetland extent identified in this project.

7.1 Discussion

The datasets and maps presented above paint a rich, albeit conflicting account of the location and extent of the pre-European wetlands within the combined PSP area. It is clear that changes since European settlement have led to a decrease in wetland extent, but the magnitude of that change cannot be definitively stated because the actual extent of the wetland pre-European settlement is unclear. Such discrepancies in the mapped or modelled extent of the pre-European wetland(s) are likely due to:

- The natural variability of wetland extent according to seasons and the prevailing climate.
- The wide variety and reliability of different data sources, many of which use different modelling methods or survey techniques to *estimate* the pre-European extent.

It is important for decisions to be made regarding the preservation and restoration of wetlands at the site, and whether restoring what is *thought* to be the pre-European wetland extent is the approach most likely to generate the best cultural and ecological outcomes. It is also important to consider how the Kalkallo Retarding basin is incorporated into development plans, given the localised patches of grassy wetland EVCs and a drainage system that supports the grassy wetland EVCs.

It is also important to consult with Traditional Owners (Wurundjeri Woi-wurrung Cultural Heritage Aboriginal Corporation) regarding their aspirations for the site, and to ensure that cultural values associated with pre-European wetlands are understood, protected and included in any future development. The data compiled as part of this project may be most useful for such conversations.

7.2 Key findings

Groundwater, which is known to be an important contributor to wetlands in the PSP area (and the region more broadly), is not accounted for in the assessments. Instead, the assessments and maps summarised in this report use a combination of vegetation surveys, historic accounts and surface water modelling to infer a pre-European wetland extent. The inclusion of groundwater dynamics in future studies would likely alter the predicted range of wetland extents in pre-European and existing climatic conditions. However, the while the addition of groundwater modelling outputs may help better align the historic maps/accounts of wetland extent and those predicted by modelling, the uncertainty in this approach is potentially large.

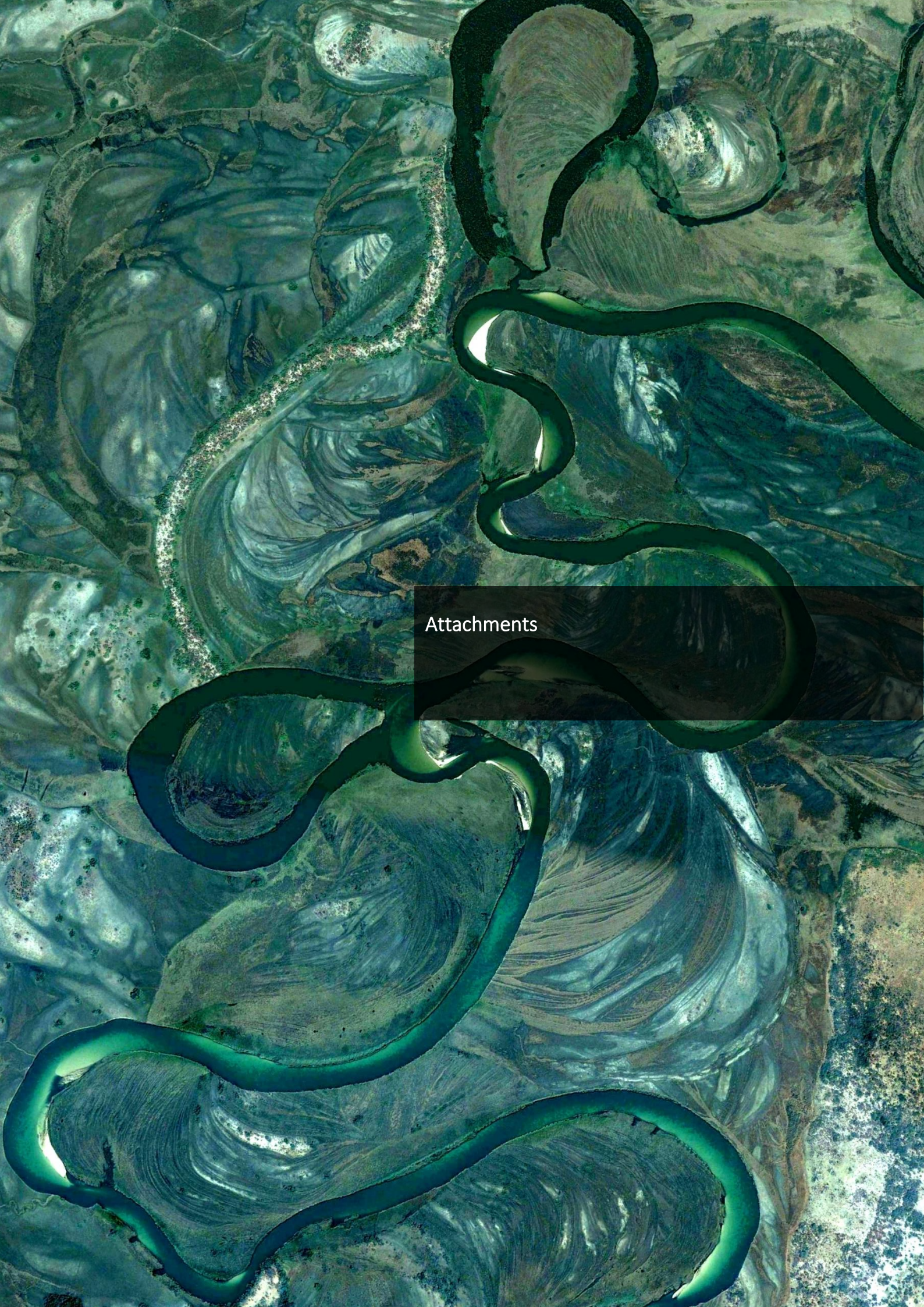
Neither wetland 70700 or wetland 70753 can be compared in quality or floristically to Burrung Buluk (Hanna Swamp). Despite this, there is high possibility for rehabilitation wetlands 70700 and 70753 (but particularly 70753). As they are the only remnant wetland patches within the development footprint and due to the presence of FFG listed *Ranunculus diminutus* in wetland 70753, both the wetlands, a buffer area around the wetlands and a suitable water supply need to be protected and rehabilitated during and after the PSP development.

Groundwater modelling will provide some further insights into the extent of pre-European wetlands, but any estimates based on groundwater modelling are likely to include significant uncertainty. Groundwater modelling is therefore a useful next step but will not provide a definitive answer as to the pre-European extent of wetlands in the study area.

7.3 Next steps to reduce uncertainty

The intent of this pre-European wetland assessment was to use the best information currently available to estimate the pre-European extent of the wetlands within the Merrifield and Beveridge South West PSP areas. Future investigations could improve confidence in the location(s) and extent(s) of pre-European wetlands on the site, although to definitively identify the pre-European wetland extent is unlikely. Future research or considerations to improve confidence in the modelled extents include:

- Groundwater studies that integrate with surface water studies to predict the range of inundation extents at the event and seasonal timescale.
- Assessment of the likely impact of both climate change and development on those extents.
- Engagement with Traditional Owners regarding cultural narratives for the site and their preferences for future management.



Attachments

Attachment 1. Historic Maps

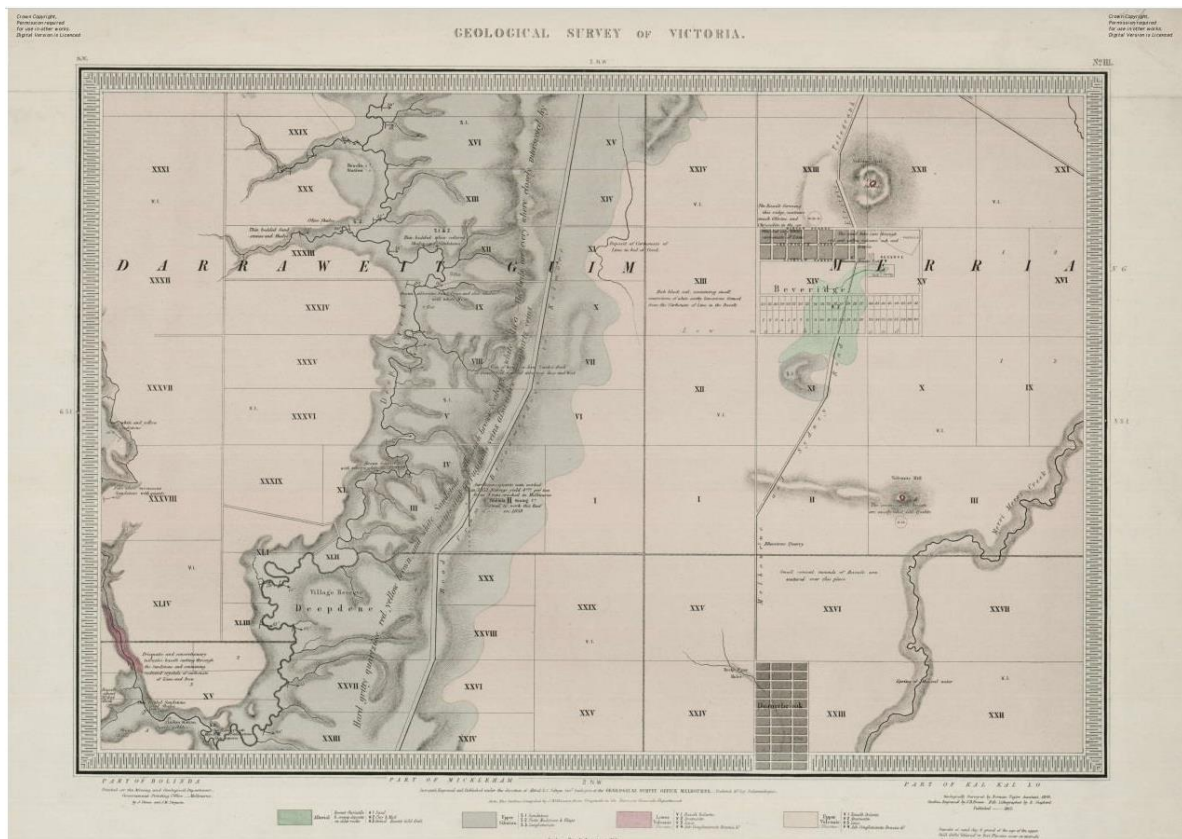


Plate A1. Geological Survey Map L3SW from MCMC 2018, showing Spring Street Swamp (green) south of Beveridge. Source: MCMC, 2018. Georeferenced image obtained from Public Records or Victoria Map Warper website.

