

FINAL REPORT:

CASEY FIELDS DSS VALUES ASSESSMENT

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1 Introduction

Streamology in partnership with Ecology Australia and Heritage Insight have been engaged by Melbourne Water to undertake a values assessment within the Casey Fields South, Devon Meadows and Clyde South Precinct Structure Plan (PSP) areas in south-east Melbourne. The outcomes from this project will be used to inform the Drainage Services Scheme (DSS) design which includes DSS asset and outfall locations, waterway corridor widths and consideration of management interventions that may be required to support significant flora and fauna and waterway condition.

1.1 Project scope

The purpose of this project is to identify geomorphic, flora, fauna and heritage values associated with the waterways within the Casey Fields South, Devon Meadows and Clyde South PSPs. Specifically, this project aims to:

- Identify significant or listed flora and fauna species with reference to the Melbourne Strategic Assessment (MSA) mapping.
- Identify implications of significant or listed species found within the study area under National, State or local legislation and policy as well as relevant Melbourne Water strategies.
- Identify suitable Southern Brown Bandicoot habitat and provide advice on incorporating new or existing vegetation to support bandicoot movement.
- Identify suitable Growling Grass Frog habitat and provide advice on potential future use of eDNA or seasonal surveys.
- Identify potential Dwarf Galaxia habitats.
- Provide a desktop assessment of geomorphic values and sensitivity of waterways with reference to Healthy Waterways Strategy objectives.
- Identify cultural heritage values within the waterway and historic swamp footprints.
- Provide recommendations on areas that should be protected because of high vegetation values, significant geomorphic form or floodplain areas associated with headwaters.
- Identify the sensitivity of waterways to post-development hydrological change.
- Provide recommendations on suitable outcomes for waterways post-development (e.g., retain as is, convert to constructed waterway).

1.2 Study location

The Casey Fields South, Devon Meadows and Clyde South PSP areas are located approximately 50 km south-east of the Melbourne CBD, in the south-eastern growth corridor. (Figure 1). They are located within the City of Casey and the PSP areas are bounded by Craig Rd in the west, Ballarto Rd in the north, Monks Rd in the south and Yallambee Rd in the east. The three precincts cover a combined area of approximately 1,646 ha.

The project area is situated within the larger Westernport catchment and falls within the Gippsland Plain Bioregion. The area is generally low gradient, and the geology consists of predominantly sedimentary lake and swamp deposits (Department of Jobs Regions and Precincts 2021). Prior to European settlement, this geology was associated with widespread heathlands, swamps, grasslands, and grassy woodlands (DELWP 2021) and as such, the study area formed part of the Koo Wee Rup Swamp.

Historic land use changes in the area, predominately for agriculture, resulted in Koo Wee Rup Swamp being drained in the 1800s with the construction of many straight, flat drains and heavy clearing of vegetation. The result of which is highly fragmented patches of remnant native vegetation (City of Casey 2018).

Despite the change that the region has undergone since European settlement, the area is located alongside historic sand dune systems that contain high value habitats and Westernport Bay which is a Ramsar listed site.

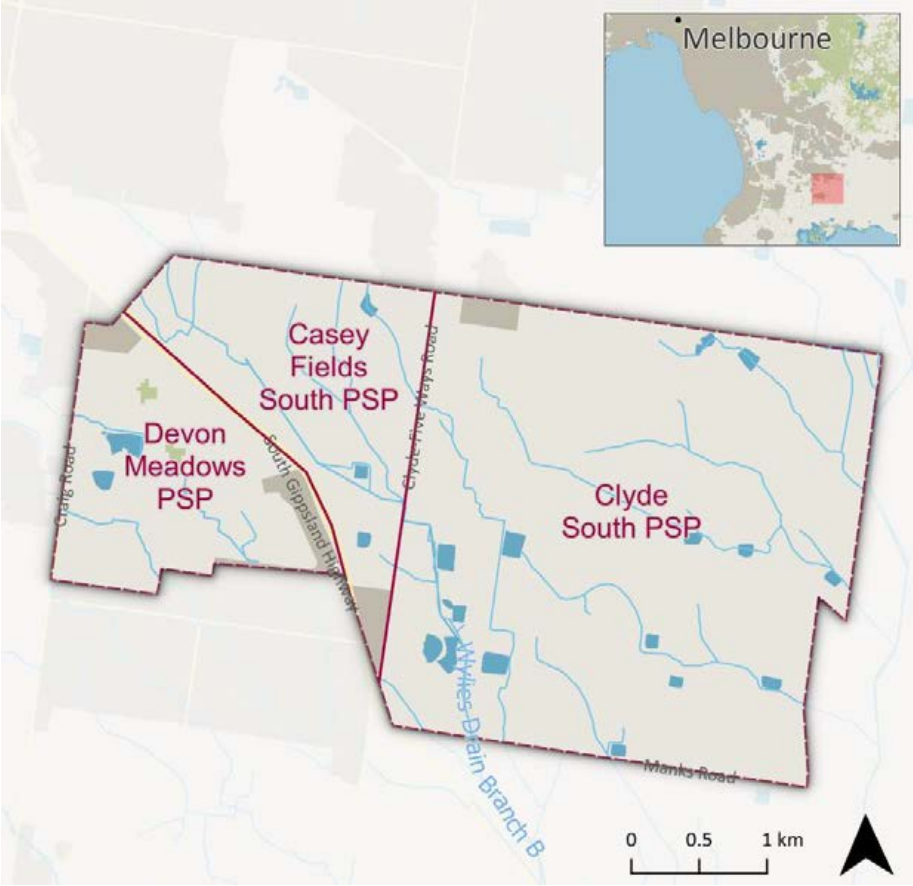


Figure 1. Location of the study site

1.3 Legislative context

The following section summarises the legislative and policy context for identifying and protecting values with the PSP areas, particularly related to the flora and fauna components of this project.

Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

The EPBC Act is the federal legislation and framework to protect and manage nationally and internationally significant flora, fauna, ecological communities, and heritage places. Under the EPBC Act, any action that could impact on matters of national significance including significant flora, fauna, ecological communities, or Ramsar wetland sites, need to be assessed and the impacts mitigated.

Flora and Fauna Guarantee Act 1988 (FFG Act)

The FFG Act is the Victorian legislation and framework that is in place to manage and protect flora and fauna considered significant at the state level. Flora, fauna and ecological communities that are not considered significant at the federal level under the EPBC Act, may be considered significant by the State of Victoria. As such, any potential impact on these matters will need to be assessed and approval confirmed by the state regulatory authorities prior to any works being undertaken. Generally, flora and fauna that are significant under the EPBC Act will also be significant under the FFG Act.

Regional biodiversity plans

Regions, Local Government Areas (LGA) and councils may have a range of biodiversity or flora and fauna management planning frameworks for managing threatening processes at a local level. Relevant to this study are documents such as Growling Grass Frog Masterplan for Melbourne's Growth Corridors, Melbourne Strategic Assessment (DELWP 2017a), Biodiversity Conservation Strategy Melbourne Strategic Assessment, Sub-regional Species Strategy for the Southern Brown Bandicoot (DEPI 2013) and Sub-regional species strategy for the Growling Grass Frog (DEPI 2013b).

Regional planning documents are usually developed in response to state and regional directives and should seamlessly link to legislation at the state and federal level.

2 Desktop Assessment – Aboriginal Heritage

This section of the report serves as a preliminary desktop heritage study which considers both Aboriginal archaeological sites and post-contact heritage assessment and whether a cultural heritage management plan is required pursuant to the *Aboriginal Heritage Act 2006*. The Registered Aboriginal Party (RAP) for the activity area is the Bunurong Land Council Aboriginal Corporation (BLCAC). No consultation was carried out with BLCAC as part of the report.

2.1 Existing conditions

Four separate areas of cultural sensitivity are present in the study area, as defined by the *Aboriginal Heritage Regulations 2008.* These are the land within 50m of the 20 registered Aboriginal Places (r(25)), the land within 200m of Clyde Creek (r (26)), the western fringe of the Koo Wee Rup Plain (r(34)), and the multiple sand sheets in the west, south, and east of the study area (r (41)). The study area also contains numerous unnamed tributaries that have been modified over time.

2.2 Resources available to Aboriginal People

Plant resources and pre-contact vegetation

The study area is a part of the Gippsland Plain bioregion and contains four Ecological Vegetation Classes (EVCs) that existed prior to 1750 (Department of Environment, Land, Water and Planning – Nature Kit, 2021) (Figure 2). The Gippsland Plain is characterised by low-lying coastal and alluvial plains, with gentle undulations dominated by barrier dunes, floodplains, and swampy flats.

Plants were extensively exploited by Aboriginal people for food, medicine and fibres for weaving. Plant components utilised would have included berries, fungi, roots, tubers, bulbs, leaves, pith from fleshy plants, seeds and sap. Gum was also collected from wattle and stored in known locations for seasons when food was less abundant (Zola & Gott 1992).

Fauna resources

A number of animals would have been present within the activity area and are likely to have been hunted by Aboriginal people. The nearby coastal environment would have been an abundant source of fish, molluscs, and crustaceans (Luebbers 1998, p.6). Situated in the floodplains and swamplands, various birds and their eggs would have been caught with traps and throwing sticks. Similarly, fish and eels were speared and trapped in the creeks. The fauna of the wider region would have included a range of mammals, such as kangaroos, wallabies, possums, bandicoots, bats, antechinus, echidnas, and rats, as well as reptiles like skinks and snakes, and amphibian species including the Spotted marsh frog and Southern brown tree frog (Viridans Biological Databases 2012). As well being a valuable food source, kangaroos and possums provided raw materials for the manufacture of cloaks, while kangaroo teeth were worn (as well as bones and shells) as hair decorations and echidnas provided quills which were used to make necklaces (Sullivan 1981, p.23; Rhodes & Rawoteea 2007, p.18). The native fauna in the geographic region is significantly diminished in modern times, largely as a result of the loss of habitat, with many animal species once present, now locally or regionally extinct.



Figure 2. Pre-1750s EVC mapping across the study area

Water Resources

Today the activity area contains many artificial drainage ways and water courses, however before European colonisation the geographic region contained extensive swamplands that would have provided sources of fresh water in close proximity to the activity area. The wider Gippsland Plain bioregion contains many major waterways including the Avon River, Bass River, La Trobe River, Macalister River, Mitchell River, Tambo River, Tarwin River, Thompson River, and the Yarra River (Department of Environment, Land, Water and Planning 2021). The study area is also close to the Port Phillip coastline and the low-lying coastal and alluvial plains associated with it. The ready access to fresh water is likely to have influenced both Aboriginal and European settlement in the immediate area, as the swampland would have contained edible flora and attracted various fauna as well.

Stone Resources

No stone resources and outcrops suitable for the manufacture of stone tools have been recorded within the study area; however suitable stone for the manufacture of stone artefacts was certainly available in the surrounding region, with basalt outcrops in Berwick and Cranbourne and quartz pebbles found in most creeks and drainage lines. Highly sought-after materials for stone tool manufacture, such as silcrete and chert, are available inland on the Mornington Peninsula and would likely have been traded in from here (Murphy et al. 2006, p.13). Along the Mornington Peninsula is a much more varied landscape with sources of silcrete, quartz, and chert found at places like Devilbend Creek and Baxter (Ellender 1991, p.10; Weaver 1992).

2.3 Search of the Aboriginal Victorian Heritage Register

The Victorian Aboriginal Heritage Register (VAHR), accessed through Aboriginal Cultural Heritage Register and Information System (ACHRIS), was searched to identify any previously registered Aboriginal Places within the geographic region for the activity area, as well as the results of previous archaeological assessments. The register was accessed 21 September 2021.

Aboriginal places in the study area

A search of the VAHR identified 20 registered Aboriginal Places within the study area, comprising a total of 33 components (Table1; Figure 4). Of these components, 45% are artefact scatters (n=15) and 55% are Low density artefact distributions (LDAD) (n=18). It is worth noting that many of the artefact scatters are associated with isolated or low density finds. They were registered prior to the introduction of the LDAD component type to the Victorian Aboriginal Heritage Register but conform to its requirements and definition. Silcrete and quartz are the dominant materials present however other materials such as quartzite, hornfels, and flint are also found in the landscape.

These Places mainly occur in the west of the study area along the South Gippsland Highway and Clyde- Fiveways Road. These focus areas are in part a result of the Cranbourne Sand sheet in the east, and previous heritage works that have been conducted along the main roads. The lack of Aboriginal Places in the west of the study area is most likely due to a lack of heritage testing rather than a lack of cultural heritage in the area. Indeed, the search indicated that only 14 Cultural Heritage Management Plans (CHMP) have been conducted in the study area (Figure 3).

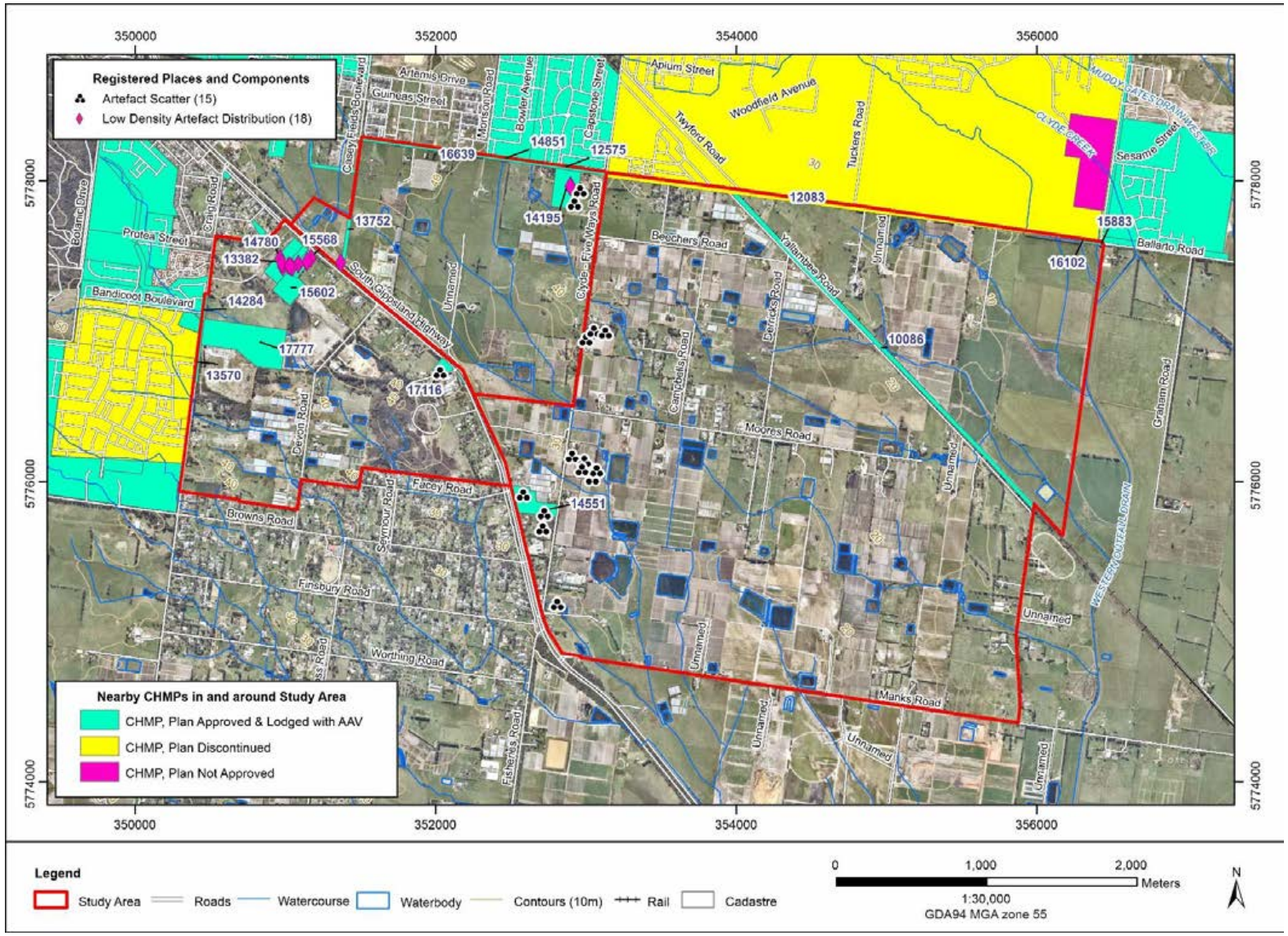


Figure 3. Prior CHMPs near the study area

Aboriginal Places are often located along creeks and drainage lines such as those in the west leading to the swamplands and coast, as waterways were an important source of fresh water and associated resources for Aboriginal people who camped beside them and used creeks as routes through the landscape. Although many of these western drainage lines have been modified to irrigate the drained pastures, it is likely they closely follow the original water courses and should be considered to have archaeological potential.

Historic Heritage

A search of the Victorian Heritage Database (VHR) indicated that one heritage listed building exists in the study area (Figure 5). Heritage Overlay HO148 is located at 10 Ballarto Road, Clyde, and contains an Edwardian weatherboard villa built in 1912. Given the association of such houses with early farmland, there is moderate to high potential for historic structures and landscape features such as plantings, tracks, and fences relating to the early settlement and farming of the land to be preserved within the study area. If any such features are preserved, they may meet the criteria for statutory protection under *the Heritage Act 2017* and/or the *Planning and Environment (Planning Schemes) Act 1996*. As all historic archaeological sites in Victoria are protected by the *Heritage Act 2017*, further assessment of the uninspected sections of these places may be required in future, particularly if the heritage or archaeological values of the place are threatened by development or change of use.

Table1. Summary of registered Aboriginal Places within the study area

VAHR No.	Aboriginal Place Name	Component type(s)	Description	Landform
7921-024	Five Ways 1	Artefact scatter	Quartz artefact scatter	Lowland (<300m), Dune, Floodplain, Hill, Mudflat/Mangrove
7921-0125	Five Ways 2	Artefact scatter	Undefined artefact scatter	Lowland (<300m), Dune, Floodplain, Hill
7921-0426	Lamantina 1	Artefact scatter	4 silcrete and quartz artefacts	Lowland (<300m), Hill
7921-0427	Lamantina 2	Artefact scatter	4 silcrete and quartz artefacts	Lowland (<300m), Hill
7921-0428	Lamantina 3	Artefact scatter	3 silcrete and quartz artefacts	Lowland (<300m), Hill
7921-0429	Lamantina 4	Artefact scatter	3 silcrete and quartz artefacts	Lowland (<300m), Hill
7921-0430	Lamantina 5	Artefact scatter	1 silcrete artefact	Lowland (<300m), Hill
7921-0431	Burnalook 1	Artefact scatter	3 quartz artefacts	Lowland (<300m), Hill
7921-0432	Burnalook 2	Artefact scatter	5 silcrete and mudstone artefacts	Lowland (<300m), Dune, Hill
7921-0433	Burnalook 3	Artefact scatter	8 silcrete, quartz, quartzite and hornfels artefacts	Lowland (<300m), Dune, Hill
7921-0442	Bath'mun 1	Artefact scatter	4 silcrete, quartz and flint artefacts	Lowland (<300m), Sandsheet/Drift
7921-1548	1724 South Gippsland Hwy	Low density artefact distribution	3 quartz and quartzite artefacts	Lowland (<300m), Dune, Hill
7921-1578	1753 South Gippsland Hwy, Cranbourne East, LDAD	Low density artefact distribution	1 silcrete artefact	Lowland (<300m), Dune, Hill
7921-1614	1470 Ballarto Rd, Clyde, AS 1	Artefact scatter	10 silcrete and quartz artefacts	Lowland (<300m), Hill, Sandy undulation
7921-1615	1470 Ballarto Rd, Clyde, LDAD 1	Low density artefact distribution	2 silcrete artefacts	Lowland (<300m), Dune, Hill
7921-1643	Clyde scatter 2	Artefact scatter Artefact scatter Earth feature	19 silcrete artefacts 689 silcrete, quartz, quartzite and trachyte artefacts Circular hearth	Lowland (<300m), Flats, Sandsheet
7921-1644	Clyde scatter 1	Artefact scatter	10 silcrete and quartz artefacts	Lowland (<300m), Sandsheet, ephemeral wetland
7921-1720	1734 South Gippsland Hwy, LDAD1	Low density artefact distribution	7 silcrete and quartz artefacts	Lowland (<300m), Dune, Hill
7921-1729	1730 South Gippsland Hwy, LDAD1	Low density artefact distribution	5 silcrete artefacts	Lowland (<300m), Dune, Hill
7921-1868	5 Rawlins Rd AS	Artefact scatter	201 silcrete, quartz, quartzite, crystal quartz and chert artefacts	Lowland (<300m), Low rises

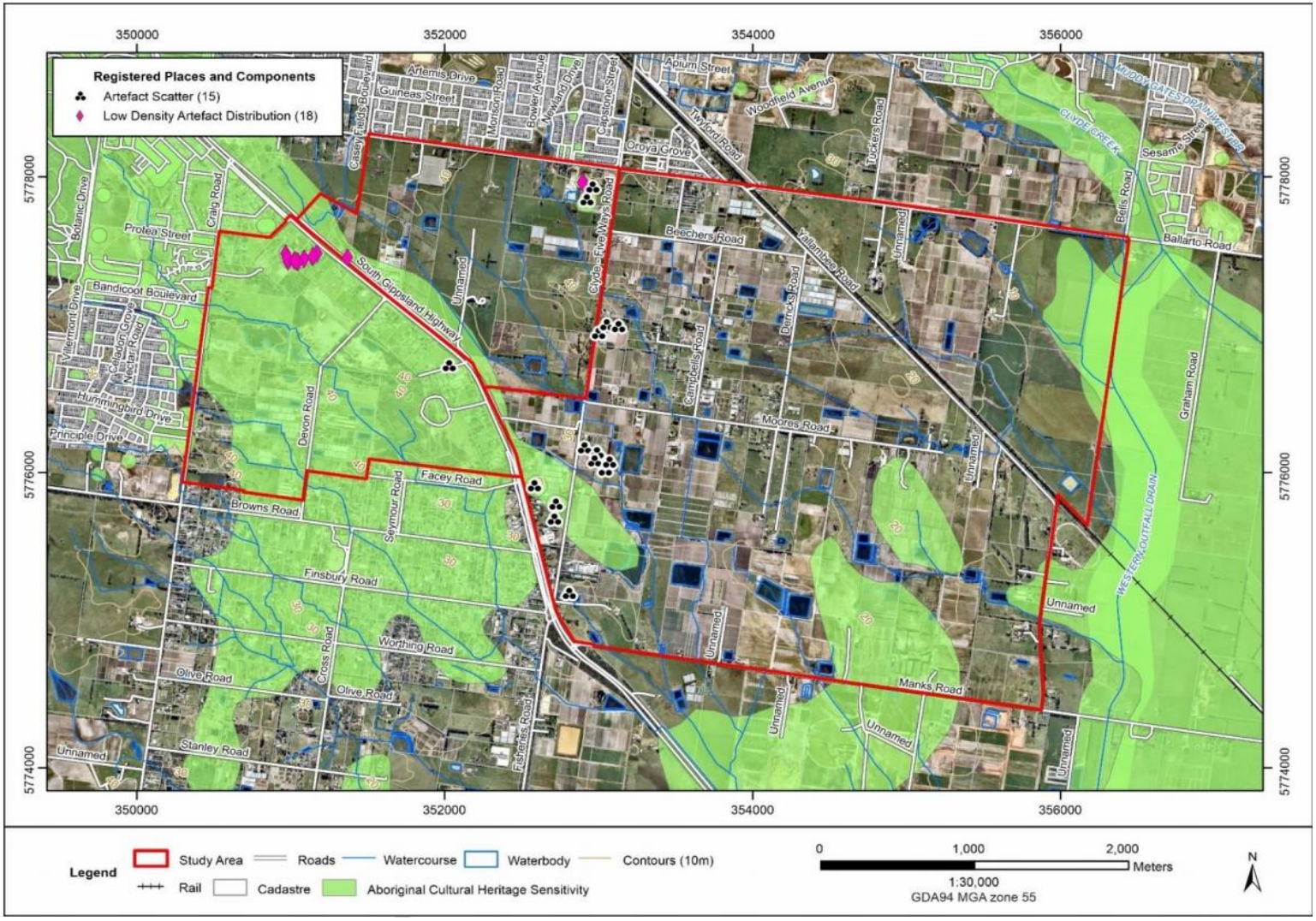


Figure 4. Aboriginal Cultural Heritage sensitivity and Registered Places within the study area

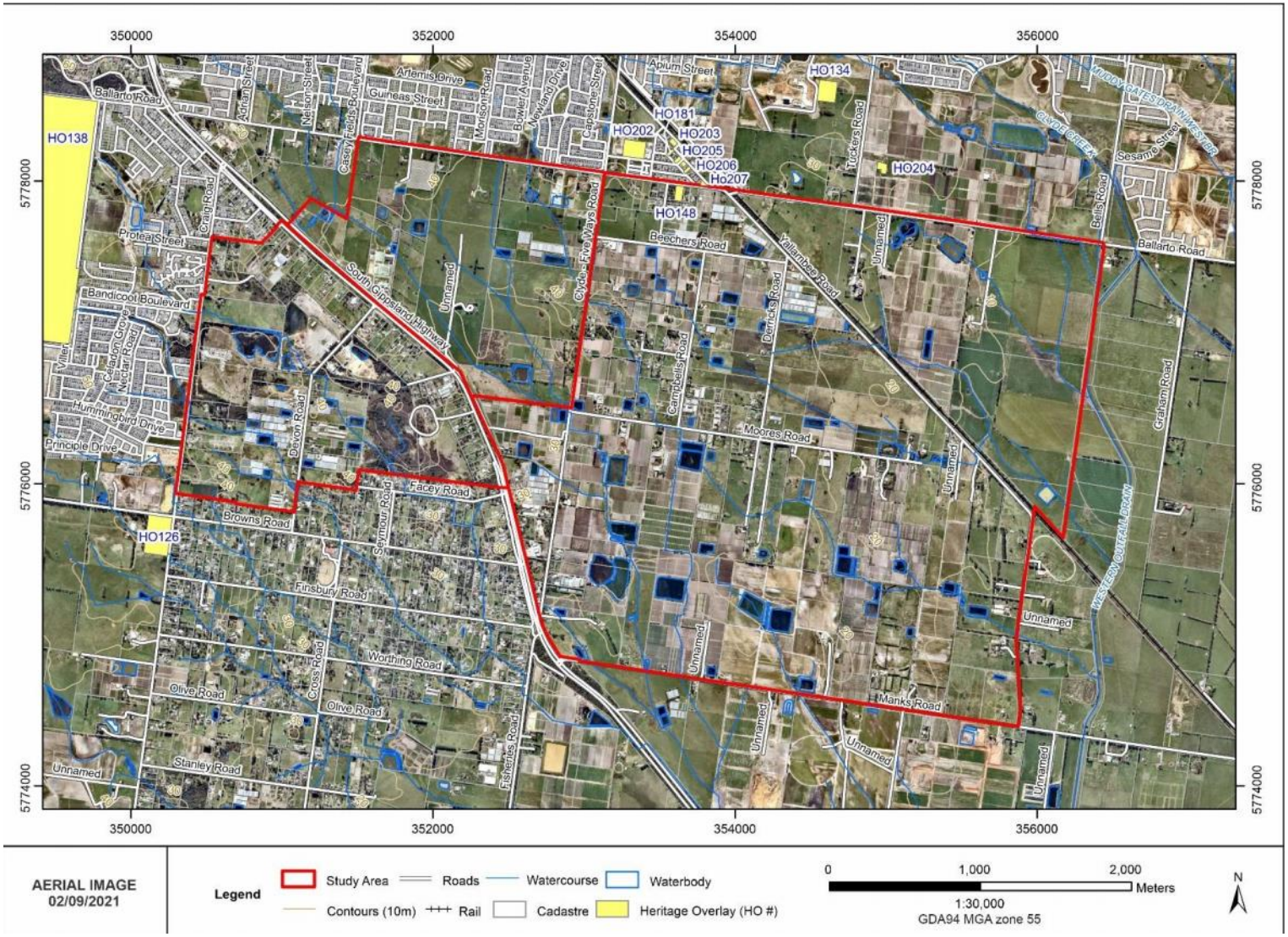


Figure 5. Historical heritage places within the study area

2.4 Previous work in the study area

Thirty-nine reports have been undertaken within the study area. From this number, the results of relevant regional and localised studies are presented below to assist with the formulation of the site prediction model.

Previous Investigations in Close Proximity to the Activity Area

Proposed Service Station at 5 Rawlins Road, Devon Meadows CHMP# 17116 (Stradwick, Waldie & Spencer-Gardner 2021)

This CHMP was prepared for the construction of a service stations at 5 Rawlins Road, Devon Meadows. The desktop assessment found the activity area was located on the culturally sensitive Cranbourne Sands and found 45 previously registered Aboriginal Places in the region, predominantly LDADs and artefact scatters. The standard assessment involved four auger holes across the activity area as well as the ground survey. The augers confirmed the desktop assessments findings of past gardening in the activity area by the disturbance of the top 500mm of soil. The B horizon is composed of a medium grey sandy sediment with clay inclusions. The complex assessment involved the excavation of one 1x1m test pit, seven 2mx1m mechanical test pits reaching a maximum depth of 1.3m. One Aboriginal Place was registered as 5 Rawlins Road AS, VAHR 7921-1868, consisting of 201 stone artefacts.

Mayfield Outfall Sewer, Cranbourne East CHMP# 13752 (Hislop 2021)

Heritage Insight was commissioned to undertake this CHMP for the construction of a sewer outfall pipeline approximately 1.65km in length between Nelson Street and the South Gippsland Highway in Cranbourne East. The desktop assessment found the activity area was located on the culturally sensitive Cranbourne Sands and that Aboriginal Places were most likely to be found on well-drained sandy high ground. The standard assessment noted extensive disturbance from land clearance, drainage construction, and fence installation from early European settlement. Two 1x1m test pits and 27 shovel test pits were excavated as a part of the complex assessment. A single silcrete artefact, VAHR 7921-1578, was recorded as a result of the assessment.

Residential Subdivision: 1895 Ballarto Road, Clyde, Victoria CHMP# 16102 (Brook, Light & Raudino 2019)

This CHMP was conducted for an extensive residential development at 1895 Ballarto Road, Clyde. The desktop assessment identified VAHR 7921-1730 (LDAD) within the activity area. Poor ground surface visibility impeded the standard assessment, and VAHR 7921-1730 was not relocated. Three 1x1m test pits, 16 mechanical test pits and 34 shovel test pits were excavated as part of the complex assessment, and found relatively intact stratigraphic deposits, with the rise landforms displaying sandy silt overlying increasingly sandy deposits, and the swamp/floodplain displaying shallower deposits of silt overlying clay. A total of 90 stone artefacts were recovered during the complex assessment and registered as VAHR 7921-1769, an artefact scatter of 59 silcrete, quartzite, and quartz artefacts located on the elevated sandy plain, VAHR 7921-1768, an artefact scatter of 23 silcrete, quartzite, and tachylyte artefacts located on a low sandy rise surrounded by floodplain, and VAHR 7921-1770, an LDAD of eight silcrete artefacts spread across sandy plain areas.

Bells Road Gravity Sewer, Clyde North CHMP# 15883 (Strickland, White & Morrison 2018)

This CHMP was prepared for the construction of a gravity sewer to connect sewer assets within the McPherson PSP sewerage scheme. The alignment covers approximately 3.7km from the Sewerage Pump Station at Clyde Creek the proposed Ballarto Sewer Pump Station off Ballarto Road. The desktop assessment found no Aboriginal Places within the activity area, however artefact scatters and LDADs are found throughout the wider region, predominantly recorded within sandy rises overlooking areas of swamp and wetland. The standard assessment noted that the activity area crossed open semi-modified rural and farming paddocks that had undergone disturbance as a result of agricultural practices and road construction and drainage cuts. The complex assessment included the excavation of two 1x1m test pits, six 1.2x2m machine trenches, and 15 shovel test pits. VAHR 7921-1730, 1895 Ballarto Road LDAD, was recorded along Bells Road near Clyde Creek as a result of the assessment.

Use of Land for Industry (Concrete Batching & Landscape Garden Supplies) 1470 Ballarto Road, Clyde CHMP# 14195 (Murphy & Rymer 2016)

This CHMP was prepared for an industrial development at 1470 Ballarto Road, Clyde. The desktop found no previously registered Places within the activity area but did note an area of archaeological potential on a sandy plain under the modern market garden. Despite poor ground surface visibility, the standard assessment confirmed the desktop's findings of a sandy undulating plain landform in part of the activity area. The complex assessment saw the excavation of 25 test pits and five machine trenches, which noted varying depths of the A horizon. Two Aboriginal Places were recorded: artefact scatter VAHR 7921-1614, and LDAD VAHR 7921-1615.

Proposed Carpark: 1730 South Gippsland Highway, Devon Meadows CHMP# 15602 (Dugay 2019)

This CHMP was conducted for a proposed carpark at the Pentecostal Church at 1730 South Gippsland Highway, Devon Meadows. The desktop and standard assessments noted the disturbance caused by land clearing and agricultural practices. The complex assessment excavated five 1x1m test pits and 13 shovel test pits, noting extensive disturbance down to depths of 900mm in the north of the activity area. Modern debris was found across the entire area in the upper deposits. South Gippsland Highway LDAD 1 VAHR 7921-1729 was identified in the south section of the activity area.

Relevant local and regional studies

Melbourne 2030 Casey-Cardinia Growth Area. Aboriginal Archaeological Desktop Report, Report ID 3883 (Feldman & Long 2006)

This study assesses the distribution of Aboriginal archaeological sites based on known and potential site locations, with a view to establishing their implications for future growth in the Casey-Cardinia Growth Area. Feldman and Long proposed six landscape zones with discrete archaeological characteristics that define the Casey-Cardinia Growth Area. The present activity area is located at a point within the Casey-Cardinia Growth Area where Zone 1: Major Drainage Corridors, Zone 2: Intermediate Plains and Zone 6:
Cranbourne Massif intersect. These zones are described by Feldman and Long (2006, pp.27–28) as:

• Zone 1 – the foothills and intermediate plains drained by the four major creek complexes (Cardinia Creek, Toomuc Creek, Deep/Pakenham Creek and Ararat/Back Creek). These creeks have been a focus for Aboriginal occupation in the recent past. The creek margins are associated with comparatively dense artefact scatters and scarred trees;

• Zone 2 – a slightly elevated band of flat or undulating land bordering the northern foothills and Koo Wee Rup Swamp to the south. This region has been dominated by agriculture and urban development. The archaeological record is dominated by stone artefact occurrences on alluvial flats and outwash fans associated with creeks draining the foothills. These occur as comparatively dense, localised scatters and diffuse isolated finds. There is the potential for buried deposits to occur to a depth of 800mm, possibly in association with a complex of palaeo-landforms (prior and former stream channels), obscured below the current alluvial land surface. Scarred trees, a notably significant site type in this region due to their rarity, may also occur within stands of native remnant vegetation in this zone; and

• Zone 6 – an area of undulating plains centred on an elevated ridge of volcanics and sedimentary rock (Cranbourne Massif). This region is characterised by widespread sand drifts (Cranbourne Sands). Today the area is dominated by irrigated agriculture and urban development. The archaeology is dominated by localised dense scatters of stone artefacts associated with sand drifts, ridgelines and drainage lines, within a broader diffuse scatter of isolated artefacts occurring widely in the landscape. Burials may occur within sand deposits.

Tuckers Road Reserve and Pattersons Road Reserve Clyde North, Interim Upgrade Complex CHMP 13425 (Rae & Welsh 2015)

This CHMP was undertaken for Pattersons Road and Tuckers Road, to the south of Pattersons Road. The desktop assessment concluded that disturbance was likely along much of the road reserve, but not all of it. No Aboriginal Places were identified during the standard assessment. The field survey confirmed that the level of disturbance within much of the activity area was high. The complex assessment targeted the areas of the activity area that were less likely to be disturbed. Nine 1x1m test pits were excavated. One Aboriginal Place was located (VAHR 7921-1551) comprising three silcrete artefacts. The site was assessed as having low local significance.

Desalination Project Transfer Pipeline and Power Utilities Corridor, Wonthaggi to Cranbourne, Victoria: CHMP 10620 (Debney et al. 2009).

Debney et al. (2009) carried out an extensive linear CHMP for the desalination pipeline and utilities corridor which crosses north of Ballarto Road. A transect of ten shovel test pits were excavated in the paddock north of Ballarto Road. VAHR 7921-0970 contained two quartz artefacts in a sandy subsurface context. Debney et al. (2009) argued that these artefacts were a low-density scatter in a "lunette complex". However, on the basis of the Sargeant's (1996) Ko/Sr soil profile, this sandy deposit is likely an ephemeral or incidental prior stream channel.

The Royal Botanic Gardens, Cranbourne, Victoria. Completion of landscape development in the Australian Garden Stage Two: Cultural Heritage Management Plan 10038 (Ellender, Luebbers & Bowler 2009)

This CHMP was conducted for landscape works at the Royal Botanic Gardens Cranbourne. The desktop assessment noted that the activity area contained seven previously registered Aboriginal Places (VAHR 7921-0255, -0256, -0300-0303 and -0365) comprising four artefact scatters and three isolated artefacts. The desktop assessment noted that artefact deposits within the upper grey units of Cranbourne Sands likely represent the Australian Stone Tool Tradition. However other evidence suggests older sites can be located in the darker deeper sand units. A geomorphological investigation identified an exposed dune face to be of Late Pleistocene/early Holocene in age. Mechanical excavation was utilised to investigate the dune sediments. Four OSL samples were taken. These dates were:

- BG01 (Pit 11) 27 ± 2 ka from 350mm beneath basal coffee rock;
- BG02 (Pit 10) 38 ± 3 ka from a buried palaeosol;
- BG03 (Pit 10) 22 ± 2 ka from 1m above the dune-palaeosol contact; and
- BG04 (Pit 10) 22 ± 2 ka from 1m below the surface, 1.5m above BG02.

No Aboriginal cultural material was located during the complex assessment.

Coastal economies and the Westernport catchment', School of Humanities, La Trobe University, Melbourne (Gaughwin & La Trobe University. Theses. 1983)

Denise Gaughwin undertook an archaeological survey to develop a site prediction model for the Westernport Catchment region. She created this model by comparing the regional distribution of Aboriginal Places, their contents, regional landforms, and historical records. The catchment contains three landforms: the coastal margins, the coastal plains, and the upland hills (Gaughwin 1983: 33). The coastal margins contained 247 Places comprising of shell middens and artefact scatters (Gaughwin 1983:109-110). The coastal plains contained 13 artefact scatters and one quarry site, mostly found on might ground overlooking the swamps and wetlands (Gaughwin 1983:109-114). Only four artefact scatters were recorded in the upland hills, as the landform consisted of ploughed fields with limited visibility (Gaughwin 1983: 153). The results of this study demonstrated that the coastal plains were the most actively utilised areas, especially in relation to the wetlands which provided various resources.

2.5 Historical and Ethno-historical accounts

Prior to European occupation, the central portion of what is now the state of Victoria was occupied by Aboriginal people who shared a common language and political, social, religious and economic affiliations and who identified themselves as Kulin, the label meaning 'man' in the dialect spoken in the Melbourne region (Blake 1991, p.31). The area of land occupied by the Kulin people extended as far north as present-day Echuca, west as the Richardson River, Mt Avoca, Fiery Creek and Mt Emu Creek, south to the Victorian coastline and east to the Tarwin River and Wilsons Promontory (Blake 1991, p.30; Clark 1990).

Within the Kulin, a number of different but related dialects or wurrung (= lips, speech, mouth) were spoken. Generally speaking, different dialect groups among the Kulin were delineated by association with a specific area of country. These dialect groups, named the Woiworung, Bunurong, Taungurong, Nguraiwurung, Wadawurrung and Dja dja wurrung, comprised a 'regional cultural confederacy known as the Kulin' (Barwick 1984, pp.104–105). The activity area lies within land which was occupied by clans speaking the Bunurong dialect of the Kulin language.

Among the Kulin, political, social and economic relationships were shaped by affiliation with the main unit of social organisation (the clan) and affiliation with one of two groups linked with creation ancestors. A clan was usually formed from a number of related families (a lineal descent group) which claimed guardianship over a particular tract of land (Howitt 1904, p.41; Cotter 2001). Kulin clans supposedly traced descent through the male line (patrilineal descent) (Clark 1990, p.363), although this is disputed by some contemporary descendants of the BLCAC.

The Kulin were also divided into two groups (described as moieties by western anthropologists) linked with creation ancestors. These groups were Waa (Australian Raven) and Bunjil (the eaglehawk) (Barwick 1984, p.105). Affiliation of an individual with either Waa or Bunjil was determined at birth by the group/moiety affiliation of the father and the father's clan (Barwick 1984, p.105; Clark 1990).

In traditional Kulin law, moiety and clan affiliation determined marriage. Individuals were required to marry outside their clan and to a person belonging to the opposite moiety. Thus, an individual who belonged to the Waa descent group could only marry a person from another clan and from the Bunjil descent group. Marriages were often arranged at large ceremonies involving clans from a number of different geographical locations.

Marriage had an extremely important influence on social and economic relationships, and individuals could acquire considerable status and economic power through marriage ties, particularly men who could afford to support more than one wife. Access to the land and resources of another clan was most often gained by a kin relationship formed by marriage (Barwick 1984, p.106), although geographical proximity of birth or descent could also form grounds for access. Marriage also imposed a mutual obligation of each clan to provide access to some or all of the resources of another, so that reciprocal sharing of resources was fundamental to land management (Barwick 1984, p.106).

William Thomas, Assistant Protector of Aborigines in the Westernport district from 1839, spent much of his time travelling with Bunurong people between his hut at Arthur's Seat, the Aboriginal reserve (which he established at Narre Warren during 1841), and the Aboriginal camps around Melbourne (Sullivan 1981, p.25; Cannon 1983). According to Thomas, the Bunurong claimed 'all the country south of the Yarra River, whose creeks and inlets falls into the sea from the Werribee River west

to the Tarwin River, east of Cape Patterson' (Thomas papers, Vol. 7, 17/1/1860, cited in Clark 1990).

Gunson (1974, p.10) stated that members of the Bunurong usually camped beside waterholes, creeks, and at coastal locations. Early settlers of the Westernport region also noted that Aboriginal campsites containing huts were often found beside rivers and creeks (Sullivan 1981, p.33). There are no burial sites recorded within a 5km radius of the activity area; however, Thomas saw a burial location beyond Torbinerk (Lang Lang) in 1840 (Gunson 1974, p.10). Members of the Kulin were known to both bury their dead and place them in tree hollows that were often subsequently burnt. Thomas noted that:

"Wood was pulled up to a height of 3 feet and the ground burnt all around, this was of long standing as the woods were literally decayed and dirt over them, I suppose there were 50 sticks laid horizontal thus. At the end was a large dead trunk and hollow burnt in it as if not done by chance. I examined it but could not trace anything worthy of remark further than it appeared to have been many years previous" (Gunson 1974, p.10).

2.6 Land use history of the study area

The study area covers the suburbs of Casey Fields, Clyde, and Devon Meadows. During the 1840s and 1850s, enormous squatting empires were forming within Victoria, and around this time the larger of these runs were being divided and sold as freehold in an effort to restrict these huge pastoral enterprises. The Cranbourne township was first surveyed by H.B Foote in 1852 and reserved out of the surrounding pastoral runs 'Mayune', 'Towbeet' and 'Barkers Heifer Station' (Spreadborough & Anderson 1983). The study area was originally a part of the 'Barkers Heifer Station' pastoral run in the Parish of Sherwood (Figure 6).

Clyde, named after the Clyde Creek flowing east towards Koo Wee Rup Swamp, was originally settled further north and established on the property bought by John Bakewell (Figure 7). Early amenities in the township includes the Cranbourne National school, two churches, a public hall, and a general store opened in the mid-19th century ('Victorian Places' 2015a). When the railway connected to the southeast in 1888, the township was moved to centre on Clyde Railway station, and the original township was

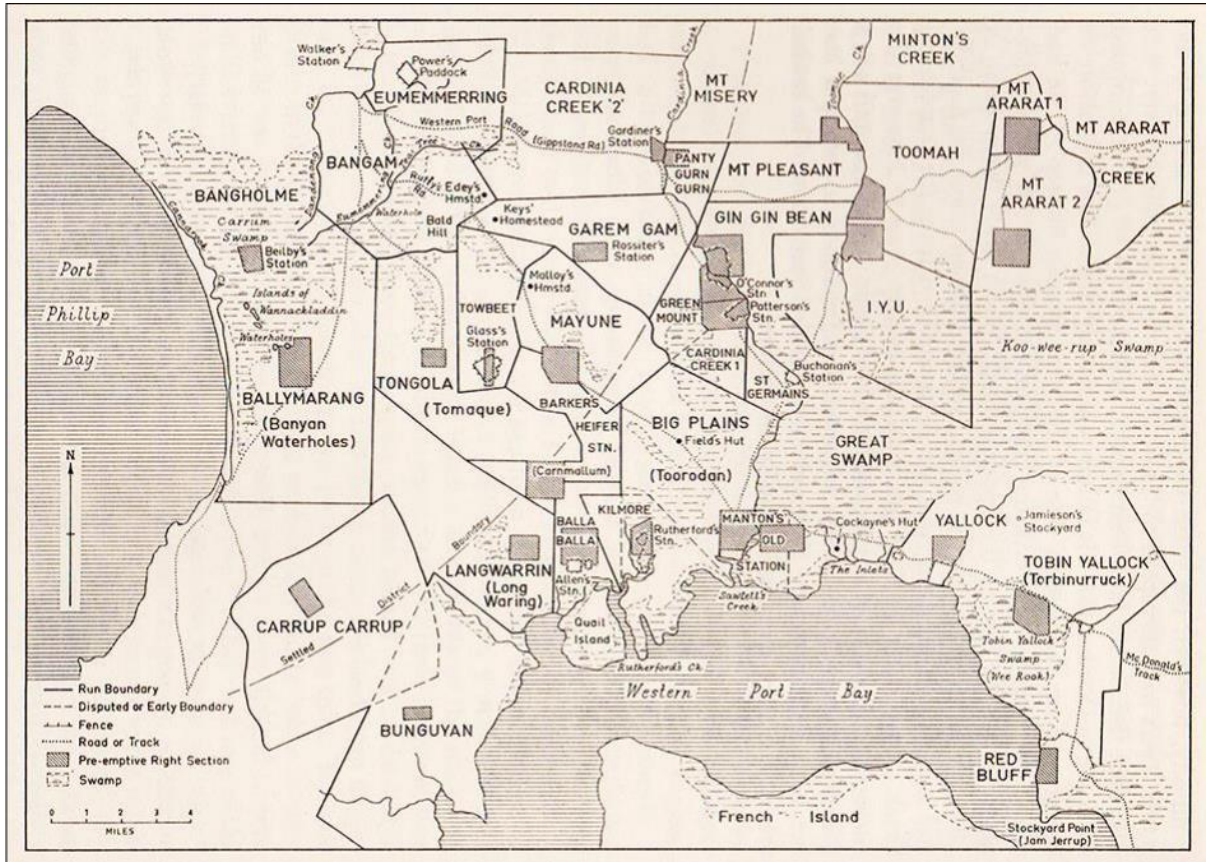


Figure 6. Map of Westernport squatting runs, sourced from "The Good Country" (Gunson 1984)

renamed Clyde North. Much of the area has been used for a mixture of market gardening (notably around Pattersons Road) and dairy farming.

Devon Meadows is a much more recent suburb, established in 1912 to support the local farming community. Since the 1970s, the area has gained residential development but remains a relatively rural township ('Victorian Places' 2015b). Similarly, Casey Fields is a subdivision of Cranbourne East's growth corridor and has in recent decades become a residential area.

Aerial photography from the twentieth century indicates that the study area has been predominantly used for agricultural purposes. Agricultural activities would have included extensive vegetation clearing, ploughing, dry stone wall and dam construction, and the introduction of exotic flora and fauna.

A 1957 image shows the study area's lots have been divided into paddocks with major roads already sealed (Figure 8). Few houses and farm buildings are visible. Satellite images from 2005 and 2015 illustrate that despite some urban growth and residential development, the majority of the study area has remained agricultural in use (Figure 9; Figure 10).



Figure 7. 1858 map of Sherwood Parish (Public Lands Office, Victoria)

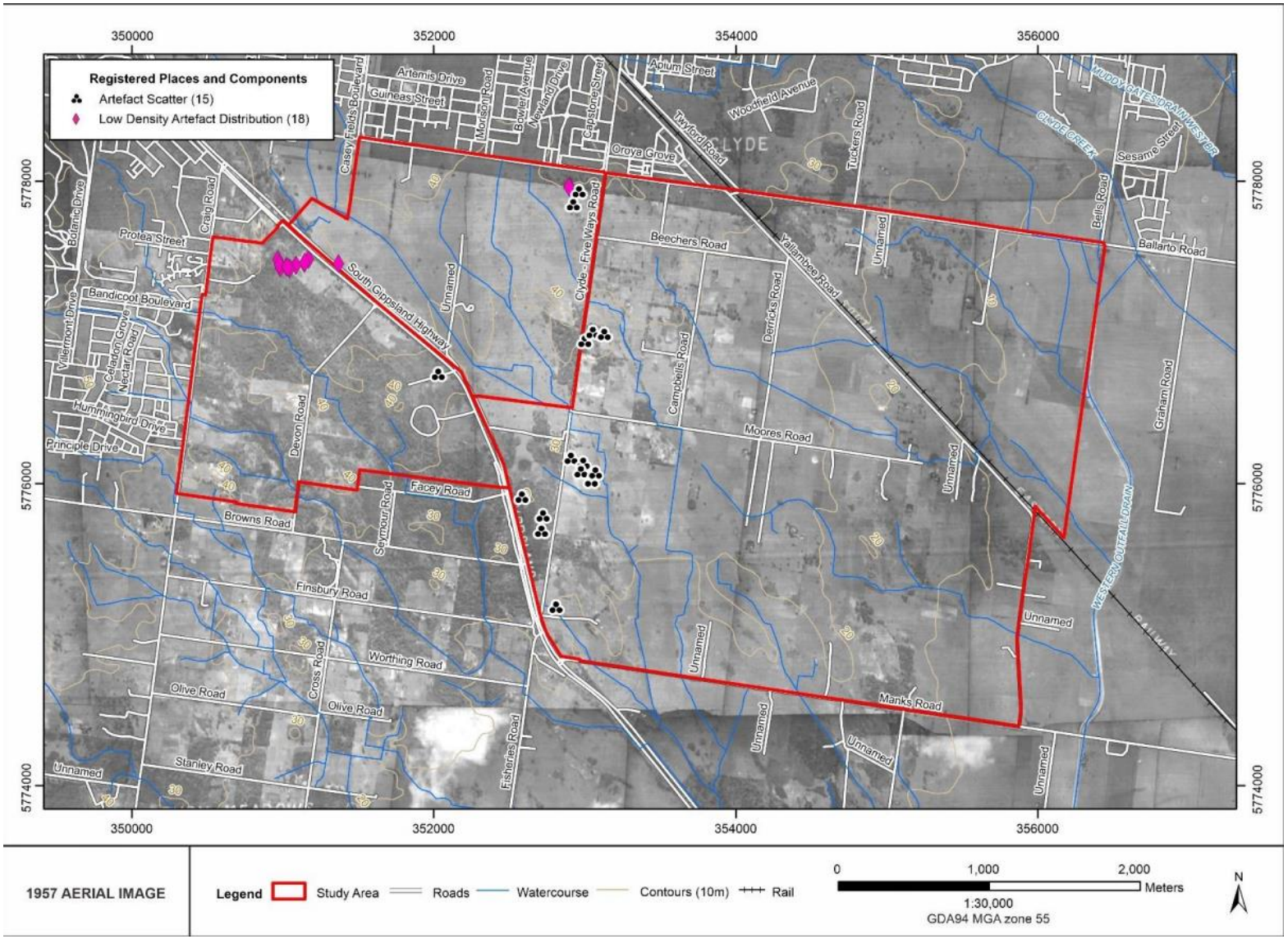


Figure 8. 1957 aerial photo study area (DELWP, 2021)

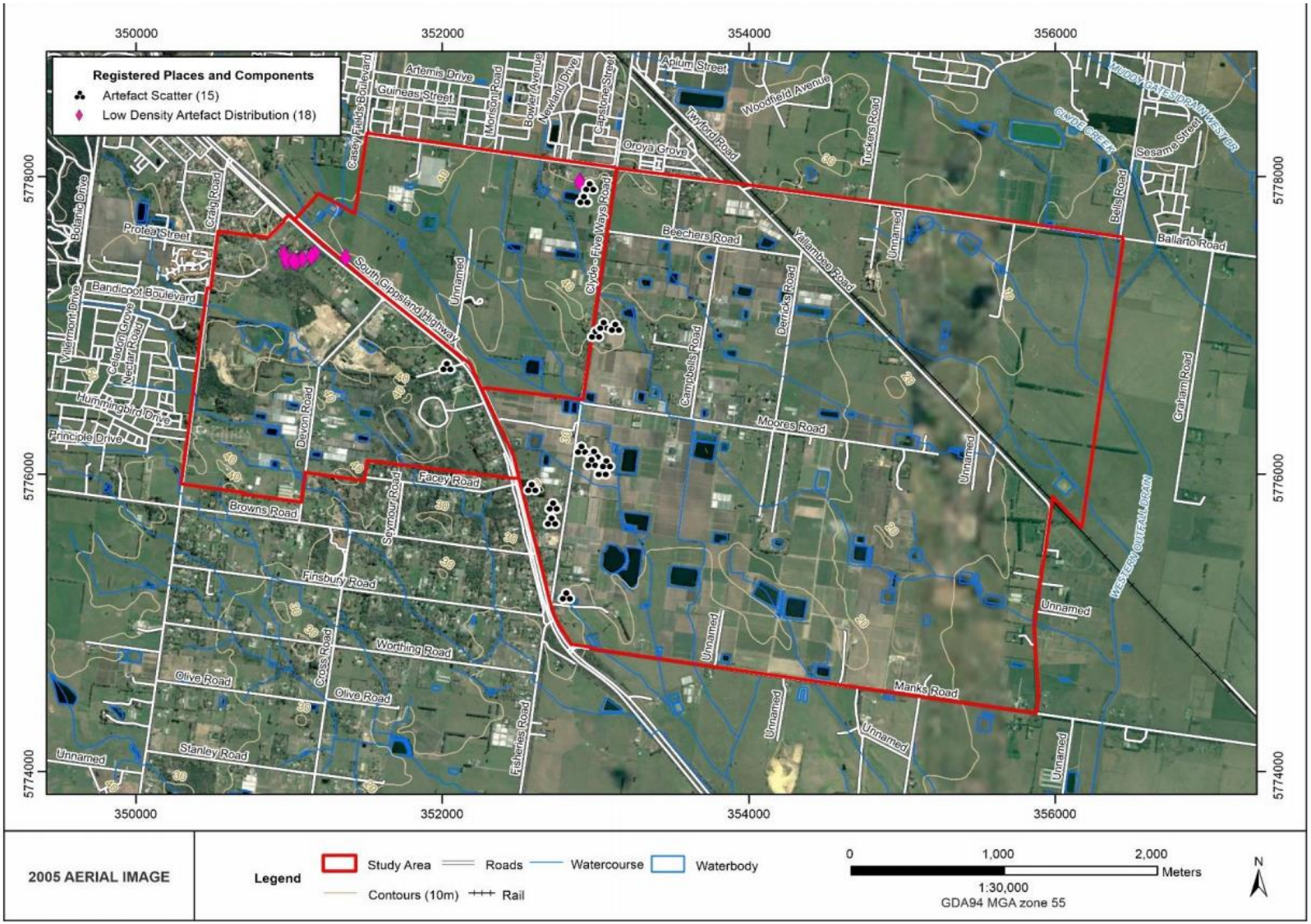


Figure 9. 2005 aerial image of the study area (Google Earth, 2021)

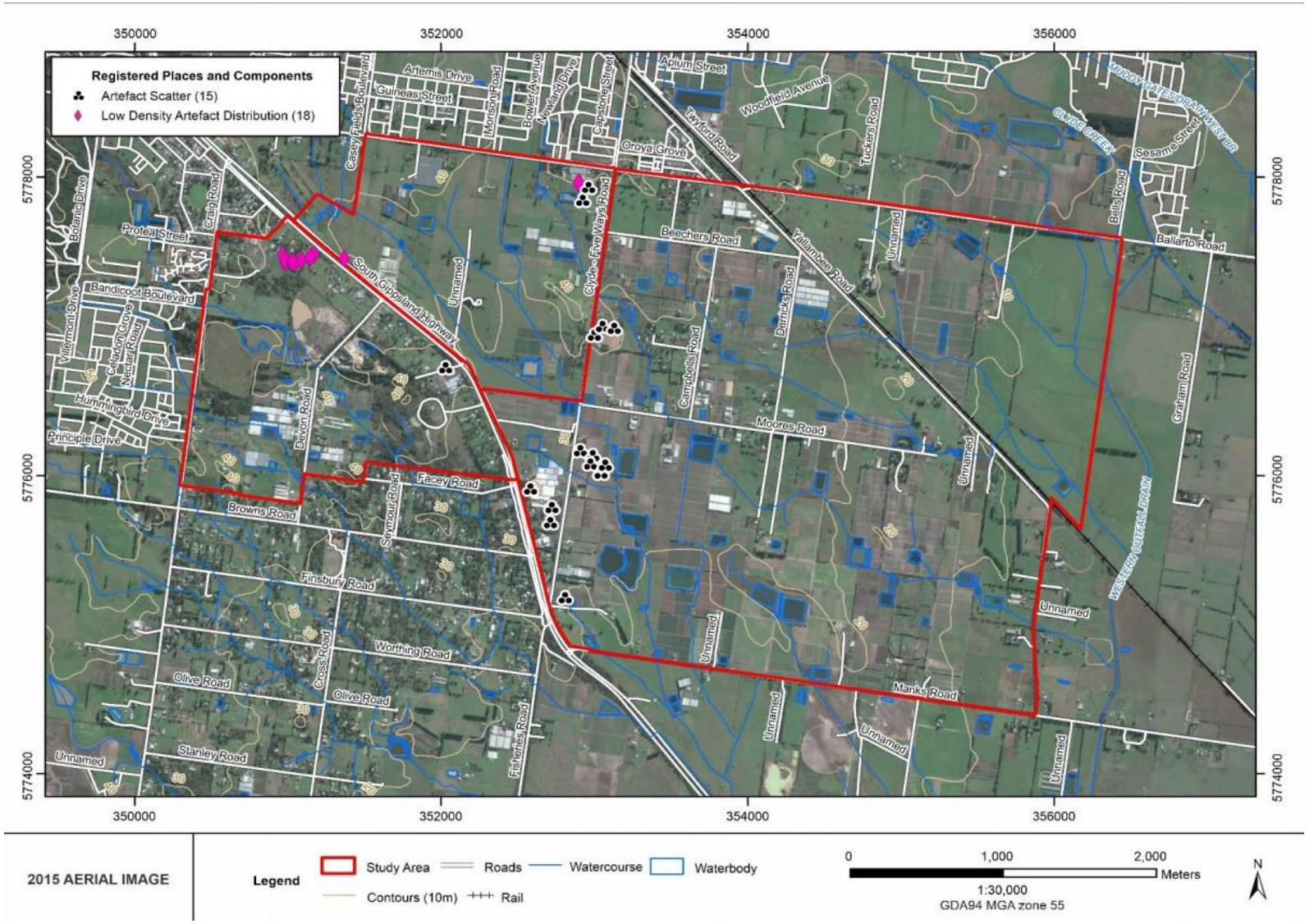


Figure 10. 2015 aerial image of the study site (Google Earth, 2021)

2.7 Discussion

The areas of Aboriginal cultural sensitivity in the study area can be divided into the Cranbourne Sand sheet in the west and the low-lying plains and unnamed tributaries in the which drain into the Koo Wee Rup Swamp (Figure 11). The 20 Registered Aboriginal Places within the study area are focused in the west on the edge of the Cranbourne Sands, where previous archaeological work has been conducted along South Gippsland Highway and Clyde-Fiveways Road. These past assessments have mainly found LDADs and small artefact scatters in association with the sand sheets, however, intact cultural deposits have been found in the floodplains and on small sandy rises within the floodplains.

The minimal heritage currently recorded in the study area is likely a reflection of the limited archaeological testing that has occurred in the region, as both the Cranbourne Sands to the west and the Koo Wee Rup Swamp to the east contain a large number of Aboriginal Places. The study area would most likely have been a transitional landscape that Aboriginal people would have often traversed between the two areas and certainly would have left their mark on the land.

With this in mind, there is moderate to high potential for Aboriginal cultural heritage in the sand dunes to the west, and on any small, sandy rises overlooking the waterways throughout the eastern floodplains. There is also moderate potential for Aboriginal cultural heritage to occur in the floodplain deposits along the unnamed waterways. The closer to the Koo Wee Rup swampland in the east, the higher the likelihood of cultural material. This is especially true of Clyde Creek along the eastern border of the study area. The predicted site types are LDADs and small artefact scatters. There is potential for larger artefact scatters to be found in the sand sheets to the west.

Although only one heritage overlay exists in the study area over 10 Ballarto Road (HO148), the south west region was settled relatively early as proven by the land use history. A review of aerial photography has shown that the entirety of the study area has since been cleared and paddocked for agricultural purposes. Although a detailed review of historic records is beyond the scope of this due diligence, a review of an 1858 historic survey map of the Parish of Sherwood indicates the early stage of colonial settlement at which lots had been purchased (Figure 7). Therefore, it is highly probable that historical heritage is also present throughout the study area in association with this early colonial occupation.

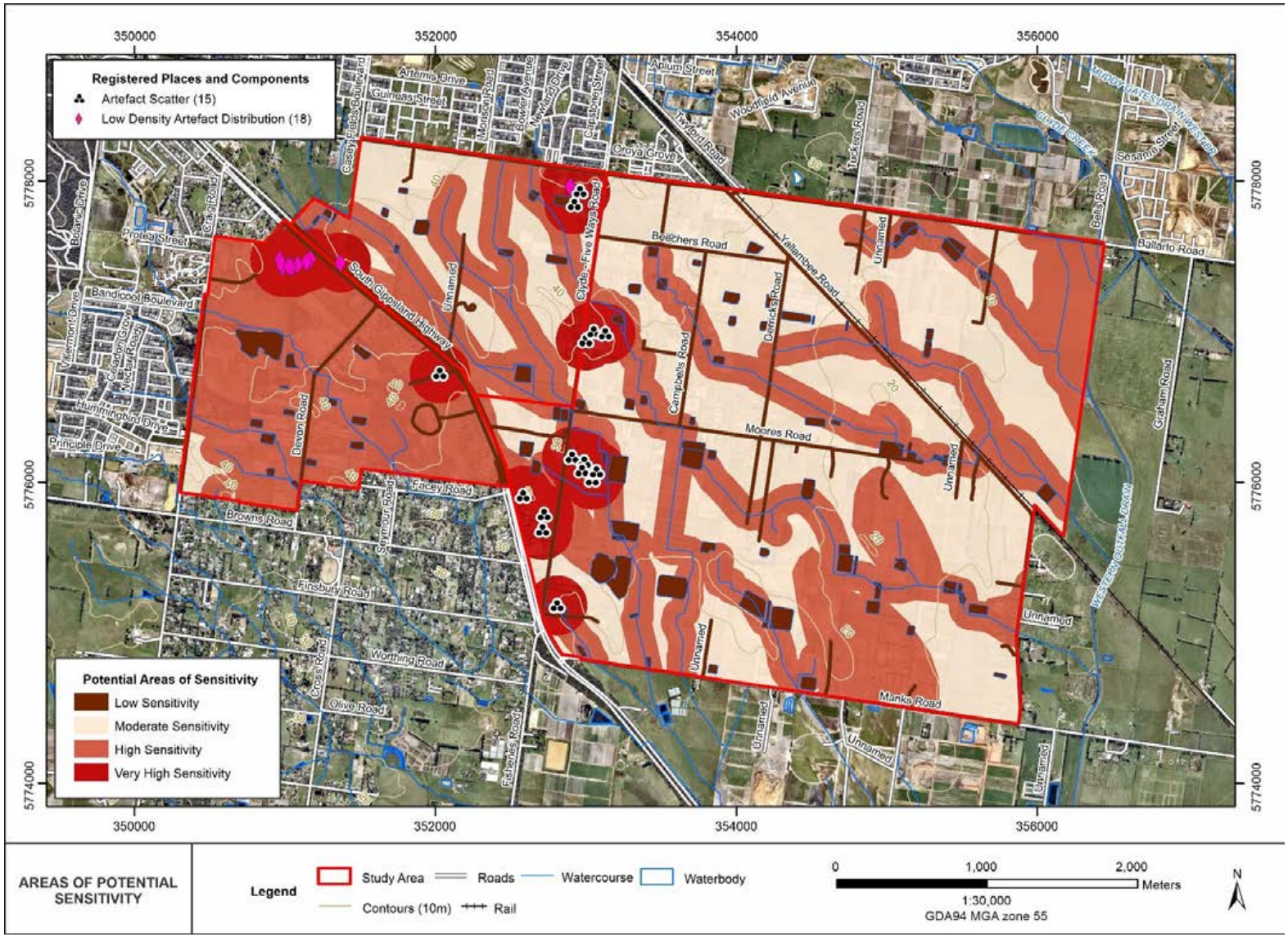


Figure 11. Potential areas of sensitivity

2.8 Legislative requirements

Regulation 7 of the Aboriginal Heritage Regulations 2018 makes provision for when a Cultural Heritage Management Plan (CHMP) is required.

7 When a cultural heritage management plan is required

(1) A cultural heritage management plan is required for an activity if-

(a) all or part of the activity area for the activity is an area of cultural heritage sensitivity; and

(b) all or part of the activity is a high impact activity.

Area of cultural heritage sensitivity

The study area contains 20 Aboriginal Places composed of 33 components described in Table 2. Land within 50m of these Places is defined as areas of cultural heritage sensitivity under regulation 25.

25 Registered cultural heritage places

(1) A registered cultural heritage place is an area of cultural heritage sensitivity.

(2) Subject to subregulation (3), land within 50 metres of a registered cultural heritage place is an area of cultural heritage sensitivity.

(3) If part of the land within 50 metres of a registered cultural heritage place has been subject to significant ground disturbance, that part is not an area of cultural heritage sensitivity.

The east boundary of the study area passes within 200m of Clyde Creek which is defined as an area of cultural heritage sensitivity under regulation 26.

26 Waterways

(1) Subject to subregulation (2), a waterway or land within 200 metres of a waterway is an area of cultural heritage sensitivity.

(2) If part of a waterway or part of the land within 200 metres of a waterway has been subject to significant ground disturbance, that part is not an area of cultural heritage sensitivity.

It should be noted that Waterways as referenced in sub-regulations (3) and (2) above is defined in regulation 5 of the Aboriginal Heritage Regulations 2018 as:

(a) a river, creek, stream or watercourse the name of which is registered under the Geographic Place Names Act 1998 and includes any artificially manipulated sections; or

(b) a natural channel the name of which is registered under the Geographic Place Names Act 1998 and includes any artificially manipulated sections in which water regularly flows, whether or not the flow is continuous.

The study area contains numerous unnamed tributaries that have been modified over time but likely follow the courses of earlier waterways. These unnamed tributaries could become named under the Geographic Place Names Act 1998 at any stage, at which point they will become areas of cultural sensitivity.

The east boundary of the study area contains the western fringe of the Koo Wee Rup Plain, which is defined as an area of cultural heritage sensitivity under regulation 34.

34 Koo Wee Rup Plain

(1) Subject to subregulation (2), the Koo Wee Rup Plain is an area of cultural heritage sensitivity.

(2) If part of the Koo Wee Rup Plain has been subject to significant ground disturbance, that part is not an area of cultural heritage sensitivity.

(3) In this regulation, Koo Wee Rup Plain means an area identified as "Qg" and "Qm1" in the Surface Geology of Victoria 1:250 000 map book.

The study area contains multiple sand sheets in the west, south, and east. These are defined as areas of cultural heritage sensitivity under regulation 41.

41 Sand sheets

(1) Subject to subregulation (2), a sand sheet, including the Cranbourne sand, is an area of cultural heritage sensitivity.

(2) If part of a sand sheet, including the Cranbourne sand, has been subject to significant ground disturbance, that part is not an area of cultural heritage sensitivity.

(3) In this regulation, sand sheet, including the Cranbourne sand, is an area identified as "Qd1" and "Qxr" in the Surface Geology of Victoria 1:250 000 map book.

High impact activities are specified in Division 5 of the Regulations and include numerous development projects and utility installations.

46 Buildings and works for specified uses

(1) The construction of a building or the construction or carrying out of works on land is a high impact activity if the construction of the building or the construction or carrying out of the works—

(xxvii) a utility installation, other than a telecommunications facility, if—

(A) the works are a linear project that is the construction of an overhead power line with a length exceeding one kilometre or for which more than 10 power poles are erected; or

(B) the works are a linear project that is the construction of a pipeline with a length exceeding 500 metres; or

(C) the works are a linear project with a length exceeding 100 metres (other than the construction of an overhead power line or a pipeline with a pipe diameter not exceeding 150 millimetres); or

(D) the works affect an area exceeding 25 square metres.

2.9 Historical Heritage – Heritage Overlay Planning Permits

Under the Planning and Environment (Planning Schemes) Act 1996, and Planning and Environment Regulations 2015, provision is made for the protection of heritage places that are significant to a local area; these places are listed on a planning scheme under the local council Heritage Overlay. A heritage place listed on the Heritage Overlay includes the listed item and its associated land. The Planning Scheme for the relevant authority established under the Act sets out permit application requirements for places listed on the Heritage Overlay.

There is one site currently listed on the Heritage Overlay – City of Casey (HO148, 10 Ballarto Road, Clyde). In compliance with Clause 43.01 of the City of Casey Planning Scheme, a Planning Permit would be is required to damage or significantly alter this listed place.

2.10 Recommendations

The study area contains areas of cultural heritage sensitivity from the Cranbourne Sand sheets in the west, Clyde Creek and Koo Wee Rup swamp in the west, and the previously registered Aboriginal Places that exist along the South Gippsland Highway and Clyde-Fiveways Road. Previous studies have uncovered large artefact scatters in the sand sheet deposits, and LDADs and small artefact scatters in the floodplain deposits. There is also potential for historic heritage places to exist throughout the activity area as a result of long settlement history. Recommendations for the management of and Aboriginal and historical heritage are listed below.

1. Mandatory CHMPs will be required for any high impact activities in areas of cultural sensitivity in accordance with r.7 of the Aboriginal Heritage Regulations 2018. These include any activities specified in r.46 (see high impact activities above) and others as specified in the regulations.
2. Where there are no current areas of sensitivity, it is recommended that voluntary CHMPs be conducted given the high archaeological potential of the study area. This is especially prudent for land along the unnamed tributaries, as they could become named in the future and therefore become areas of cultural sensitivity at any stage, at which point a mandatory CHMP will be required, even if construction permits have already been issued.
3. This advice is a high-level desktop assessment. The predictive modelling and advice in this document can be refined by preliminary field assessment of the study area.
4. It is recommended that Bunurong Land Council Aboriginal Corporation be engaged for consultation early on in all planning and design processes.
5. It is recommended that a Historical (non-Aboriginal) Heritage Assessment (HHA) (including a desktop assessment and targeted field survey of potential historic heritage) be undertaken given the potential for previously unidentified historic heritage sites/places to be preserved within the study area. This HHA should determine the presence of historic heritage sites/places and make an assessment of their significance to determine if they meet the criteria for statutory protection under the Heritage Act 2017 and/or the Planning and Environment (Planning Schemes) Act 1996.

3 Desktop Assessment – Geomorphology

3.1 Geology

The study area is dominated by undifferentiated, consolidated sedimentary rocks dating to the Cenozoic. This geologic unit comprises sandstone, limestone and conglomerate (Figure 12).

The area covering most of the Devon Meadows PSP is dominated by Quaternary aged colluvial deposits comprising boulders, gravels and sands. The remainder of the southwest corner of the study site overlays undifferentiated marine sandstone and mudstones of the late Silurian to early Devonian.

The northwest of the study site overlays a small section of Monbulk Volcanic Group which comprise olivine basalt deposits from the Miocene.

A small area along the eastern boundary of the study site overlays Quaternary aged alluvial deposits comprising, gravels, sands, silts and clays.

There are no sites of geological or geomorphological significance within the study area.

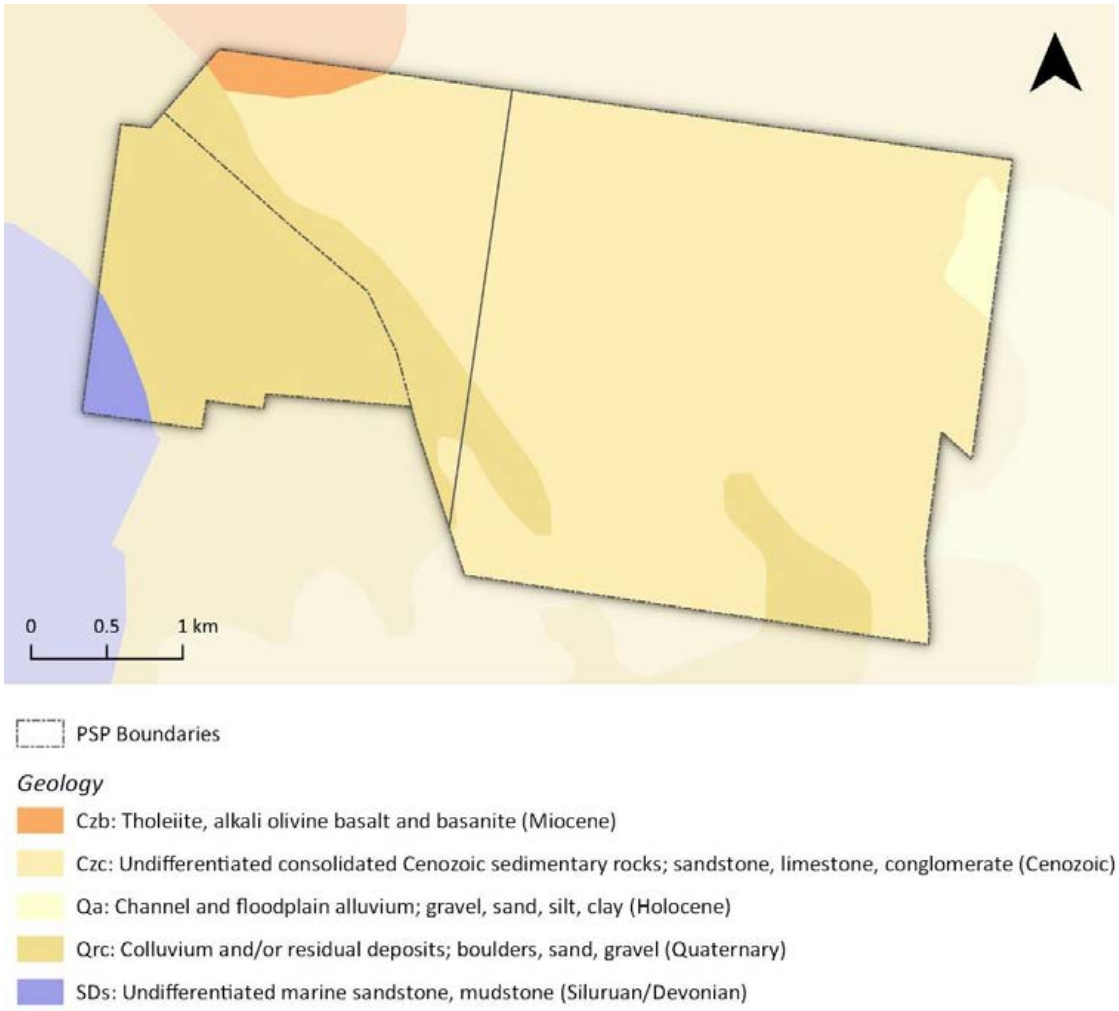


Figure 12. Geology of the study site

3.2 Soil

The two main soil units present in the study area are the Cranbourne Sands, which is a culturally sensitive sand sheet in the west, and the Dalmore Clays which occupy the swamp to the east (Figure 13).

Chromosols

Chromosols are soils that have a strong texture contrast between the A and B horizons but have a B horizon which is not sodic or acidic (CSIRO 2016).

Vertosols

Vertosols are shrink-swell clay soils that exhibit strong cracking when dry. Vertosols have a field texture of 35% or more clay throughout the solum (CSIRO 2016).

Sodosols

Sodosols are soils that have a strong texture contrast between the A and B horizons with the upper 0.2 m of the B2 horizon being sodic. Sodosols are likely to possess a bleached A2 horizon (CSIRO 2016).

Kurosols

Kurosols are soils with a clear textural B horizon in which the major part of the upper 0.2 m of the B2 horizon is sodic (CSIRO 2016).

Podosols

Podosols are soils that had a B horizon dominated by the accumulation of organic compounds, aluminium, or iron. They are typically found close to the coast (CSIRO 2016).

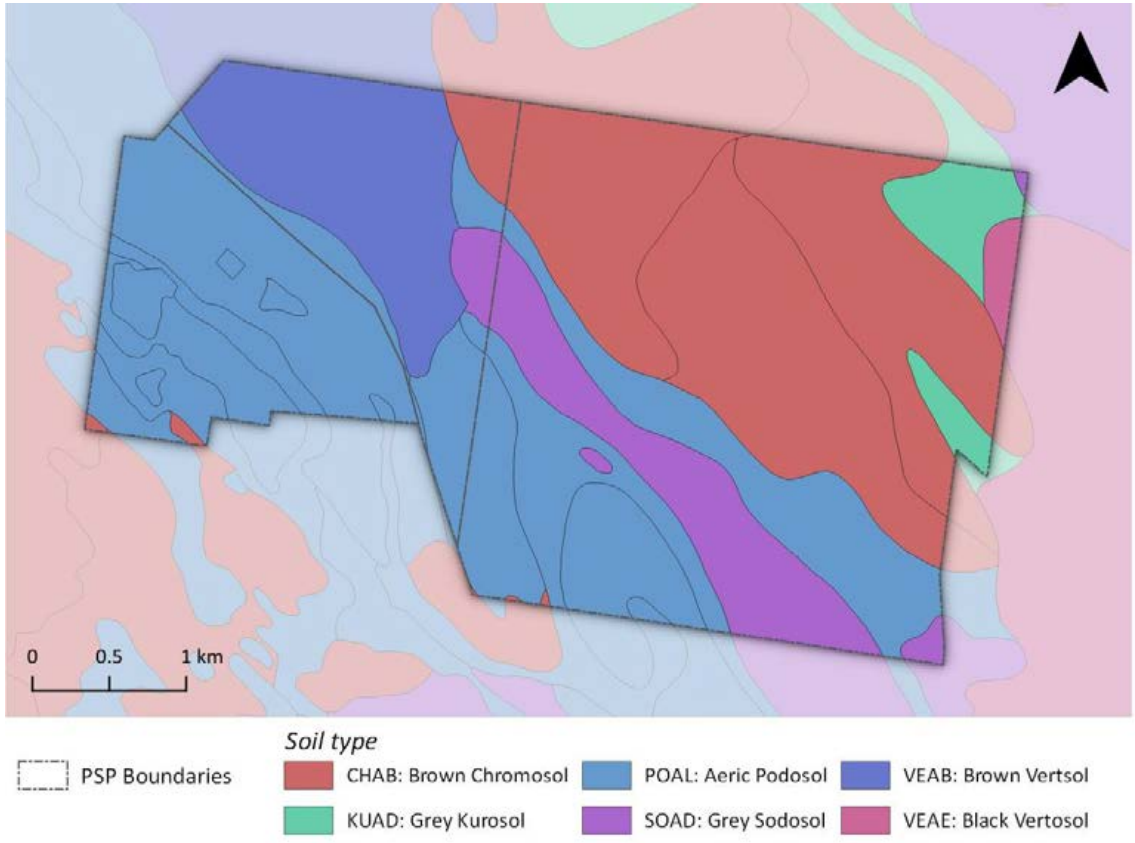


Figure 13. Soils of the study area

Dispersive sodic soils

Dispersive sodic soils may pose a risk to future development due to their fragile nature and the difficulties associated with managing them. The high sodium content of these soils makes them dispersive upon contact with water and in some cases the low fertility associated with these soils can inhibit plant growth and further exacerbate erosion and dispersion issues. Sodic soils generally possess a bleached horizon and often display columnar or prismatic structures (CSIRO 2016). Common indications of sodic soils that can be observed in the field include the presence of piping and tunnel erosion (Ford et al. 1993). Across the study area, a narrow band has been classified as a Grey Sodosol. Field assessments across this area did not indicate the presence of dispersive subsoils with none of the characteristics associated with sodic soils noted. For this reason, risks due to dispersive soils are considered low across the PSP areas



Figure 14. Typical dispersive sodic soil in the field. Note the bleached horizon and evidence of tunnelling.

Acid Sulfate Soils

Acid sulfate soils occur naturally along many parts of Victoria's coastline. They form in environments where there is deposition of organic matter in water-logged soils that are high in metal cations and sulfate (VRO 2021). If left undisturbed, acid sulfate soils pose no risk, however, once disturbed and soil is allowed to drain, a reaction between the soil and oxygen can occur producing sulfuric acid (VRO 2021). This can result in the acidification of soil and water, the corrosion of building and construction material and a decrease in water quality. In 2010, DSE and DPI updated mapping of potential acid sulfate soils. These updated maps indicate that there are no areas within the PSP boundaries that are considered as potential sites for these soils, although there are areas to the south of the study area that have been identified. For this reason, acid sulfate soil risk within the study area may be considered low.



Figure 15. Prospective acid sulfate soil mapping within the vicinity of the study area

3.3 Groundwater

A detailed assessment of the groundwater system across the study area has not been undertaken as a part of this project.

A range of standard groundwater information is available online via Visualising Victoria's Groundwater. Across the study site, the depth to the water table has been mapped using data from Visualising Victoria's Groundwater (Figure 16).

The dataset indicates that across most of the study area the depth to the water table is less than 5 m which would be expected given the region's history as a large swampland. Along the eastern boundary of the Clyde South PSP area, there is a corridor where the depth to the water table ranges between 10 and 20 m.

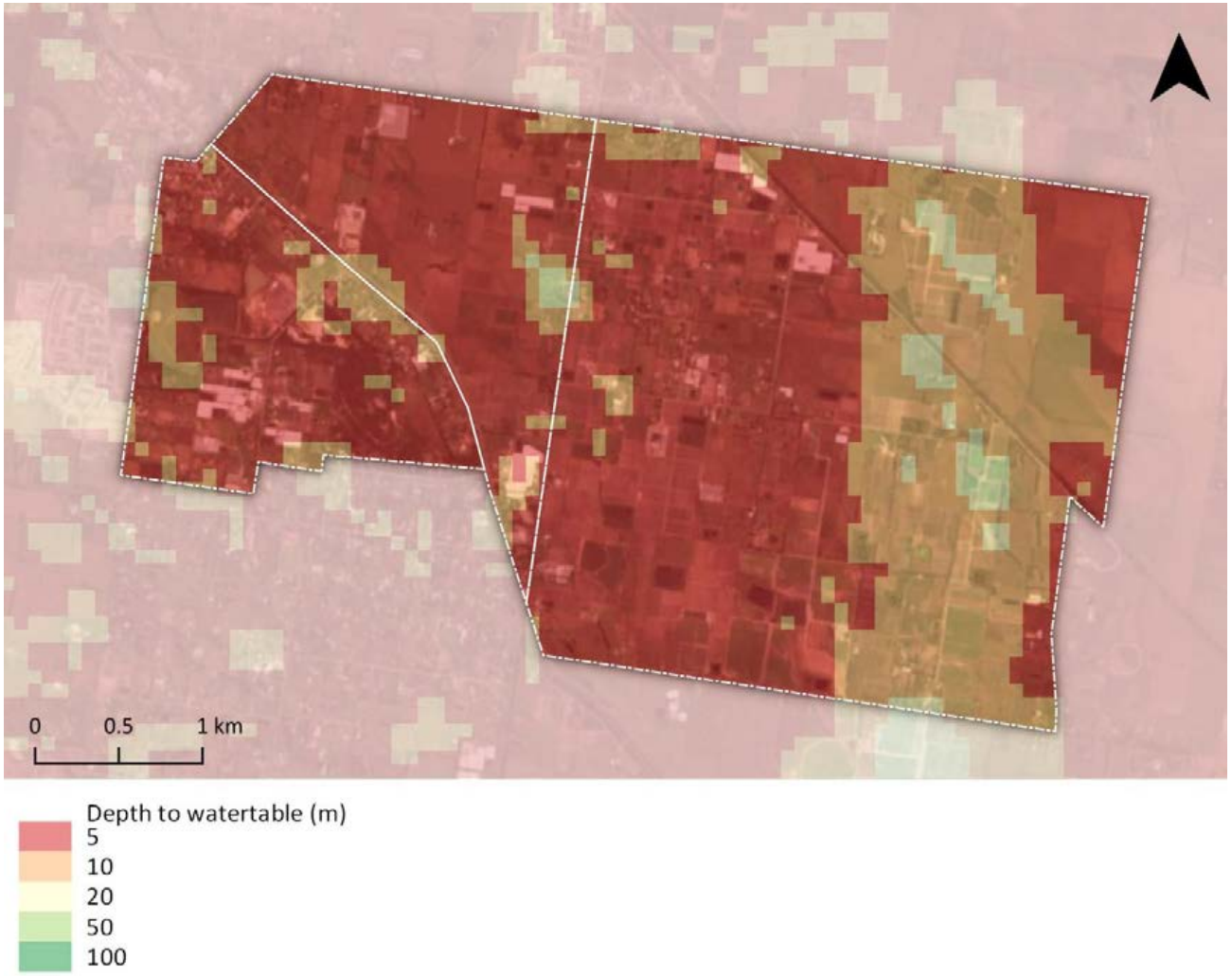


Figure 16. Depth to water table

3.4 Geomorphological management units

Geomorphological management units provide a classification of diverse information about the landscape, geology, stratigraphy and geomorphology. There are four geomorphological management units found across the study area (Figure 17).

3.3.1 Very low relief plateau of the Southern Uplands

This geomorphological unit is represented by weakly dissected, undulating plains of generally less than 100 m. The unit is covered by Palaeozoic sediments that are overlaid by Neogene sediments, particularly sands (VRO 2017).

3.3.3 Very low relief basaltic residuals of the Southern Uplands

This geomorphological unit is characterised by low rounded crests with broadly spaced flats and depressions. It comprises Paleogene basalt with late Neogene alluvium in drainage lines. Low lying areas may be affected by salinity (VRO 2017).

7.1.1 Coastal plains of the Eastern Plains central sunklands

This geomorphological unit is typified by a series of northwest trending dune ridges, parallel to the current coastline which are thought to represent former coastlines or Neogene dune ridges.

7.1.2 Alluvial plains of the Eastern Plains central sunklands

This geomorphological unit is characterised by alluvial plains in the lower reaches of local rivers that once drained into swamps and lagoons.

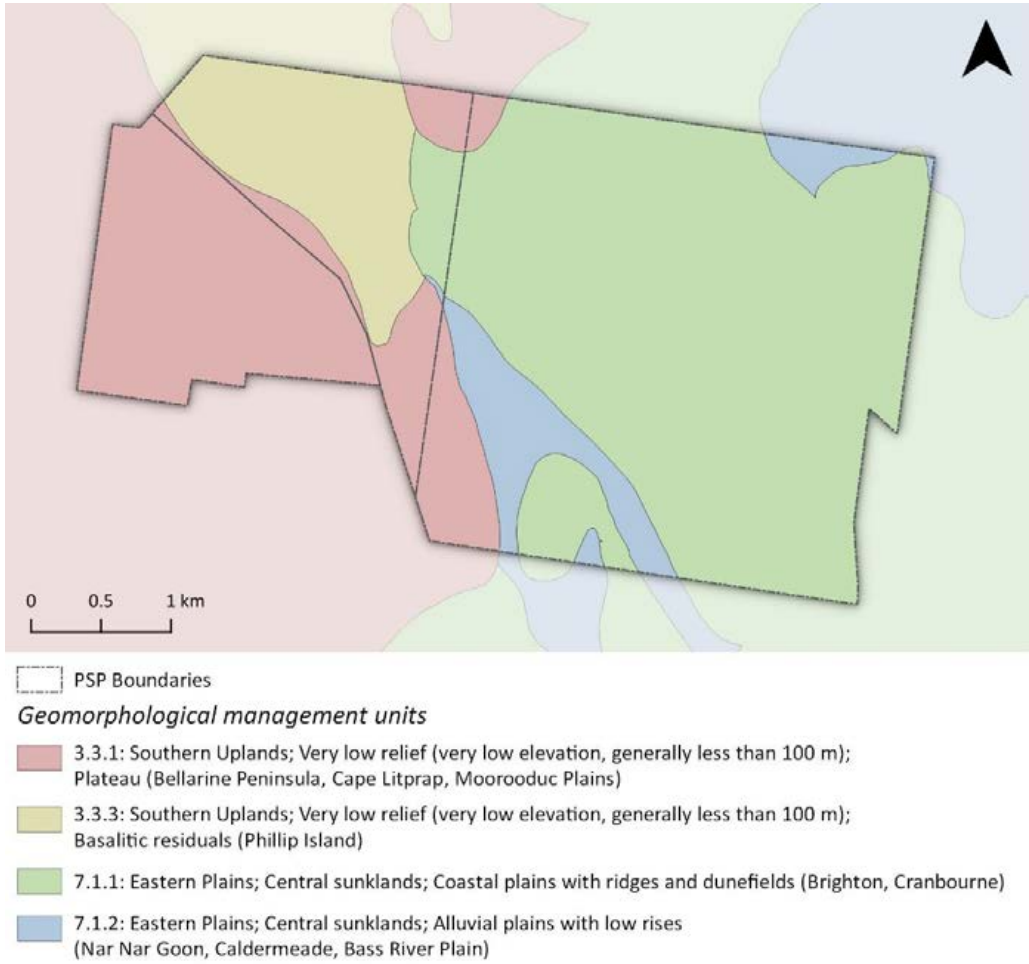


Figure 17. Geomorphological management units across the study site

3.5 RiverStyles

The RiverStyles framework is a consistent, documented and tested methodology used to categorise waterway type. The framework allows for the integration of catchment-scale geomorphic understanding of river morphology, processes and linkages.

The majority of the waterways within the PSP area have not previously been classified according to the RiverStyles framework. Two reaches of Wylies Drain Branch F have been classified. One reach was classified as an anthropogenic shaped channel and the other was classified as a piped channel (Figure 17).

Where a classification has yet to be given, it will be classified based on field observations.

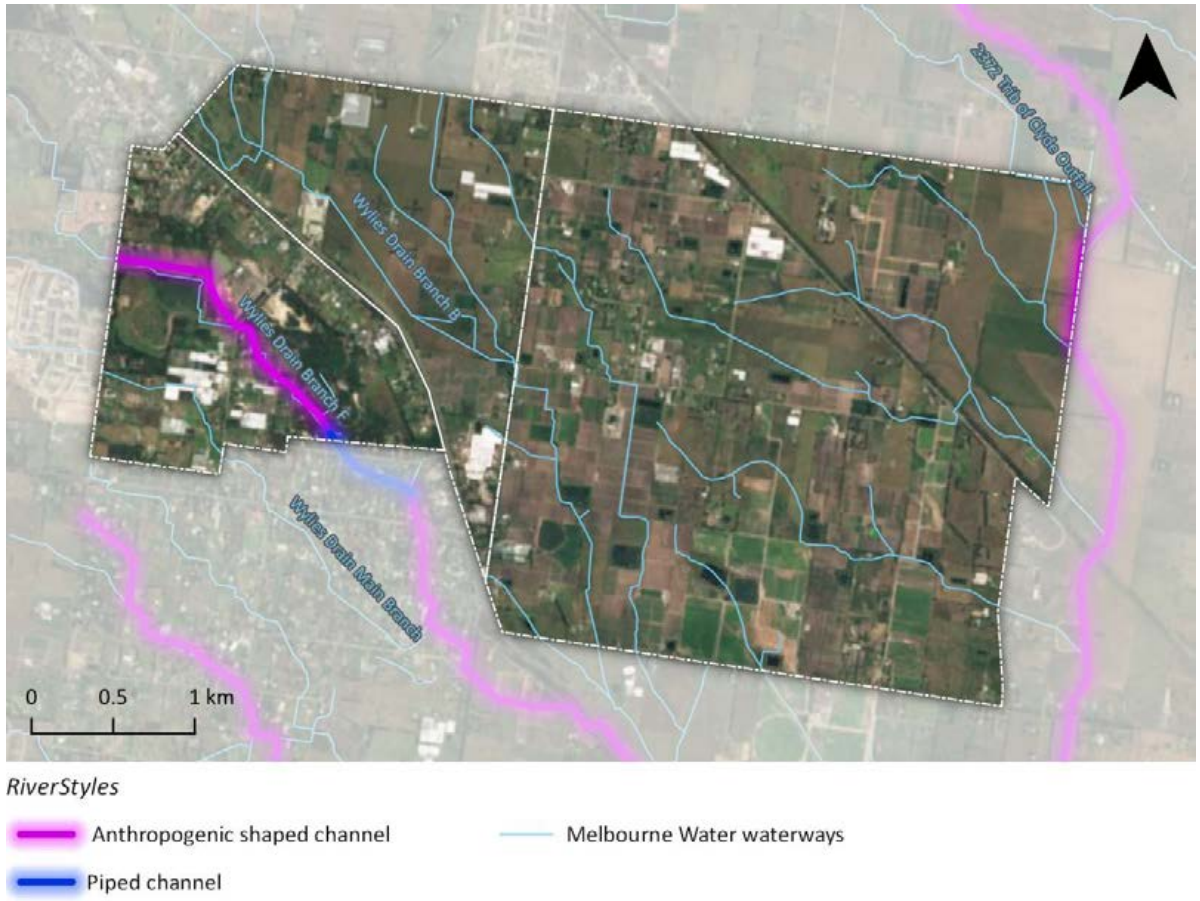


Figure 18. RiverStyles across the study area

3.6 Geomorphic condition

The geomorphic condition for waterways within the Melbourne Water area has previously been assessed by Streamology (2019) as part of developing the Framework for Physical Form Asset Management for Melbourne Water.

Waterway condition is informed by a range of physical stream attributes including; bank slope, width to depth ratio, sinuosity, instream woody habitat, attenuated forest cover susceptibility. The waterways that were included in the development of the framework were found to range in condition between poor and fair (Figure 19).

Wylies Drain Branch B was the only waterway found to be in fair condition. Wylies Drain Main Branch and the upper reach of Wylies Drain Branch F were found to be in low condition. One reach of Wylies Drain Branch F was found to be in poor condition. The Tributary of the Clyde Outfall was found to have one reach in low condition and one reach in poor condition.

Across the broader Dalmore Outfalls sub catchment, the Melbourne Water Healthy Waterways Strategy (2018) found physical form condition to be in high condition and the target trajectory in this sub catchment is also high. However, the current physical form trajectory for waterways within the sub catchment is low.

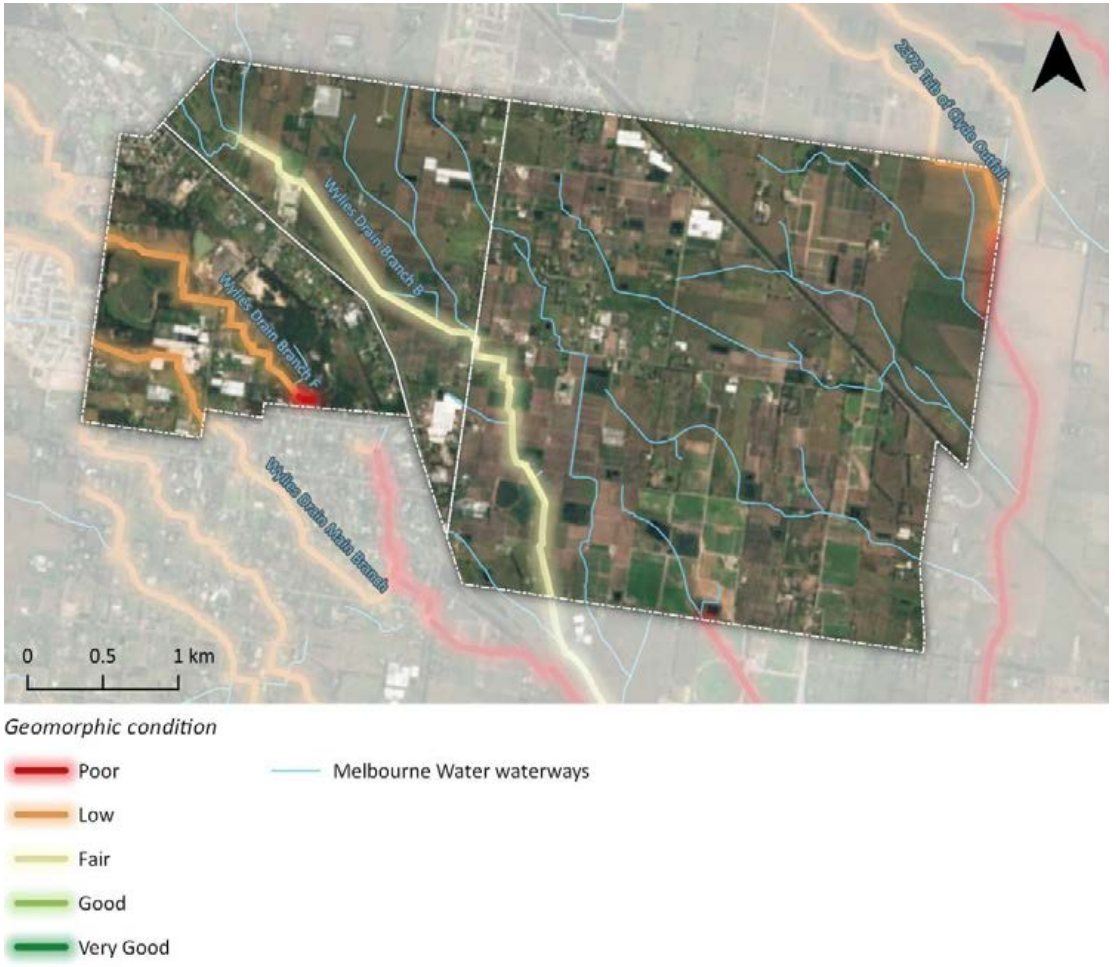


Figure 19. Geomorphic condition of waterways across the study area

3.7 Geomorphic sensitivity

The geomorphic sensitivity for waterways within the Melbourne Water area has previously been assessed by Streamology (2019) as part of developing the Framework for Physical Form Asset Management for Melbourne Water.

Waterway sensitivity is informed by a number of physical stream attributes including; bank slope, bed slope, attenuated forest cover and landscape and soil metrics such as soil classification, lithology and geomorphology unit.

The waterways that were included in the development of the framework were found to range in sensitivity from very low to medium (Figure 20).

Wylies Drain Branch B was found to have a low sensitivity to change. Wylies Drain Main Branch and Wylies Drain Branch F were found to have a medium sensitivity to change. The Tributary of the Clyde Outfall was found to have a very low sensitivity to change.

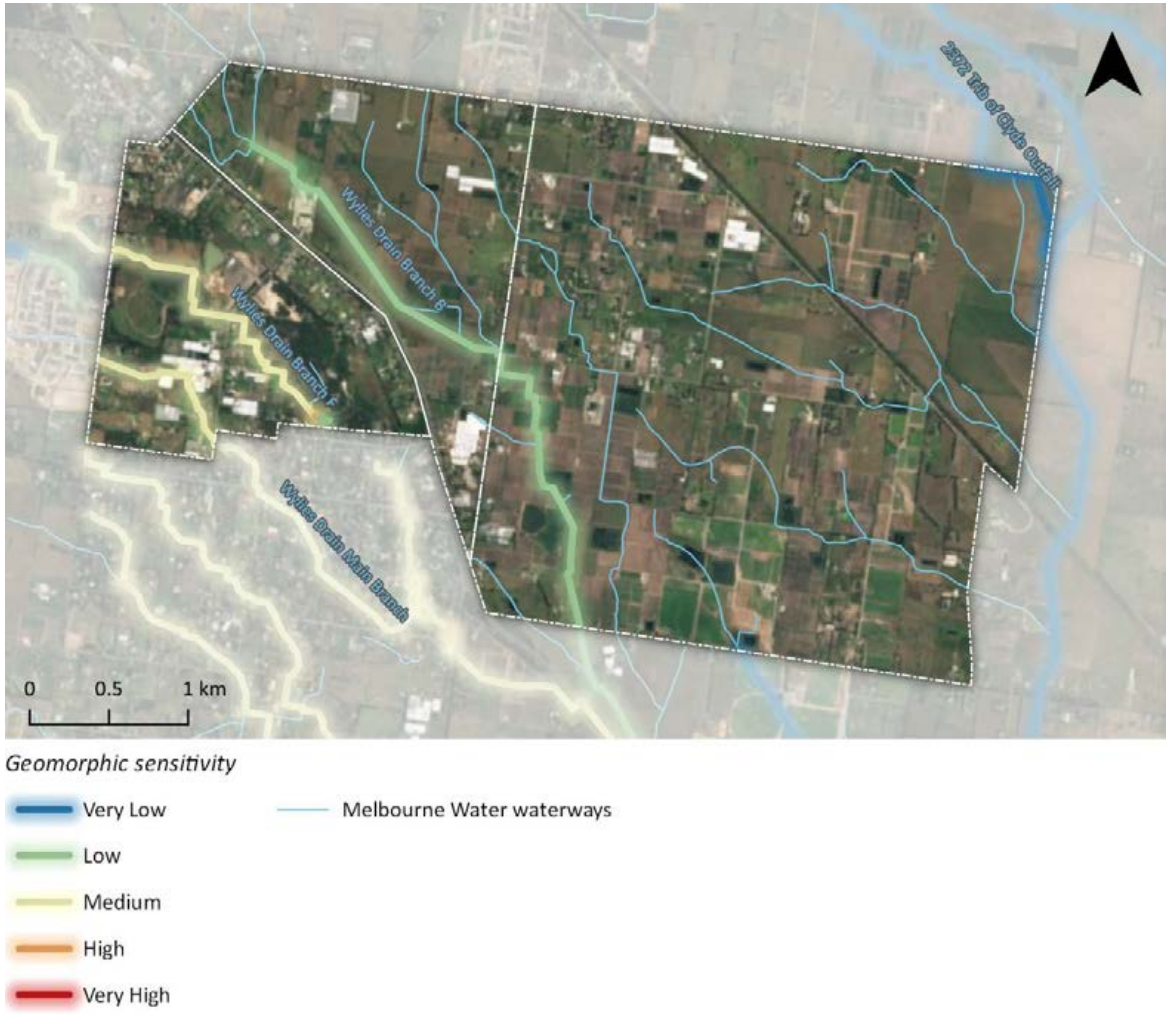


Figure 20. Waterway sensitivity across the study area

3.8 Geomorphic risk

The geomorphic risk for waterways within the Melbourne Water area has also previously been assessed by Streamology (2019) as part of developing the Framework for Physical Form Asset Management for Melbourne Water.

Geomorphic risk is informed by the all the physical stream attributes that contribute to geomorphic condition and sensitivity but also includes an attenuated imperviousness score which provides a metric for catchment stress.

At present, Wylies Drain Main Branch, Wylies Drain Branch B and Wylies Drain Branch F are considered to have low geomorphic risk. The tributary of Clyde Outfall is considered to have a very low geomorphic risk. These risk ratings are likely to change with development as attenuated imperviousness is a key factor in determining risk and this will increase under future development scenarios (Figure 21).

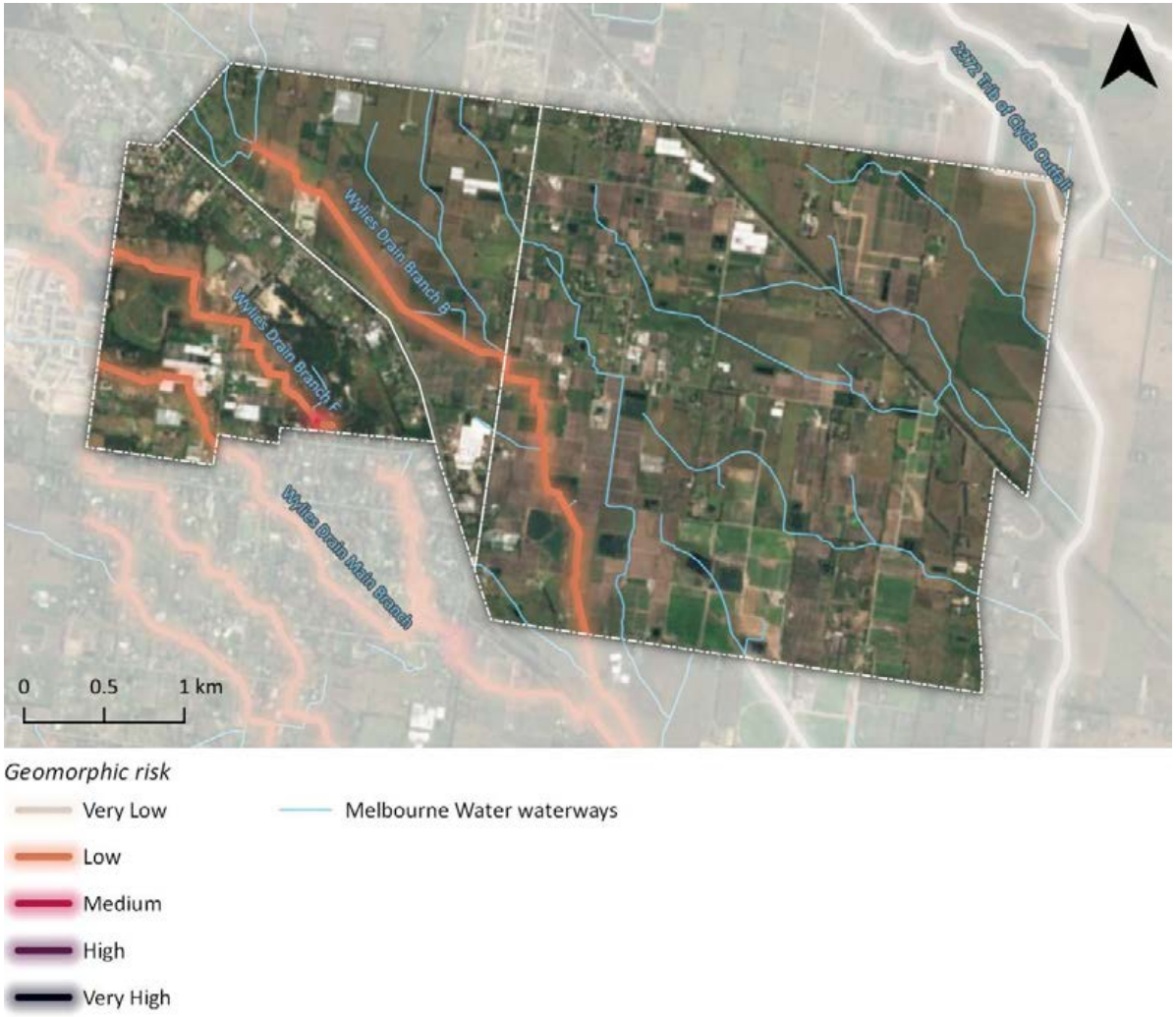


Figure 21. Geomorphic risk for waterways across the study area

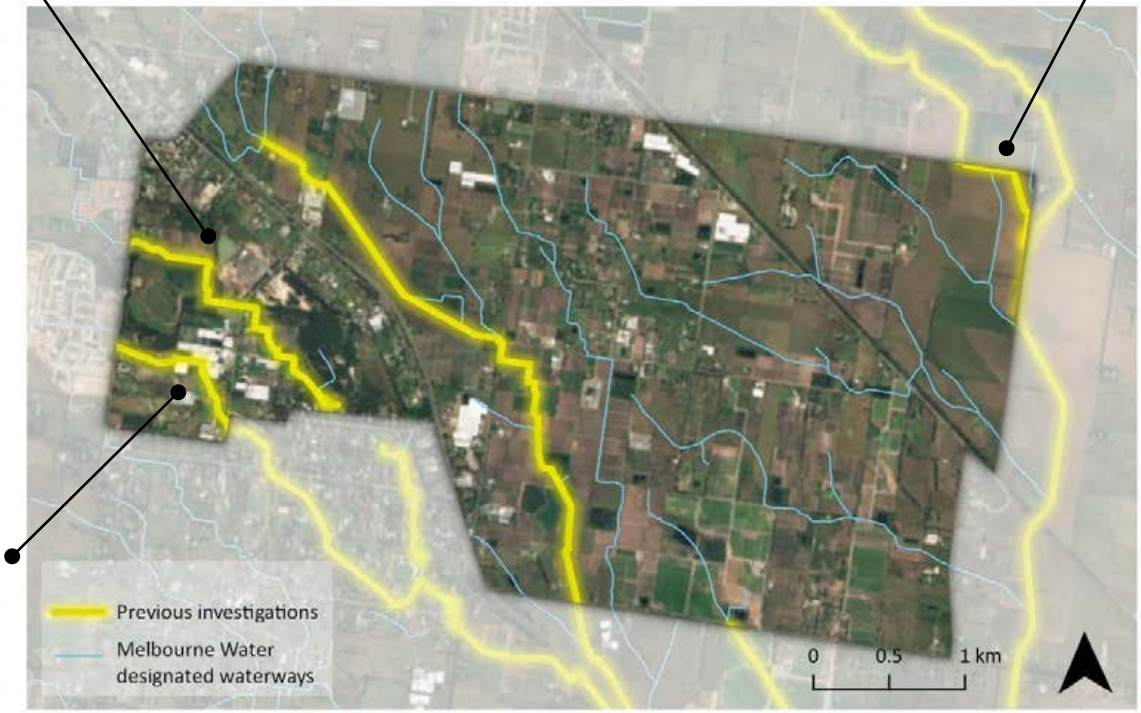
3.9 Previous investigations

SKM 2012b

SKM examined the stability and trajectory of waterways within the current study area using desktop and field assessments. They found that the waterways they assessed were moderately unstable using the Stream Stability Index. However they argued that results were skewed towards unstable because of the fine-grained nature of bed and bank sediments and the absence of riparian vegetation. They concluded that based on the visual assessment of the waterways, they appear to have stable beds and banks.

SKM 2012c

SKM assess Wylies Drain and found that geomorphic values were low to insignificant given that it is predominately a man made drainage channel. They concluded that a significant shear stress was required to erode that channel meaning its sensitivity to change is very low. They concluded the overall geomorphic risk in Whylies Drain was medium to low.



SKM 2012a

SKM found that an increase in the magnitude and frequency of flows associated with future development posed a high risk to the geomorphic values of most reaches within their study area. However, the study noted that geomorphic values were generally considered low given most reaches are man made drains.

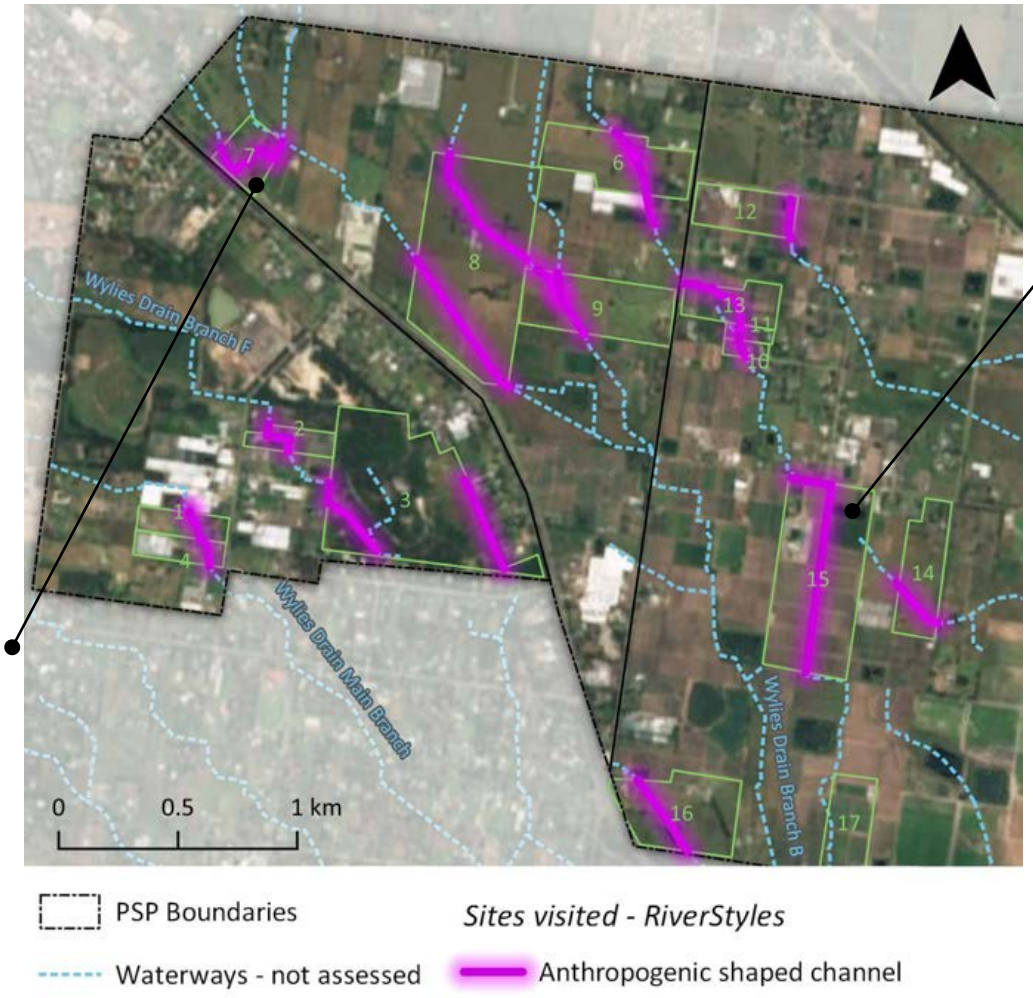
They indicated that increased flows may result in an increase in bed and bank erosion and thois was of most concern for the upper reaches of Muddy Gates Drain (outside the current study area) which would alter the important valley fill stream form.

4 Field Assessment – Geomorphology

Waterways across the study area are fairly uniform in terms of physical characteristics. In the field, all waterways assessed have been classified as anthropogenic shaped channels using the RiverStyles Framework. A summary of each of the waterways assessed is provided in the following pages.



Anthropogenic channels across the study area are mostly small, well grassed drainage lines within agricultural fields used largely for grazing.





The study area contains a number of large market garden properties. Waterways within these properties have also been classified as anthropogenic shaped channels however, on these properties they tend to be larger, more defined and have less vegetation cover.

4.1 Wylies Drain Main Branch with properties # 1 & 4

Wylies Drain Main Branch is an anthropogenic agricultural drain that is heavily vegetated with exotic grasses and blackberry in the reach that was assessed. There are limited habitat values and no geomorphic values along this reach.

Parameter	Anthropogenic shaped channel
Channel	Single, continuous channel
Bank/valley sides	Anthropogenic shaped channel. Well defined approximately 1-1.5 m wide. Waterway banks range from 0.5 m – 2 m deep and are moderately sloping to steep. Bank material is silty clay.
Bed	Bed of the waterway is well vegetated with bed material likely to be silty clay. Bed gradient is very gentle.
Planform	Straight, earthen drainage channel.
Geology	Quaternary colluvium (boulder, sand and gravel)
Land use	Cleared agricultural land – no grazing or farming. Adjoining paddock – egg farm.
Soil type	Aeric Podosol - B horizon dominated by the accumulation of organic compounds, aluminium, or iron.
Sediment load	Not determined due to low flow at the time of survey and very high vegetation cover.
Riparian vegetation	Cleared riparian area. Now consists of largely exotic grasses. Section of the water has a significant blackberry infestation.
In stream vegetation	Mostly exotic grasses. At the upstream extent of the reach assessed, there was a very high load of *Phragmites*.
Habitat value	Limited habitat values present.







4.2 Wylies Drain Branch F on property #2

Wylies Drain Branch F is an anthropogenic agricultural drain that collects runoff which is stored in two dams on the property. There are no geomorphic values along this reach.

Parameter	Anthropogenic shaped channel
Channel	Single, discontinuous channel
Bank/valley sides	Anthropogenic shaped channel. Well defined approximately 2-3 m wide. Waterway banks range from 1-2 m deep and are moderately sloping to steep. Bank material is silty clay.
Bed	Bed of the waterway is well vegetated with bed material likely to be silty clay although not determined through heavy vegetation. Bed gradient is very gentle.
Planform	Straight, earthen drainage channel.
Geology	Quaternary colluvium (boulder, sand and gravel)
Land use	Cleared agricultural land – horticulture
Soil type	Aeric Podosol - B horizon dominated by the accumulation of organic compounds, aluminium, or iron.
Sediment load	Not determined due to low flow at the time of survey and very high vegetation cover.
Riparian vegetation	Cleared riparian area. Now consists of largely exotic grasses.
In stream vegetation	Well vegetated instream, particularly with *Phragmites*. Limited diversity.
Habitat value	Limited habitat values present.







4.3 Wylies Drain F Branch on property #3

Wylies Drain Branch F on this property is an anthropogenic agricultural drain along the upstream extent and a constructed drainage asset owned by Melbourne Water at the downstream extent where flow is delivered into the underground drainage network. The downstream extent is fenced and has been treated for pest plants while the upstream extent is largely unmanaged.

Parameter	Anthropogenic shaped channel
Channel	Single, discontinuous channel
Bank/valley sides	Anthropogenic shaped channel – trapezoidal in the downstream reach. Well defined approximately 8-10 m wide in the downstream extent and 1.5-2m wide in the upstream extent. Waterway banks up to 2 m deep and are moderately sloping to steep. Bank material is silty clay.
Bed	Bed of the waterway is well vegetated with bed material likely to be silty clay although not determined through heavy vegetation. Bed gradient is very gentle.
Planform	Straight, earthen drainage channel.
Geology	Quaternary colluvium (boulder, sand and gravel)
Land use	Agricultural
Soil type	Aeric Podosol - B horizon dominated by the accumulation of organic compounds, aluminium, or iron.
Sediment load	Moderately turbid.
Riparian vegetation	Riparian vegetation still present at the site. Patchy in some places. Mid and overstory present but with a high proportion of exotics including blackberry.
In stream vegetation	Well vegetated instream in the upstream extent, however largely comprising blackberry. Limited instream vegetation in the downstream extent – largely reeds.
Habitat value	Some habitat values present with moderate riparian zone and adjacent vegetation cover. Limited instream habitat – lacking in geomorphic diversity.







4.4 Unnamed anthropogenic channel on property #3

This channel is an anthropogenic shaped channel which the landholder currently reports is blocked and is causing inundation of parts of the property. The waterway has some riparian cover however there are no geomorphic values present.

Parameter	Anthropogenic shaped channel
Channel	Single, discontinuous channel
Bank/valley sides	Anthropogenic shaped channel. Well defined approximately 5 -8 m wide with banks up to 1.5 m deep which are too steep. Bank material is silty clay.
Bed	Bed of the waterway is well vegetated with bed material likely to be silty clay although not determined through heavy vegetation. Bed gradient is very gentle.
Planform	Straight, earthen drainage channel.
Geology	Quaternary colluvium (boulder, sand and gravel)
Land use	Agricultural
Soil type	Aeric Podosol - B horizon dominated by the accumulation of organic compounds, aluminium, or iron.
Sediment load	No flow at the time of survey
Riparian vegetation	Narrow riparian corridor with a cover of mid and overstory species. Patchy ground cover in places. Riparian zone is a mix of native and exotic species.
In stream vegetation	Instream vegetation consists largely of grasses. Limited other instream vegetation.
Habitat value	Limited habitat values. Areas of better riparian cover provide some habitat value but there are no other instream habitat values.





4.5 Wylies Drain Branch B on property #7

This channel is an anthropogenic shaped channel adjacent to cleared agricultural land. Drainage on the property has been significantly altered with the waterway draining into a dam and a secondary drainage line diverting overflow from this dam along another channel to a dam on the neighbouring property. Adjacent to the dam is a smaller dam which was constructed to capture high nutrient runoff from the adjacent land and then used to irrigate crops.

Parameter	Anthropogenic shaped channel
Channel	Single, discontinuous channel
Bank/valley sides	Anthropogenic shaped channel. Well defined approximately 3-5 m wide with banks up to 1.5 m deep.
Bed	Bed of the waterway is well vegetated with grasses and sedges (Juncus spp.). Bed grade is gentle.
Planform	Straight, earthen drainage channel.
Geology	Quaternary colluvium (boulder, sand and gravel)
Land use	Cleared agricultural land –grazing
Soil type	Brown Vertosol - shrink-swell clay soil that exhibits strong cracking when dry.
Sediment load	No flow at the time of survey
Riparian vegetation	Cleared riparian corridor. Only grasses present, largely exotic.
In stream vegetation	Instream vegetation consists largely of grasses but also abundant sedges.
Habitat value	Limited habitat values associated with dam and Juncus cover. No geomorphic diversity.





4.6 Wylies Drain Branch B on property #8

This channel is an anthropogenic shaped channel adjacent to cleared agricultural land. It is small and not very well defined. There are no habitat or geomorphic values present at the site.

Parameter	Anthropogenic shaped channel
Channel	Single, continuous channel
Bank/valley sides	Anthropogenic shaped channel. Up to 5 m wide with gently sloping banks. Up to 1.2 m deep.
Bed	Bed of the waterway is well vegetated with grasses and has a gentle bed grade.
Planform	Straight, earthen drainage channel.
Geology	Quaternary colluvium (boulder, sand and gravel)
Land use	Cleared agricultural land –grazing
Soil type	Brown Vertosol - shrink-swell clay soil that exhibits strong cracking when dry.
Sediment load	No flow at the time of survey
Riparian vegetation	Cleared riparian corridor. Only grasses present, largely exotic.
In stream vegetation	Instream vegetation consists largely of grasses.
Habitat value	Limited habitat values associated with inundated depressions at the site.





4.7 Unnamed anthropogenic channel on property #8

This channel is an anthropogenic shaped channel adjacent to cleared agricultural land. It is small and poorly defined. There are no habitat or geomorphic values present at the site.

Parameter	Anthropogenic shaped channel
Channel	Single, continuous channel
Bank/valley sides	Anthropogenic shaped channel. Up to 5 m wide with gently sloping banks. Up 30 cm deep.
Bed	Bed of the waterway is well vegetated with grasses and has a gentle bed grade.
Planform	Straight, earthen drainage channel.
Geology	Cenozoic sedimentary rocks (sandstone, limestone, siltstone)
Land use	Cleared agricultural land –grazing
Soil type	Brown Vertosol - shrink-swell clay soil that exhibits strong cracking when dry.
Sediment load	No flow at the time of survey
Riparian vegetation	Cleared riparian corridor. Only grasses present, largely exotic.
In stream vegetation	Instream vegetation consists largely of grasses.
Habitat value	Limited habitat values associated with inundated depressions at the site.





4.8 Unnamed anthropogenic shaped channel on property #9

This channel is an anthropogenic shaped channel adjacent to cleared agricultural land. It is small and poorly defined. There are no habitat or geomorphic values present at the site.

Parameter	Anthropogenic shaped channel
Channel	Single, discontinuous channel
Bank/valley sides	Anthropogenic shaped channel. Very poorly defined. Up to 5 m wide with gently sloping banks. Up 30 cm deep.
Bed	Bed of the waterway is well vegetated with grasses and has a gentle bed grade.
Planform	Straight, earthen drainage channel.
Geology	Cenozoic sedimentary rocks (sandstone, limestone, siltstone)
Land use	Cleared agricultural land –grazing, horticulture
Soil type	Brown Vertosol - shrink-swell clay soil that exhibits strong cracking when dry.
Sediment load	No flow at the time of survey
Riparian vegetation	Cleared riparian corridor. Only grasses present, largely exotic.
In stream vegetation	Instream vegetation consists largely of grasses.
Habitat value	No habitat values present





4.9 Unnamed anthropogenic channel on property #6

This channel is an anthropogenic shaped channel adjacent to cleared agricultural land. There are three small dams at the upstream extent of the property that intercept flow and a larger dam at the downstream extent of the property. The three upstream dams are well vegetated with emergent and aquatic species and provide some habitat values at the site.

Parameter	Anthropogenic shaped channel
Channel	Single, discontinuous channel
Bank/valley sides	Anthropogenic shaped channel. Well defined. Between 5-8 m wide with very steep banks. Up to 2m deep.
Bed	Bed of the waterway is well vegetated grasses and other exotics. Gentle bed grade.
Planform	Straight, earthen drainage channel.
Geology	Cenozoic sedimentary rocks (sandstone, limestone, siltstone)
Land use	Cleared agricultural land –grazing, horticulture
Soil type	Brown Chromosol- soils that have a strong texture contrast between the A and B horizons but have a B horizon which is not sodic or acidic
Sediment load	No flow at the time of survey
Riparian vegetation	Cleared riparian corridor. Only grasses present, largely exotic.
In stream vegetation	Instream vegetation consists largely of grasses.
Habitat value	Limited habitat values associated with inundated depressions at the site.







4.10 Unnamed anthropogenic channel on properties 10, 11 & 13

The channel is an anthropogenic shaped channel adjacent to residential properties and a horticultural property. At the upstream extent of the reach a large proportion of the runoff is intercepted by two dams. At the downstream extent of the reach, the channel is poorly defined.

Parameter	Anthropogenic shaped channel
Channel	Single, discontinuous channel
Bank/valley sides	Anthropogenic shaped channel. Upstream extent is well defined up to 2m deep, 3-5m wide with moderately sloping banks. At the downstream extent, the channel is poorly defined with gently sloping banks and a maximum depth of 0.5 m.
Bed	Bed of the waterway is well vegetated grasses in the downstream extent and rushes and reeds in the upstream extent. Gentle bed grade.
Planform	Straight, earthen drainage channel.
Geology	Cenozoic sedimentary rocks (sandstone, limestone, siltstone)
Land use	Cleared agricultural land –grazing, horticulture
Soil type	Brown Chromosol- soils that have a strong texture contrast between the A and B horizons but have a B horizon which is not sodic or acidic. Aeric Podosol - B horizon dominated by the accumulation of organic compounds, aluminium, or iron.
Sediment load	No flow at the time of survey
Riparian vegetation	Cleared riparian corridor. Grasses, reeds and rushes present.
In stream vegetation	Instream vegetation consists largely of grasses (exotic) and reeds and rushes.
Habitat value	Some habitat values present associated with reeds, rushes and dam.







4.11 Unnamed anthropogenic channel on property #12

The channel is an anthropogenic shaped channel adjacent to horticultural land. The channel is well defined and devoid of vegetation cover. There is evidence of minor notching and erosion along the banks. There is a small dam at the upstream extent of the channel.

Parameter	Anthropogenic shaped channel
Channel	Single, continuous channel
Bank/valley sides	Anthropogenic shaped channel. Well defined trapezoidal channel. 5-8 m wide with very steep banks, up to 2 m deep. Bank material is silty sand.
Bed	Bed of the waterway is silty clay material with a gentle bed grade.
Planform	Straight, earthen drainage channel.
Geology	Cenozoic sedimentary rocks (sandstone, limestone, siltstone)
Land use	Cleared agricultural land – horticulture
Soil type	Brown Chromosol- soils that have a strong texture contrast between the A and B horizons but have a B horizon which is not sodic or acidic.
Sediment load	Moderately turbid.
Riparian vegetation	Cleared riparian corridor. Grasses, reeds and rushes present.
In stream vegetation	Instream vegetation consists largely of grasses (exotic) and reeds and rushes.
Habitat value	No habitat values present at the site.





4.12 Unnamed anthropogenic channel on property #15

The channel is an anthropogenic shaped channel adjacent to horticultural land. The channel is well defined and has limited vegetation cover. There are a number of crossings with culverts in various conditions and an adjacent dam. There is evidence of minor notching and erosion along the banks. There is a small dam at the upstream extent of the channel.

Parameter	Anthropogenic shaped channel
Channel	Single, continuous channel
Bank/valley sides	Anthropogenic shaped channel. Well defined trapezoidal channel. 3-5 m wide with very steep banks, up to 1.5 m deep. Bank material is silty sand.
Bed	Bed of the waterway is silty clay material with a gentle bed grade.
Planform	Straight, earthen drainage channel.
Geology	Cenozoic sedimentary rocks (sandstone, limestone, siltstone)
Land use	Cleared agricultural land – horticulture
Soil type	Aeric Podosol - B horizon dominated by the accumulation of organic compounds, aluminium, or iron. Grey Sodosol- strong texture contrast between the A and B horizons with the upper 0.2 m of the B2 horizon being sodic.
Sediment load	Moderately turbid.
Riparian vegetation	Cleared riparian corridor. Grasses and other exotics present
In stream vegetation	Instream vegetation consists largely of grasses and other exotics
Habitat value	Limited habitat values associated with inundated depressions at the site.







4.13 Unnamed anthropogenic channel on property #14

The channel is small and poorly defined in some places. The waterway lacks a riparian corridor and there are limited habitat values associated with small, inundated depressions on the property. There are no geomorphic values present at the site.

Parameter	Anthropogenic shaped channel
Channel	Single, continuous channel
Bank/valley sides	Anthropogenic shaped channel. Poorly defined with a width of 1-2 m and a depth of around 0.5 m. Very gently sloping banks.
Bed	Well grassed with a very gentle bad grade.
Planform	Straight, earthen drainage channel.
Geology	Cenozoic sedimentary rocks (sandstone, limestone, siltstone)
Land use	Cleared agricultural land – grazing
Soil type	Aeric Podosol - B horizon dominated by the accumulation of organic compounds, aluminium, or iron. Grey Sodosol- strong texture contrast between the A and B horizons with the upper 0.2 m of the B2 horizon being sodic.
Sediment load	No flow at the time of survey
Riparian vegetation	Cleared riparian corridor. Exotic grasses present. Sedges and other semi aquatic species present around shallow depressions at the property
In stream vegetation	Instream vegetation consists largely of exotic grasses
Habitat value	Limited habitat values associated with inundated depressions at the site.







4.14 Unnamed anthropogenic channel on property #16

The channel is small and poorly defined in some places. The waterway lacks a riparian corridor and there are limited habitat values associated with small, inundated depressions on the property. There are no geomorphic values present at the site

Parameter	Anthropogenic shaped channel
Channel	Single, continuous channel
Bank/valley sides	Anthropogenic shaped channel. Poorly defined with a width of 2-5 m and a depth of around 1 m.
Bed	Well grassed with a very gentle bad grade.
Planform	Straight, earthen drainage channel.
Geology	Cenozoic sedimentary rocks (sandstone, limestone, siltstone)
Land use	Cleared agricultural land – grazing
Soil type	Aeric Podosol - B horizon dominated by the accumulation of organic compounds, aluminium, or iron.
Sediment load	No flow at the time of survey
Riparian vegetation	Cleared riparian corridor. Very heavy cover of exotic grasses in the upstream extent.
In stream vegetation	Instream vegetation consists largely of exotic grasses with a good cover of reeds and rushes at the downstream extent adjacent to the dam
Habitat value	Limited habitat values associated with reeds, rushes and the dam.







5 Waterway sensitivity analysis

A waterway sensitivity analysis was undertaken across the PSP areas to determine the potential impacts on waterways that could be expected as a result of development. As a first step, a Source hydrologic model was used to simulate the rainfall-runoff over the PSPs to understand how the hydrologic characteristics of the catchment may change as a result of increased urbanisation. The time series flow data generated from the Source model under developed conditions was then used in a 2D HEC-RAS model to understand changes in different hydraulic metrics across the site that may indicate waterways that will be particularly sensitive to change in the face of urbanisation. Additional details on the set up and results of the Source model and the 2D HEC-RAS model can be found in Appendices B and C respectively.

5.1 Results and discussion

Hydraulic modelling of waterways across the PSP area revealed that many of the waterways across the site are discontinuous, informal drains. Localised depressions, largely farm dams, capture and store a large portion of the runoff from discontinuous drains at present. Under these circumstances, key hydraulic metrics such as velocity and shear stress are largely the same under current and developed hydrologic conditions.

There is an example of a continuous drain within the Clyde South PSP where meaningful results for velocity and shear stress were extracted. Results for depth, velocity and shear stress under current and developed conditions are outlined in **Error! Reference source not found.**.

Table 2. Depth, velocity and shear stress values under current and developed conditions for a drain within the Clyde South PSP area

Maximum depth (m)		Maximum velocity (ms^{-1})		Maximum shear stress (Nm^{-2})	
Current conditions	Developed conditions	Current conditions	Developed conditions	Current conditions	Developed conditions
0.44	0.44	0.9	1.03	89.48	90.22

The potential for waterways to be susceptible to erosion under new flow conditions, velocity and shear stress must exceed the resistance of the channel bed and bank surfaces. The maximum permissible velocities for a range of sediment sizes are outlined in Table 3.

Table 3 Maximum permissible velocities for a range of sediment sizes (Government of Alberta, 2011)

Sediment	Clear water (m/s)	Water carrying fine silts (m/s)	Water carrying sand and gravel (m/s)
Fine sand	0.46	0.76	0.46
Sandy loam	0.52	0.76	0.61
Stiff clay	1.13	1.52	0.91
Alluvial silts	0.61	1.52	0.61

Soils across the study area are largely silty clays which indicates that under current conditions localised erosion is likely. Under developed conditions, the likelihood of localised erosion increases with increasing velocity. With appropriately designed interventions, the sensitivity of waterways to erosion can be mitigated.

6 Desktop Assessment – Biodiversity values

6.1 EVC mapping

Three remnant EVCs are mapped across the within proximity to the PSP areas (Figure 22). The study area falls within the Gippsland Plain bioregion. Benchmark descriptions for the mapped EVCs in this bioregion are described below.

Heathy Woodland (EVC 48)

This EVC is found across a variety of different geology types and is generally associated with nutrient-poor soils. It is a Eucalypt dominated low woodland up to 10 m and lacks a secondary tree layer but supports a diverse range of narrow-leaved shrubs.

Plains Grassy Woodland (EVC 55)

This EVC is an open Eucalypt woodland up to 15 m which is found on a variety of geologies and soil types. It is commonly found on poorly drained, fertile soils or gently undulating plains at low elevations. The understory comprises a spare shrub cover but a diverse grassy or herbaceous ground cover.

Swampy Riparian Woodland (EVC 83)

This EVC is a woodland up to 15 m tall and is found along the low energy stream of the foothills and plains. Large and medium shrub species are common as well as tussock grasses and sedges.

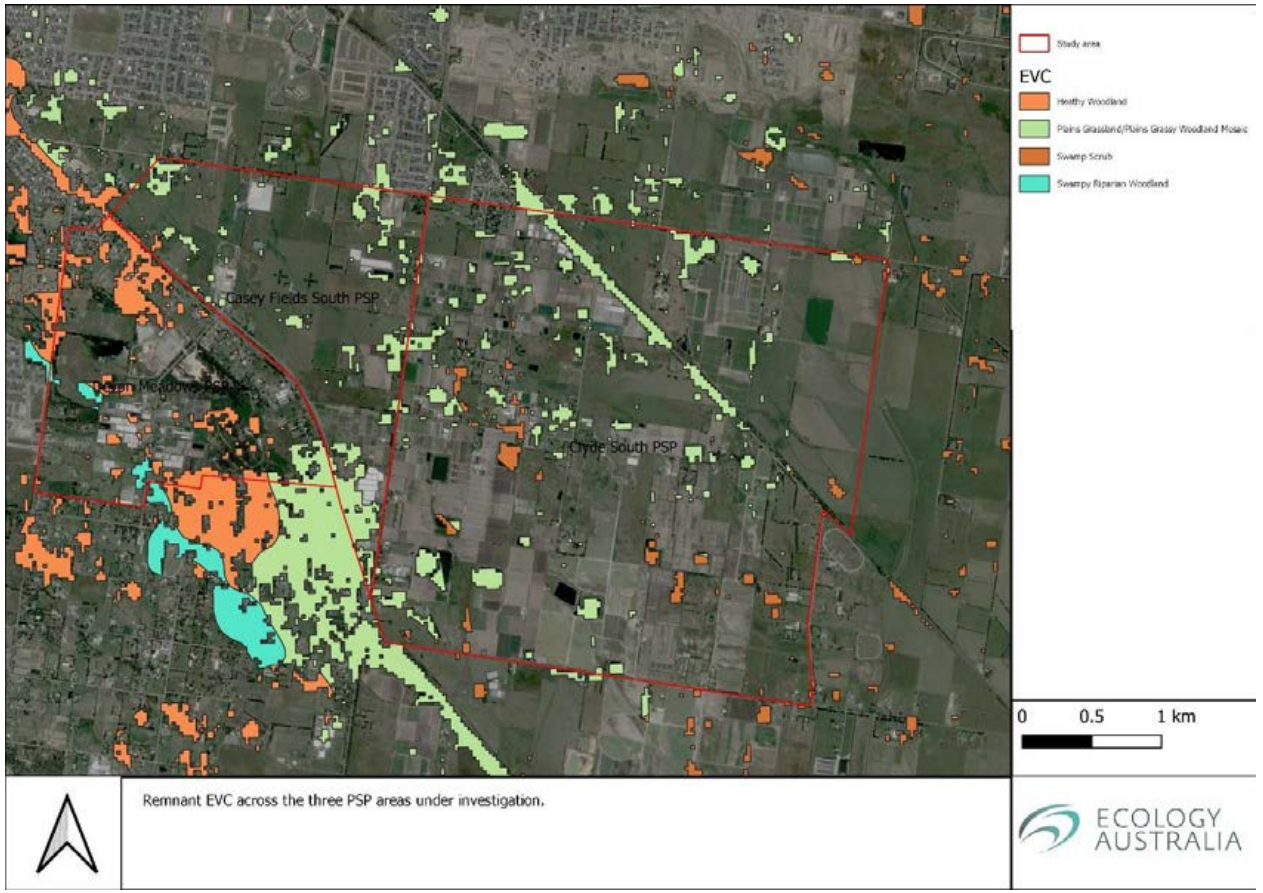


Figure 22. Remnant EVCs mapped across the study area.

6.2 Federally significant flora

Biodiversity values for this study focussed on the flora of significance under the federal EPBC Act and the Victorian FFG Act. The values in the section following are derived from reviewing the VBA and the EPBC PMST database.

Threatened species

There are 15 threatened flora species under the EPBC Act that occur or have potential habitat for within a five-kilometre radius of the study area, although there are no records within the study area boundary. Four threatened plant species have a moderate likelihood of occurring in the study area based on the desktop review (Figure 23), and they include:

- River Swamp Wallaby Grass (*Amphibromus fluitans*) (not FFG Act listed)
- Matted Flax-lily (*Dianella ameona*)
- Swamp Fireweed (*Senecio psilocarpus*)
- Swamp Everlasting (*Xerochrysum palustre*)

Threatened communities

A search within a 5 km radius of the study site using the EPBC PMST also indicated the following listed ecological communities may occur within the study area:

- Natural Damp Grassland of the Victorian Coastal Plains (Critically endangered)
- Subtropical and Temperate Coastal Saltmarsh (Vulnerable)
- Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains (Critically endangered)
- White Box - Yellow Box - Blakely's Red Gum Grassy Woodland and Derived Native Grassland (Critically endangered)

It is unlikely that the Natural Damp Grassland of the Victorian Coastal Plains and the Subtropical and Temperate Coastal Saltmarsh communities will occur in the study area. The Natural Damp Grassland community is generally absent from the area between Yarram and Cranbourne as this region is elevated above the coastal plain and tends to be an undulating landscape (DAWE 2021c). However, isolated patches may occur throughout the Gippsland Plain bioregion.

Temperate and Subtropical Coastal saltmarsh communities are coastal communities under regular or intermittent tidal influence (DAWE 2021d). As such the area under investigation is very unlikely to contain these communities.

Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains may occur in the area under investigation. This community is found on fertile plains that is conducive to agriculture (DAWE 2021e). The community is found on poorly defined drainage lines like those remaining in parts of the study area often associated with grassland communities such as the White Box - Yellow Box - Blakely's Red Gum Grassy Woodland and Derived Native Grassland. Field investigations will determine if the community remains at the site.

6.3 State significant flora

Threatened species

Of the potential threatened species list there were 26 flora species listed as threatened under FFG Act (Table 4). A likelihood of presence (LOP) has been assigned to each of these species based on the criteria outlined in Attachment A. Based on these criteria, six FFG listed plant species were deemed moderately likely to occur within the study area. These species include:

- Matted Flax-lily (*Dianella ameona*)
- Swamp Fireweed (*Senecio psilocarpus*)
- Swamp Everlasting (*Xerochrysum palustre*)
- Purple Blown Grass (*Lachnagrostis semibarbata var. semibarbata*)
- Yarra Gum (*Eucalyptus yarraensis*)
- Pale Swamp Everlasting (*Coronidium gunnianum*)

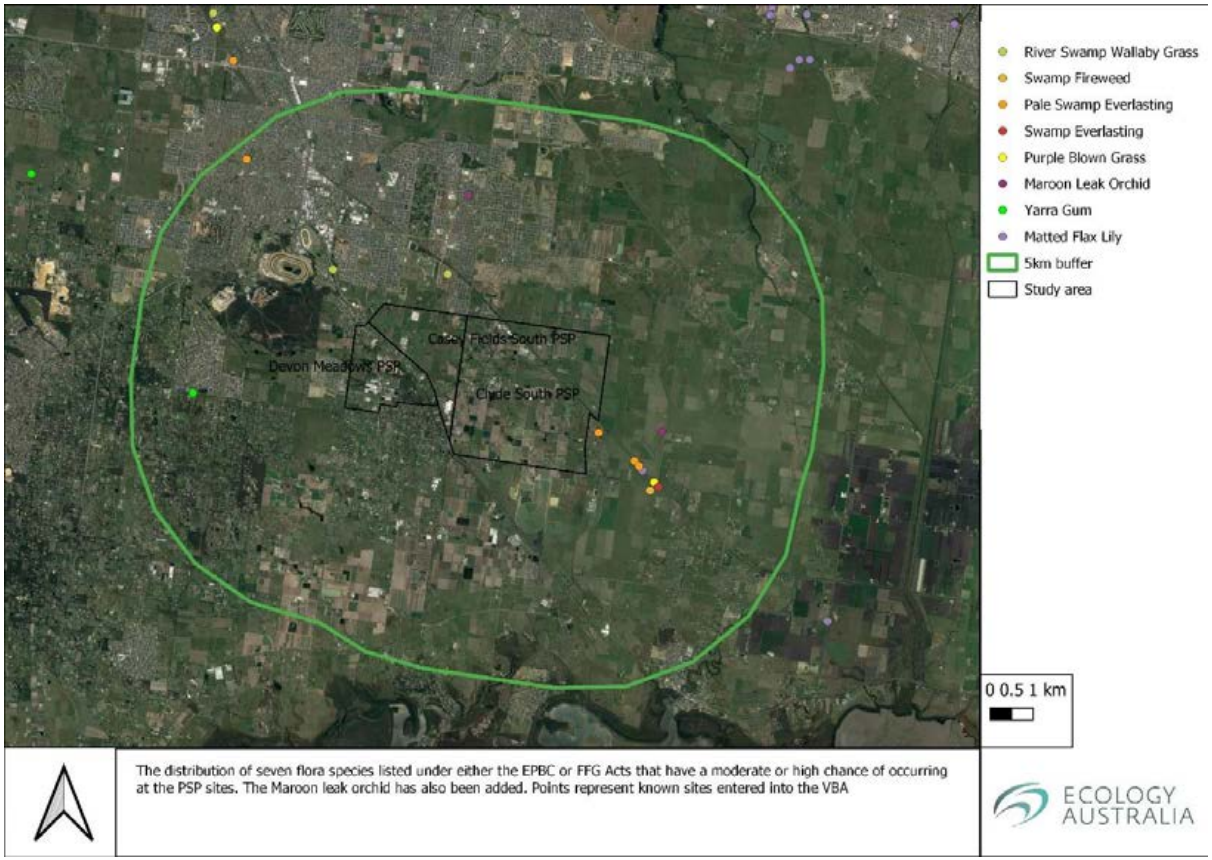


Figure 23. The records of flora with a high or moderate likelihood of presence within the study area. The green boundary indicates the 5 km buffer used to assess the proximity of threatened species.

6.4 Threatened flora likelihood of presence

A total of 30 threatened plant species have been recorded (DELWP 2021a) or have habitat modelled (DAWE 2021) within 5 km of the study area, of which 15 were EPBC Act listed and 26 were FFG Act listed (Table 4). Species with a moderate LOP were outlined in section above. No species were deemed to have a high LOP within the study area due to a variety of factors including lack of suitable habitat, length of time since last record, scarcity of records and distance from known records.

The threatened species database searches also contained eight species of plants (Table 5) which are outside of their natural range and are considered as non-indigenous to the study area. If any of the species do occur in the study area, they are presumed to have been planted as all these species have been regularly used in gardens or as street trees. Some of these species have the potential to becomes pest species but have not been documented as such in the study area.



Figure 24. Swamp Everlasting (*Xerochrysum palustre*). (Source: DSE 2011).

Table 4. Rare or threatened flora, likelihood of presence (LOP) in the study area.

Scientific Name	Common Name	EPBC	FFG Category of Threat	FFG Extinction Risk	Source	No. of Records	Last Recorded	LOP
Amphibromus fluitans	River Swamp Wallaby-grass	VU			VBA, PMST	2	2006	Moderate
Atriplex paludosa subsp. *paludosa*	Marsh Saltbush		Endangered	Victoria	VBA	2	2012	Not likely
Avicennia marina subsp. *australasica*	Grey Mangrove		Endangered	Victoria	VBA	2	2012	Not likely
Billardiera scandens s.s.	Velvet Apple-berry		Endangered	Victoria	VBA	2	1981	Not likely
Caladenia aurantiaca	Orange-tip Finger-orchid		Endangered	Victoria	VBA	1	1999	Not likely
Caladenia orientalis	Eastern Spider-orchid	EN	Endangered	Australia	PMST	NA	NA	Not likely
Caladenia robinsonii	Frankston Spider-orchid	EN	Critically endangered	Australia	VBA	1	2017	Not likely
Caladenia tessellata	Thick-lip Spider-orchid	VU			PMST	NA	NA	Not likely
Caladenia xanthochila	Yellow-lip Spider-orchid	EN	Endangered	Victoria	VBA	2	2017	Not likely
Cardamine moirensis	Riverina Bitter-cress		Endangered	Victoria	VBA	1	1998	Low
Coronidium gunnianum	Pale Swamp Everlasting		Critically endangered	Victoria	VBA	5	2018	Moderate
Correa reflexa var. *lobata*	Powelltown Correa		Endangered	Australia	VBA	1	1981	Low
Dianella amoena	Matted Flax-lily	EN	Critically endangered	Victoria	VBA, PMST	6	2005	Moderate
Eucalyptus strzeleckii	Strzelecki Gum	VU	Critically endangered	Australia	PMST	NA	NA	Not likely
Eucalyptus yarraensis	Yarra Gum		Critically endangered	Victoria	VBA	1	1992	Moderate
Glycine latrobeana	Clover Glycine	VU	Vulnerable	Victoria	PMST	NA	NA	Not likely

Scientific Name	Common Name	EPBC	FFG Category of Threat	FFG Extinction Risk	Source	No. of Records	Last Recorded	LOP
Lachnagrostis semibarbata var. *filifolia*	Purple Blown-grass		Endangered	Victoria	VBA	2	1994	Low
Lachnagrostis semibarbata var. *semibarbata*	Purple Blown-grass		Endangered	Victoria	VBA	1	2005	Moderate
Lawrencia spicata	Salt Lawrencia		Endangered	Victoria	VBA	1	2006	Not likely
Microseris scapigera s.s.	Plains Yam-daisy		Critically endangered	Victoria	VBA	2	1994	Not likely
Prasophyllum frenchii	Maroon Leek-orchid	EN	Endangered	Victoria	VBA, PMST	14	2018	Low
Prasophyllum spicatum	Dense Leek-orchid	VU	Critically endangered	Australia	PMST	NA	NA	Not likely
Pterostylis chlorogramma	Green-striped Greenhood	VU	Endangered	Victoria	PMST	NA	NA	Not likely
Pterostylis cucullata	Leafy Greenhood	VU			PMST	NA	NA	Not likely
Senecio psilocarpus	Swamp Fireweed	VU			VBA, PMST	1	2005	Moderate
Thelionema umbellatum	Clustered Lily		Vulnerable	Victoria	VBA	1	1988	Low
Thelymitra circumsepta	Naked Sun-orchid		Endangered	Victoria	VBA	5	2007	Low
Thelymitra epipactoides	Metallic Sun-orchid	EN	Endangered	Victoria	PMST	NA	NA	Low
Xerochrysum palustre	Swamp Everlasting	VU	Critically endangered	Victoria	VBA, PMST	2	2005	Moderate

Table 5. Non-indigenous threatened flora species recorded within the 5 km radius of the study area and their assigned likelihood of presence (LOP).

Scientific Name	Common Name	EPBC	FFG Category of Threat	FFG Extinction Risk	Source	No. of Records	Last Record	LOP
Acacia boormanii	Snowy River Wattle		Endangered	Victoria	VBA	2	1996	Not likely
Acacia howittii	Sticky Wattle		Vulnerable	Australia	VBA	2	2009	Low
Callitris oblonga subsp. oblonga	Dwarf Cypress-pine	EN			VBA	2	2015	Not likely
Corymbia maculata	Spotted Gum		Vulnerable	Victoria	VBA	3	2018	Moderate
Grevillea dimorpha	Flame Grevillea		Endangered	Australia	VBA	1	1995	Not likely
Hakea macraeana	Willow Needlewood		Critically endangered	Victoria	VBA	1	1995	Not likely
Melaleuca armillaris subsp. armillaris	Giant Honey-myrtle		Endangered	Victoria	VBA	6	2018	Moderate
Thryptomene calycina	Grampians Thryptomene		Endangered	Australia	VBA	1	1981	Moderate

6.5 Nationally significant fauna

There are 14 species of threatened fauna species under the EPBC Act that occur or have potential habitat within a five-kilometre radius of the study area. Two groups (pelagic seabirds and migratory shorebirds) have been excluded because their important habitat extends no further towards the study area than the edge of Westernport Bay. Of the 14 species, one species has a high likelihood of occurring in the study area, and four have a moderate likelihood of occurring in the study area based on the desktop review information, and they include:

- Southern Brown Bandicoot (*Isoodon obesulus obesulus)*
- Growling Grass Frog (*Litoria raniformis*)
- Hardhead (*Aythya australis*)
- White-throated Needletail (*Hirundapus caudacutus*)
- Little Eagle (*Hieraaetus morphnoides*)

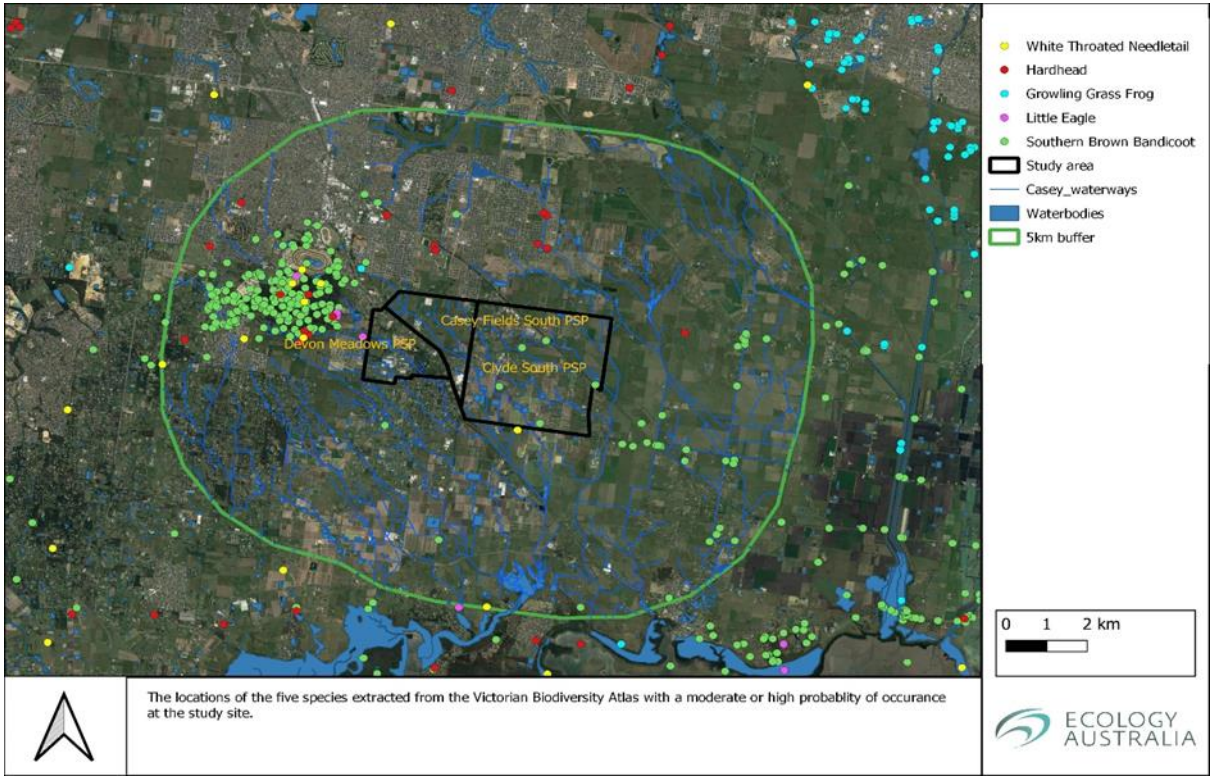


Figure 25. The records of the five fauna species extracted from the VBA that are considered to have a moderate or high likelihood of presence.

6.6 State significant fauna

Of the potential threatened fauna species there were 37 terrestrial fauna species listed as threatened under FFG Act (Table 6). A likelihood of presence (LOP) has been assigned to each of these species based on the criteria outlined in Table 4. Based on these criteria, five FFG listed fauna species were deemed highly or moderately likely to occur within the study area. These species include:

- Southern Brown Bandicoot (*Isoodon obesulus obesulus)*
- Growling Grass Frog (*Litoria raniformis*)
- Hardhead (*Aythya australis*)
- White-throated Needletail (*Hirundapus caudacutus*)
- Little Eagle (*Hieraaetus morphnoides*)



Figure 26. Southern Brown Bandicoot (source: DELWP)

6.7 Threatened fauna likelihood of presence

A total of 87 threatened animal species have been recorded within 5 km of the study area (DELWP 2021a). Of these species 41 were listed as threatened under the EPBC Act and 67 under the FFG Act. Table 6 below lists these species without two major groups – the albatrosses and migratory shorebirds. These two groups are significantly linked to pelagic and coastal areas respectively and as such are not likely to occur in a significant way. A likelihood of presence (LOP) has been assigned to each of the remaining species based on the criteria outlined in Appendix A.

Four EPBC and FFG listed animal species were deemed moderately likely to occur within the study area. Two species (Southern Brown Bandicoot and Growling Grass Frog) were deemed as highly likely to occur within the study area. Only the Southern Brown Bandicoot has VBA records inside the study site, all five records in the Clyde South PSP area. Although there are no VBA records of Growling Grass Frog within the PSP sites, it needs to be noted that there is an MSA Growling Grass Frog Strategically Important Area (Clyde Creek) just on the northeast boundary of the Clyde South PSP area.

The precautionary principle has been applied to the likelihood of Growling Grass Frogs occurring within the study area in recognition of low number of records present in the VBA. Survey effort and recording effort may be low in the area given that a large proportion of the land is in private ownership. However, given the number and proximity of drainage lines and farm dams the likelihood of frogs occurring increases.

Aquatic fauna

No threatened freshwater aquatic species records exist within the study area or in any of the upstream or downstream areas of the relevant catchments (i.e. Wylies Drain and the Western Outfall Drain). The PMST predicts that two freshwater aquatic species are possible within the study area being Dwarf Galaxias (*Galaxiella pusilla*) and Australian Grayling (*Prototroctes maraena*) (Table 7). Of these species, it is difficult to determine the LOP for Dwarf Galaxias due to several confounding factors, such as, but not limited to, the potential widespread presence of low–moderately suitable connected habitat and very limited survey effort in the study area. Australian Grayling is considered not likely to be present due to the lack of suitable habitat within the study area. This species requires larger and more perennially flowing habitats.

Table 6. Likelihood of presence for fauna species listed as threatened under the EPBC or FFG Acts.

Scientific Name	Common Name	EPBC	FFG Category of Threat	FFG Extinction Risk	Source	No. of Records	Last Recorded	LOP
Accipiter novaehollandiae	Grey Goshawk		Endangered	Victoria	VBA	5	1/07/2010	Low
Anseranas semipalmata	Magpie Goose		Vulnerable	Victoria	VBA	2	13/04/1994	Low
Anthochaera phrygia	Regent Honeyeater	CR	Critically endangered	Victoria	PMST	NA	NA	Not Likely
Ardea alba modesta	Eastern Great Egret		Vulnerable	Victoria	VBA	7	4/07/2019	Low
Aythya australis	Hardhead		Vulnerable	Victoria	VBA	207	27/07/2019	Moderate
Biziura lobata	Musk Duck		Vulnerable	Victoria	VBA	1	26/05/2018	Low
Botaurus poiciloptilus	Australasian Bittern	EN	Critically endangered	Victoria	VBA, PMST	2	1/01/2007	Low
Calamanthus pyrrhopygius	Chestnut-rumped Heathwren		Vulnerable	Victoria	VBA	4	28/07/2019	Low
Falco hypoleucos	Grey Falcon		Vulnerable	Victoria	PMST	NA	NA	Not likely
Falco subniger	Black Falcon		Critically endangered	Victoria	VBA	3	3/05/2011	Low
Grantiella picta	Painted Honeyeater	VU	Vulnerable	Victoria	VBA, PMST	3	1/11/2007	Low
Haliaeetus leucogaster	White-bellied Sea-Eagle		Endangered	Victoria	VBA, PMST	4	10/06/2018	Low
Hieraaetus morphnoides	Little Eagle		Vulnerable	Victoria	VBA	27	22/04/2019	Moderate
Hirundapus caudacutus	White-throated Needletail	VU	Vulnerable	Victoria	VBA, PMST	15	20/03/2018	Moderate
Hydroprogne caspia	Caspian Tern		Vulnerable	Victoria	VBA	8	16/09/2018	Low
Isoodon obesulus	Southern Brown Bandicoot	EN	Endangered	Victoria	VBA	1476	28/07/2020	High

Scientific Name	Common Name	EPBC	FFG Category of Threat	FFG Extinction Risk	Source	No. of Records	Last Recorded	LOP
Ixobrychus dubius	Australian Little Bittern		Endangered	Victoria	VBA	2	21/10/2002	Low
Lathamus discolor	Swift Parrot	CR	Critically endangered	Victoria	VBA, PMST	5	22/05/2009	Low
Lewinia pectoralis	Lewin's Rail		Vulnerable	Victoria	VBA	11	1/10/2011	Low
Lissolepis coventryi	Swamp Skink		Endangered	Victoria	VBA	13	1/10/2011	Not Likely
Litoria raniformis	Growling Grass Frog	VU	Vulnerable	Victoria	VBA, PMST	1	17/09/1980	Moderate
Neophema chrysogaster	Orange-bellied Parrot	CR	Critically endangered	Victoria	PMST	NA	NA	Not likely
Ninox connivens	Barking Owl		Critically endangered	Victoria	VBA	1	24/09/2005	Low
Oxyura australis	Blue-billed Duck		Vulnerable	Victoria	VBA	312	11/05/2019	Low
Pluvialis fulva	Pacific Golden Plover		Vulnerable	Victoria	PMST	NA	NA	Low
Pluvialis squatarola	Grey Plover		Vulnerable	Victoria	PMST	NA	NA	Low
Pomatostomus temporalis	Grey-crowned Babbler		Vulnerable	Victoria	VBA	1	1/01/1981	Not likely
Pseudophryne semimarmorata	Southern Toadlet		Endangered	Victoria	VBA	5	20/04/2009	Low
Rostratula australis	Australian Painted-snipe	EN	Critically endangered	Victoria	PMST	NA	NA	Low
Spatula rhynchotis	Australasian Shoveler		Vulnerable	Victoria	VBA	23	24/04/2019	low
Sternula albifrons	Little Tern		Critically endangered	Victoria	PMST	NA	NA	Low
Sternula nereis	Fairy Tern	VU	Critically endangered	Victoria	PMST	NA	NA	Not likely
Stictonetta naevosa	Freckled Duck		Endangered	Victoria	VBA	2	20/12/2018	Low

Scientific Name	Common Name	EPBC	FFG Category of Threat	FFG Extinction Risk	Source	No. of Records	Last Recorded	LOP
Synemon plana	Golden Sun Moth	CR	Vulnerable	Victoria	PMST	NA	NA	Not likely
Temognatha sanguinipennis	Jewel Beetle		Endangered	Victoria	VBA	1	4/08/2017	Low
Thinornis cucullatus	Hooded Plover	VU	Vulnerable	Victoria	PMST	NA	NA	Low
Tringa brevipes	Grey-tailed Tattler		Critically endangered	Victoria	PMST	NA	NA	Not likely

Table 7. Rare or threatened aquatic species likelihood of presence (LOP) in the study area.

Scientific Name	Common Name	EPBC	FFG Category of Threat	FFG Extinction Risk	Source	No. of Records	Last Record	LOP
Galaxiella pusilla	Dwarf Galaxias	VU	Endangered	Australia	PMST	NA	NA	Low–Moderate
Prototroctes maraena	Australian Grayling	VU	Endangered	Victoria	PMST	NA	NA	Not likely

6.8 Regional context

The *Biodiversity Conservation Strategy for Melbourne's Growth Corridors* (DEPI 2013) has identified the south-eastern growth corridor as containing significant biodiversity values, particularly associated with the major creek lines of Deep Creek, Cardinia Creek and Clyde Creek. The *Biodiversity Conservation Strategy* outlined two Conservation areas within the growth corridor, namely Conservation Area 35 (Clyde-Tooradin Rail Reserve, Clyde) and Conservation Area 36 (various Growling Grass Frog corridors) (Figure 27).

Conservation Area 35 is located within the Clyde South precinct and contains high quality native grassland which supports a significant population of the EPBC listed Maroon Leek-orchid (*Prasophyllum frenchii*). The area also adjoins rail reserve land outside of the Clyde South precinct which contains the state listed Swamp Everlasting (*Coronidium gunnianum*). Conservation Area 35 also contains appropriate habitat for other matters of national and state significance including Matted Flax-lily (*Dianella amoena*) habitat, Southern Brown Bandicoot (*Isoodon obesulus obesulus*) habitat and Plains Yam-daisy (*Microseris scapigera*) habitat.

Conservation Area 36, which is located directly northeast of Clyde South, has been identified as significant as it contains both populations and suitable habitat for Growling Grass Frogs, Australian Grayling (*Prototroctes maraena*) and Dwarf Galaxias (*Galaxiella pusilla*).

The Devon Meadows and Casey Fields South PSP areas are located adjacent to the ecologically significant Botanic Ridge precinct and the Royal Botanic Gardens Cranbourne (RBGC). Much of the significant remnant native vegetation within Botanic Ridge is located within the quarry site, the golf course, roadsides, adjacent to wetlands and waterways, or occurs as scattered trees (Growth Areas Authority 2012). The Royal Botanic Gardens Cranbourne also contain significant core habitat for threatened flora and fauna, including the Southern Brown Bandicoot. Botanic Ridge has also been found to contain records of other species of state significance including Southern Toadlet (*Pseudophryne semimarmorata*), Swamp Skink (*Lampropholis guichenoti*), Pacific Gull (*Larus pacificus*) and Wetland Blown-grass (*Lachnagrostis palustris*).

Given the significant ecological values which have been recorded within the study area and within neighbouring precincts, it is likely that waterways within the precincts have significant value as wildlife corridors. This is particularly relevant given their proximity to other features of significant value such as the Westernport and Edithvale-seaford Wetlands Ramsar sites. The *Sub-regional Species Strategy for the Southern Brown Bandicoot* (DEPI 2014) also identified Devon Meadows precinct as a key habitat connectivity corridor for the species, linking the stable population in the RBGC with the broader Southern Brown Bandicoot Management Area.

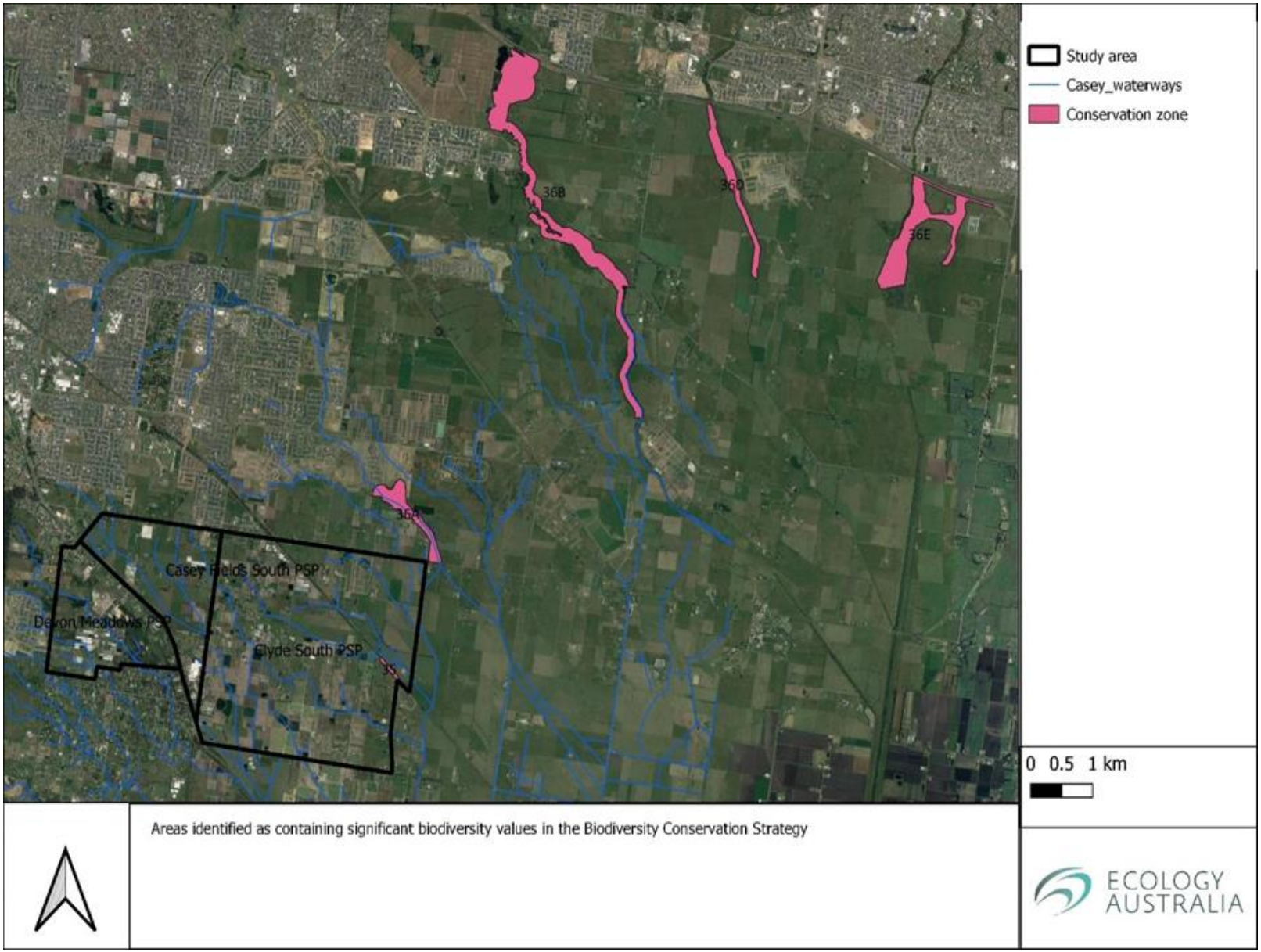


Figure 27. South-east growth corridor conservation zones in relation to the three PSP areas of the study.

7 Southern Brown Bandicoot habitat

The Southern Brown Bandicoot (SBB) is known to use a range of habitats ranging from sedgelands and heathlands through to open forests (DAWE 2021). In Victoria, SBB habitat includes heathlands, shrublands, open forests and woodlands. Generally, these habitats are associates with well-drained soils and heath communities (Menkhorst and Seebeck 1990). The upper stratum of the habitat can be low or tall woodland, but the critical factor in what is considered good SBB habitat is a dense groundcover. Suitable habitat will contain an understory with 50–80% foliage density in the height range of 0.2–1 m. The distinction between native and non-native vegetation is not important for the bandicoot, and often species like Blackberry (*Rubus fruticosus L. agg.*) provides good habitat as it can form dense stands.

The three precincts that comprise the study area are highly modified and used mainly for agriculture. As a result, much of the previous native vegetation has been removed. The precincts are positioned between important Southern Brown Bandicoot populations – Cranbourne Botanical Gardens in the west, and via agricultural land to Quail Island and North Westernport Nature Conservation Reserve in the south, and Koo Wee Rup in the east. Of the three precincts, Devon Meadows provides the greatest area of native vegetation, where land has not been completely cleared for agricultural or urban development.

Devon Meadows is specifically mentioned in the Sub-regional Species Strategy for the Southern Brown Bandicoot Supplement: Habitat Connectivity (DEPI 2014). Within this document, commitment has been made to improve Devon Meadows (and Botanic Ridge to the west) connectivity for the Southern Brown Bandicoot to the rural areas outside the Urban Growth Boundary. Specific reference is made to create and enhance habitat within drainage reserves and other areas unsuitable for development, to enhance movement corridors.

Under the MSA environmental mitigation, Clyde South and Casey Fields are proposed as SBB habitat along the wetlands and drainage lines (for both SBB and Growling Grass Frog). However, this is potentially a broad-based possibility of occurrence. The VBA show very few records in the area, and the databases suggest habitat is severely altered. Although clearing for agriculture has removed much of the overstory vegetation, it is difficult to assess the density of the lower strata. Dense low shrubs or graminoids will still provide very good habitat for SBBs. It is likely that these denser low strata vegetation will occur near drainage lines where horticultural use is typically more limited.

Part of the Sub-regional strategy for the Southern Brown Bandicoot is improving connectivity between populations and patches of habitat towards Quail Island in the south and Koo Wee Rup in the east. Under this strategy, habitat in the urban growth corridor will be created or enhanced while minimising impact on the primary function of open spaces and land available for development.

Drainage lines form one natural feature that could be improved as corridors for SBBs. With a combination of revegetation, fencing and weed management, these areas can provide good corridors to link patches of habitat through the Urban Growth Corridor. However, the drainage lines are also the areas that are likely to be used to mitigate floods and runoff.

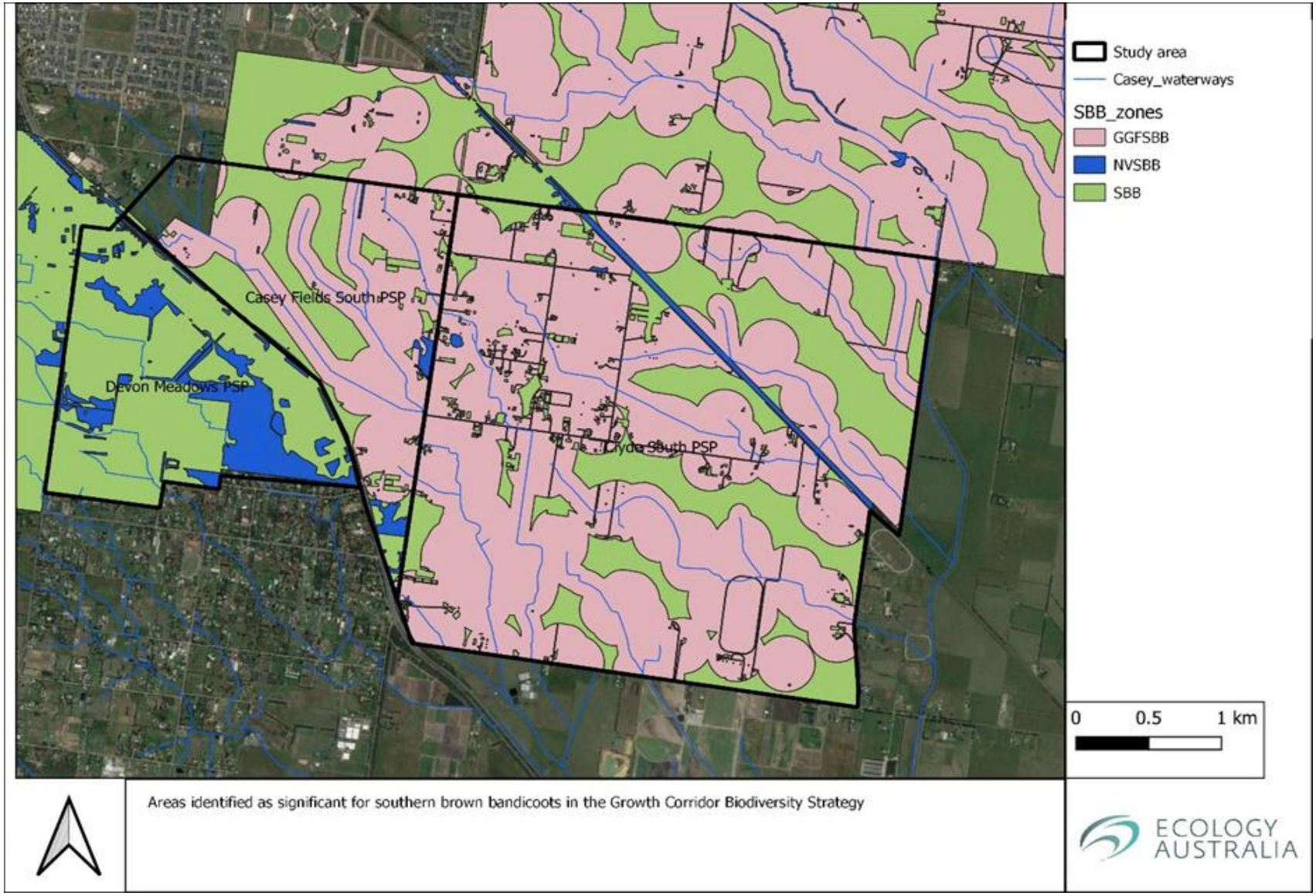


Figure 28. Areas proposed as significant habitat for Southern Brown Bandicoot. The areas of blue represent the remaining native vegetation that could provide appropriate bandicoot habitat.

A habitat corridor can be defined as a wide corridor capable of supporting a resident SBB population and maintaining gene flow over a long distance. Constructed corridors are designed to have three zones – a core zone, a buffer zone, and a defendable area. The core zone width should be a minimum of 50 m wide as guided by the SBB EPBC Referral Guidelines (DSEWPaC 2011). For corridors longer than 1.1 km, the width of the core corridor increases. The core area should be fenced with predator proof fencing to exclude potential predators. The buffer zone of about 30 m surrounds the core zone and should be fenced to exclude people, stock and pets. This zone provides a buffer against edge effects and 'insulates' the core zone from the impact of neighboring land-use. The defendable zone has a main function of fire protection. This zone should comprise areas of mown grass and scattered trees at least 6 m wide. This zone can be used for passive recreation.

The core section of the corridor may need to be restored with strategic planting of native vegetation suitable for SBB habitat. In the restoration, focus needs to be on the structural components that provide good habitat – a dense low strata (50–80% average foliage density), some middle level strata (20%) and some larger canopy trees (5%). Any planned works should minimize or avoid removal of native vegetation that forms part of the existing SBB habitat.

The buffer zone should be planted with medium to large shrubs and acts to screen the main fence from public view. A 2.5 m clear access area is required as a buffer next to all fence lines. The defendable space should be maintained as mown grass within fire management guidelines.

7.1 Recommendations

On-ground assessments of the potential habitat will be needed to provide a better understanding of the quality of habitat available for the bandicoots. Significant structural habitat in the form of dense understory (native or non-native) provides the ideal habitat, and this is not possible to assess quantitatively with the use of desktop methods only.

Structural habitat assessments will involve assigning rankings (high, medium or low) to areas of contiguous habitat based on its ability to meet the habitat requirements of the species.

8 Growling Grass Frog habitat

Growling Grass Frogs (GGFs) are associated with permanent or semi-permanent waterbodies that are either still or very slow flowing. Ideally these waterbodies contain a diverse range of aquatic vegetation including emergent, submerged, and floating vegetation. The range of aquatic vegetation is particularly important during breeding events. In addition to the aquatic requirements of the pools themselves, relatively open terrestrial habitat is required adjacent to waterbodies. The terrestrial habitat is used to overwinter or when temporary pools dry up. The terrestrial surrounds are also used for feeding.

Growling Grass Frog populations should be looked at as an interconnected metapopulation, where individual populations are connected through dispersal pathways. Dispersal pathways are mainly along drainage line or along other low-lying areas in the landscape. The ongoing persistence of the population is therefore strongly linked to the ability to shift between wetlands as the current wetland being used temporarily becomes less habitable. GGFs can move up to 1 km during a single night, meaning that strong sub-populations can be found where suitable wetlands are within close proximity to each other.

Besides the damage to and removal of habitat for GGFs, secondary impacts may also play a part in the persistence of populations. Tadpoles of the GGF are susceptible to horticultural chemicals including fertilisers and pesticides. Within agricultural zones this may have a significant effect on potential wetland sites. In addition, Eastern Gambusia (*Gambusia holbrooki*) are a major predator of frog eggs and larvae. Where Eastern Gambusia are present frogs often struggle to establish a healthy population. Fish, both native and introduced, such as Redfin (*Perca fluviatilis*) also prey on eggs, tadpoles and adult frogs, and can influence the survival of future generations of frogs.

Where aquatic systems are interlinked, even if the link is only seasonal, native and non-native fish species are very likely to be present, particularly Eastern Gambusia. Populations of GGF will survive and potentially flourish in permanently disconnected wetlands. Should connectivity be available to nearby channels or other wetlands, the off-stream wetlands may be able to provide a source population to recolonise nearby wetlands.

In the three PSP areas under discussion in this report, all three have significant GGF overlays particularly along creeks and drainage lines (DEPI 2013). Just outside the boundary of the study area is the Clyde Creek GGF corridor that forms part of Conservation Area 36. Devon Meadows potentially provides areas with the most natural habitat, but land use is generally mixed with parts rural, residential and small agricultural operations. The drainage channel in the south of Devon Meadows PSP connects to wetlands in the south of the Cranbourne Botanic Gardens and this may provide the means for frogs to move between these wetlands and Devon Meadows habitats. The second drainage line coming from the north passes next to the most natural appearing wetland in the area and continues to the south-east out of the designated growth corridor.

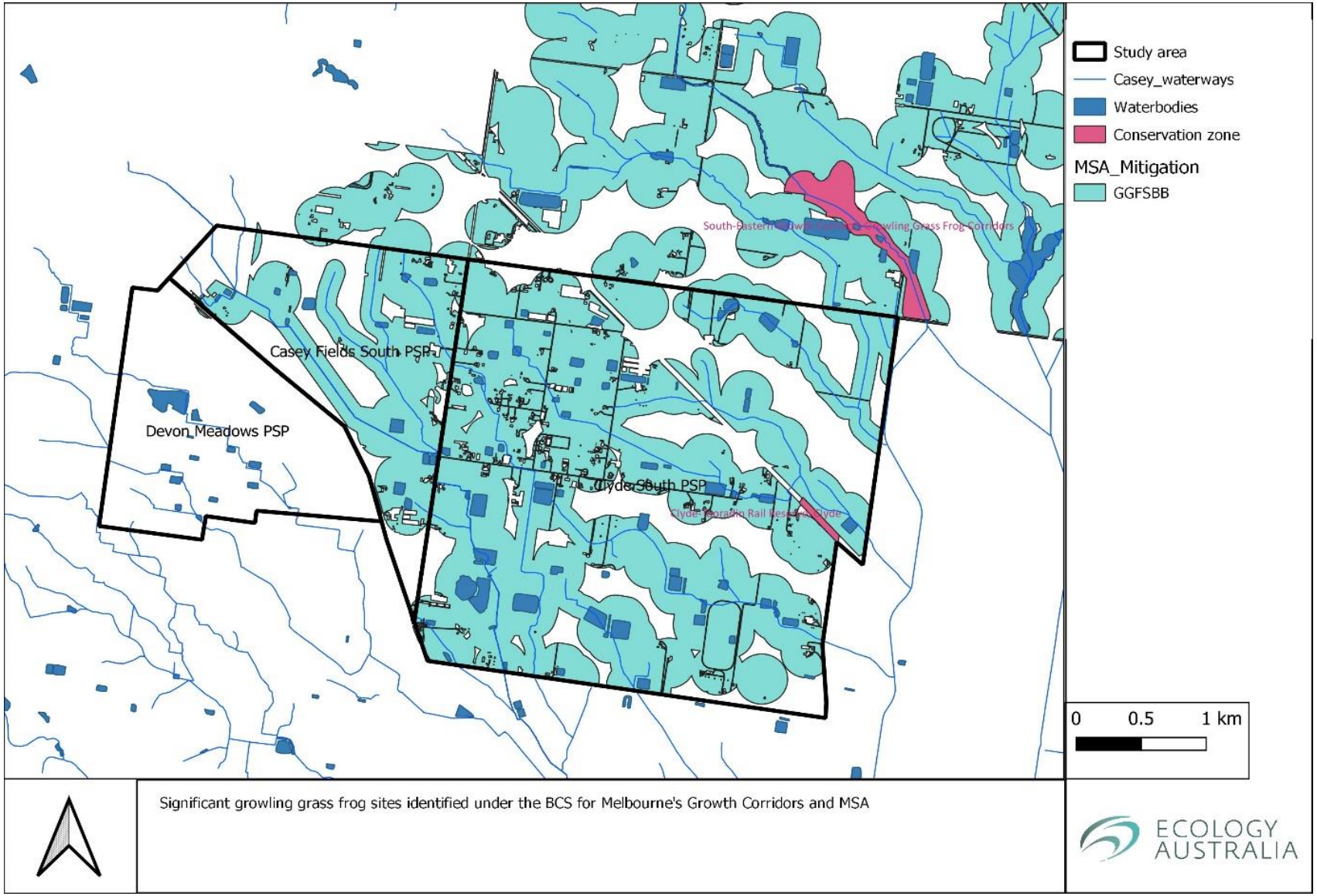


Figure 29. Significant Growling Grass Frog habitat as proposed under the BCS forming part of the mitigation strategy in the south-eastern growth corridor.

Casey Fields South PSP has the least amount of potential habitat with very few wetlands or farm dams through the site. Drainage lines have been significantly altered and, in some cases, may not exist anymore. However, in the south there where two drainage lines converge there are two potential sites that could provide some habitat features conducive to holding GGF populations.

Of the three sites, Clyde South provides the greatest potential for GGF populations. This PSP area has the physical attributes of very good GGF habitat – still water connected to each other through drainage lines. This is particularly relevant to the south-west of the area. Although the physical attributes are good, irrigation dams are often devoid of plant material, particularly floating and submerged plants as these can cause issues during pumping.

In the current situation, water quality may also be an important factor in maintaining a GGF population in the area. A report on Wylies Drain found water quality to be poor with high nutrient and suspended solid levels in the water (SKM 2012). This is likely to be the case across most the drainage lines in the area due to agricultural activity. In addition to nutrients and sediment loads there is a strong likelihood of pesticides or herbicides used as part of the agricultural activities that will find its way into the waterways.

8.1 Recommendations

Growling Grass Frog records in relevant databases are not well represented within the 5 km buffer used during the desktop study. However, we believe this may partly be due to a few studies not documenting and recording frogs into the Victorian Biodiversity Atlas (VBA). In addition, a site to the northeast of the PSP areas (Clyde Creek) is designated MSA Growling Grass Frog habitat.

The Clyde South precinct has numerous farm dams with little or no emerging vegetation. This can provide good habitat for Growling Grass Frogs. Seasonal surveys during the calling period could provide the level of habitat provided for Growling Grass Frogs through this area.

9 Dwarf Galaxias habitat

Dwarf galaxias have not been recorded within the Devon Meadows, Casey Fields or Clyde South PSP boundaries, or in any of the upstream or downstream areas of the relevant catchments (i.e. Wylies Drain and the Western Outfall Drain). However, aquatic fauna survey data (VBA data, Melbourne Water Fish database) and other data sources (e.g. Bloink 2012) from these relevant catchments is extremely limited, with past surveys within these catchments either occurring in or nearby to the estuary or in the northernmost relevant catchments (Table 7; Figure 30).

Previous broad-scale rapid surveys were undertaken specifically to fill this knowledge gap in Dwarf Galaxias distribution (Bloink 2012). Targeted Dwarf Galaxias surveys were undertaken at three locations within the Clyde South PSP areas, at four locations in upstream and downstream connected areas of the same catchments, and six locations in neighbouring catchments. The surveys detected only common native fish species such as Short-finned Eel (*Anguilla australis*) and Common Galaxias (*Galaxias maculatus*), together with Common Yabby (*Cherax destructor*), pest fish species such as Eastern Gambusia (*Gambusia holbrooki*) and common frog species and tadpoles as bycatch.

Dwarf galaxias have been recorded in surrounding catchments with records surrounding the study area to the west, north and east, the most recent record being from the east in 2016. The nearest records of dwarf galaxias are from approximately 5 km west of the Devon Meadows PSP boundary, in the upper reaches of the Eastern Contour Drain catchment, a population that was only discovered in 2007 and is the only known population for that catchment. Another population is known to occur in the Langwarrin Creek catchment approximately 7 km south-west of the Devon Meadows PSP boundary and in the Cardinia Creek catchment approximately 6 km north-east of the Clyde South PSP boundary.

Desktop assessment of potential dwarf galaxias habitat was undertaken as part of the 2011–2012 study (Bloink 2012), however, the focus was on selecting appropriate sites for survey and to maximise survey access coverage of the entire south-east growth area within the available budget.

Dwarf Galaxias has broad habitat requirements and is resilient to many forms of habitat degradation, making it difficult to rule out habitat as unsuitable unless it is devoid of aquatic vegetation, is estuarine or comprises offline dams with no flood connection. All remaining habitat was assessed on the basis of desktop assessment as expected to be of high, medium, low or negligible likelihood of supporting a Dwarf Galaxias population based on the following unweighted criteria:

- Likely degree of water permanence and corresponding habitat usage (e.g. refuge habitat, spawning habitat)
- Proximity of contrasting connected habitats (e.g. If ephemeral habitat – where Is the likely nearest permanent refuge)
- Habitat type and connectivity (e.g. watercourse, online or floodplain dam/wetland etc.)
- Riparian shading
- Instream vegetation cover (where discernible)
- Degree of hydrological disturbance to catchment
- Degree of connectivity and likely fish barriers.

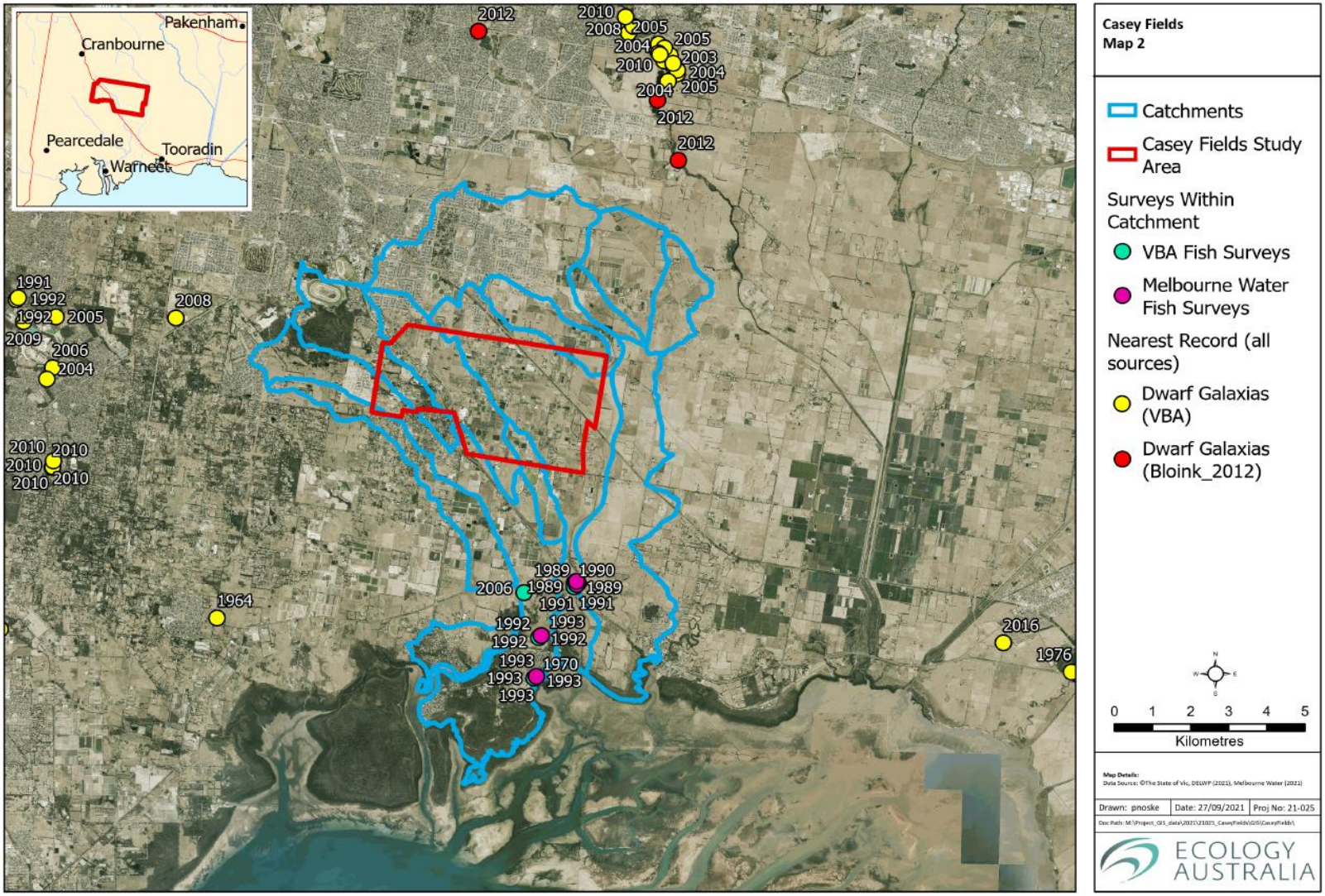


Figure 30. Locations of all surveys conducted within the relevant catchments searched and the locations of the nearest Dwarf galaxias records from the broader area.

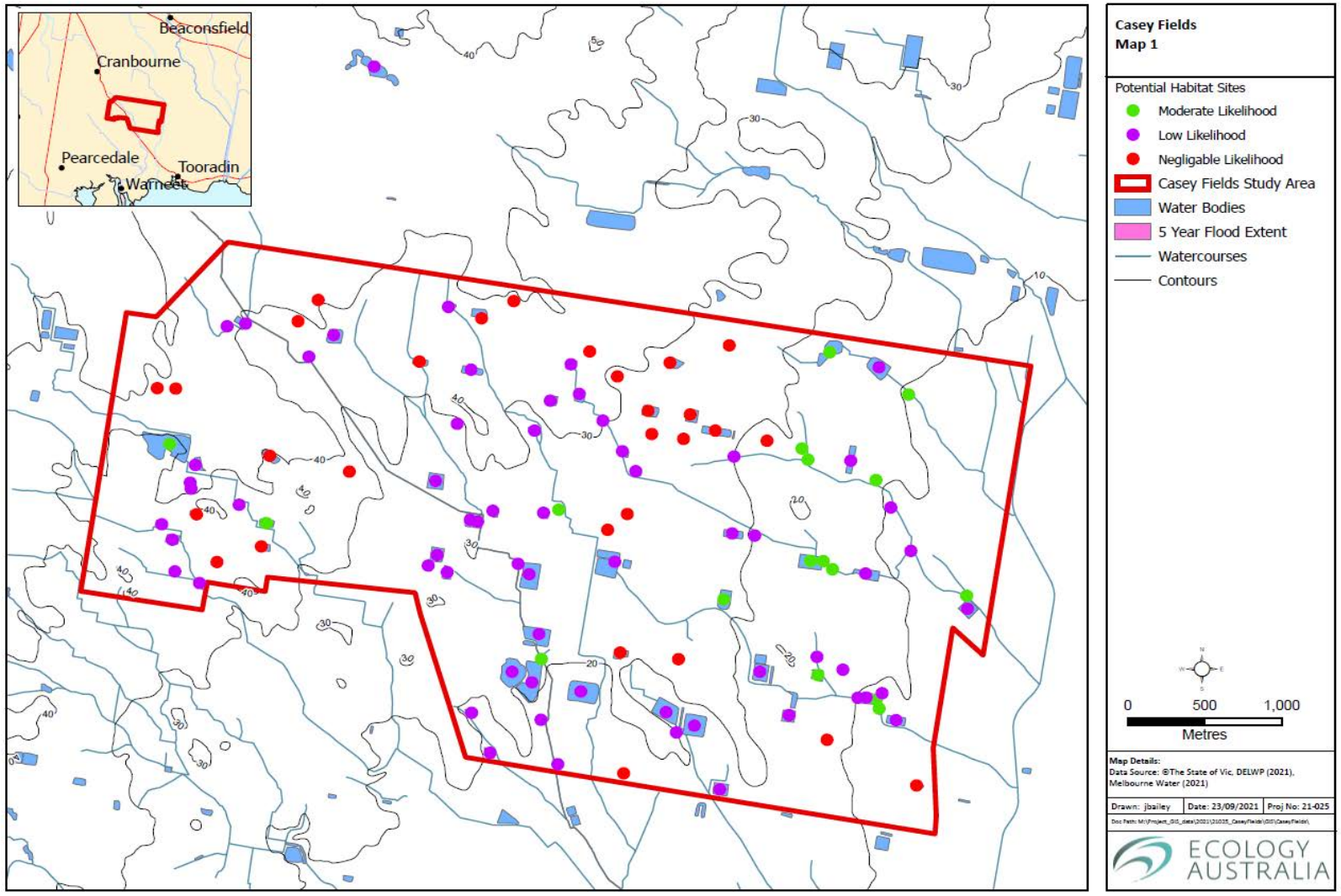


Figure 31. An assessment of all suitable Dwarf galaxias habitats within the study area ranked from moderate - negligible likelihood of supporting Dwarf galaxias population. Note no high likelihood potential habitats were identified.

All suitable potential habitats (over 100 waterbodies) within the study area were assessed for likelihood of supporting a Dwarf Galaxias population (Figure 31). Seventeen of these habitats were deemed to have a moderate likelihood of supporting a Dwarf Galaxias population, with these waterbodies being the most likely habitats within the study area. There were no high likelihood waterbodies identified.

9.1 Recommendations

Due to the very limited survey effort conducted within the study area coupled with the resilience of the Dwarf Galaxias and the presence of a significant number of moderately suitable potential habitats, we recommend conducting Dwarf Galaxias surveys within and downstream of the study area. Dwarf Galaxias surveys of the moderate likelihood habitat and/or low likelihood would further allow us to better predict the LOP for the Dwarf Galaxias for the rest of the study area.

Dwarf Galaxias surveys would be undertaken using a range of complementary techniques including dip netting, bait trapping (with a fish attractant) and eDNA techniques, largely following the DoEE survey guidelines (Department of the Environment 2021). Typically, dip netting would be used in the first instance, supplemented by bait traps deployed overnight (with a glow stick placed inside to serve as an attractant) if dip netting does not detect the species. eDNA would be used to provide broader scale survey coverage of the study area, particularly in instances where landholder access is denied, i.e. eDNA would be taken from nearest roadside waterway crossing if flow is present.

10 Field assessment – Flora and Fauna

10.1 EVCs mapped within the study area

Heathy Woodland (EVC 48)

Bioregional conservation status: Least Concern

Description (from EVC benchmark): Spans a variety of geologies but is generally associated with nutrient-poor soils including deep uniform sands (aeolian or outwash) and Tertiary sand/clay which has been altered to form quartzite gravel. Eucalypt-dominated low woodland to 10 m tall lacking a secondary tree layer and generally supporting a diverse array of narrow or ericoid-leaved shrubs except where frequent fire has reduced this to a dense cover of bracken. Geophytes and annuals can be quite common but the ground cover is normally fairly sparse.

Typical indicator species observed: coast manna gum *Eucalyptus viminalis* subsp. *pryoriana,* austral bracken *Pteridium esculentum* and prickly tea-tree *Leptospermum continentale.*





Figure 32. Example of higher quality Heathy Woodland from a property surveyed at 1934 South Gippsland Highway, Devon Meadows (EVC 48) (Top right) and an example of lower quality Heathy Woodland (EVC 48) (Bottom right) from a property surveyed at 1934 South Gippsland Highway, Devon Meadows. Here, there is a simplified vegetation structure consisting predominantly of austral bracken with only scattered coast manna gums.

Swamp Scrub (EVC 53)
Bioregional conservation status: Endangered
Description (from EVC benchmark): Closed scrub to 8 m tall at low elevations on alluvial deposits along streams or on poorly drained sites with higher nutrient availability. The EVC is dominated by swamp paperbark *Melaleuca ericifolia* (or sometimes woolly tea-tree *Leptospermum lanigerum*) which often forms a dense thicket, out-competing other species. Occasional emergent eucalypts may be present. Where light penetrates to ground level, a moss/lichen/liverwort or herbaceous ground cover is often present. Dry variants have a grassy/herbaceous ground layer.

Typical indicator species observed: swamp paperbark



Figure 33. Example of Swamp Scrub (EVC 53) from a roadside surveyed in Clyde South

Swampy Riparian Woodland (EVC 83)
Bioregional conservation status: Endangered
Description (from EVC benchmark): Woodland to 15 m tall generally occupying low energy streams of the foothills and plains. The lower strata are variously locally dominated by a range of large and medium shrub species on the stream levees in combination with large tussock grasses and sedges in the ground layer.

Typical indicator species observed: swamp gum *Eucalyptus ovata,* swamp paperbark, weeping grass *Microlaena stipoides* var. *stipoides* and austral bracken



Figure 34. Example of Swampy Riparian Woodland (EVC 83) from a property surveyed at 1934 South Gippsland Highway, Devon Meadows.

Plains Grassy Wetland (EVC 125)
Bioregional conservation status: Endangered
Description (from EVC benchmark): This EVC is usually treeless, but in some instances can include sparse river red gum *Eucalyptus camaldulensis* or swamp gum *Eucalyptus ovata*. A sparse shrub component may also be present. The characteristic ground cover is dominated by grasses and small sedges and herbs. The vegetation is typically species-rich on the outer verges but is usually species-poor in the wetter central areas.

Typical indicator species observed: common spike-sedge *Eleocharis acuta*. Plains Grassy Wetland was generally confined to shallow drainage lines located within fields otherwise dominated by exotic pasture. This EVC represents the best-fit for a likely-derived vegetation type which was present within a highly modified agricultural landscape.



Figure 35. Example of Plains Grassy Wetland (EVC 125) and surrounding exotic pasture from a property surveyed at 1845 South Gippsland Highway, Casey Fields South.

Sedge Wetland (EVC 136)

Bioregional conservation status: Vulnerable

Description (from EVC benchmark): Occupies seasonal wetlands and consists of generally treeless vegetation dominated by sedges. May contain a fringe of shrubs and isolated shrubs may also be present throughout. Usually of low diversity in central areas, but richer on verges and in some more ephemeral forms of the EVC. Frequently on soils of high organic content, in depressions within sandy terrain.

Typical indicator species observed: vegetation categorised as Sedge Wetland was not a true expression of the EVC and was instead a derived and highly modified vegetation type which consisted predominantly of a range of *Juncus* spp. occurring in seasonally inundated areas. Sedge Wetland provided the best fit in terms of the lifeforms present in addition to the site hydrology and geomorphology.



Figure 36. Example of Sedge Wetland (EVC 136) from a property surveyed at 1715 South Gippsland Highway, Casey Fields South.

Tall Marsh (EVC 821)

Bioregional conservation status: None provided

Description (from EVC benchmark): Occurs on Quaternary sedimentary geology of mainly estuarine sands, soils are peaty, silty clays, and average annual rainfall is approximately 600 mm. It requires shallow water (to 1 m deep) and low current-scour, and can only tolerate very low levels of
salinity. Closed to open grassland/sedgeland to 2-3 m tall, dominated by common reed *Phragmites australis* and cumbungi *Typha* spp. Small aquatic and semi-aquatic species occur amongst the reeds.

Typical indicator species observed: common reed and common spike-sedge.



Figure 38. Example of Tall Marsh (EVC 821) dominated by common reed from a property surveyed at 115 Devon Road, Devon Meadows.



Figure 37. Example of Tall Marsh (EVC 821) fringing a dam from a property surveyed at 76-80 Devon Road, Devon Meadows. In this instance the dominant native species typical of the EVC was common spike-sedge. The non-native lesser reed-mace Typha latifolia is also present in the background, where it is likely filling the niche of other typical native tall marsh species such as cumbungi *Typha domingensis* and broad-leaf cumbungi *Typha orientalis*.

Exotic Vegetation

Non-remnant vegetation observed near waterways throughout the three PSPs most frequently consisted of either exotic pasture, market gardens or dams and drainage lines fringed primarily with lesser reed-mace *Typha latifolia,* amongst an assortment of other non-native species.



Figure 39. Example of a drainage line dominated by lesser reed-mace, bordered on one side by kikuyu *Cenchrus clandestinus* and a market garden on the other side. This was noted from a property surveyed at 76-80 Devon Road, Devon Meadows.

10.2 Rapid vegetation assessments

Where access could not be gained to sites, native vegetation patches were assessed from a distance (i.e. over fences) via a rapid method whereby the EVC was determined and a score was provided based upon the Melbourne Water Healthy Waterway Strategy *Vegetation Visions* scoring rubric. This method classifies vegetation in one of five categories which are summarised below:

- 1 (very low) – riparian vegetation is highly modified and fragmented, consisting predominantly of exotic species
- 2 (Low) – Riparian vegetation is highly modified and fragmented, but the structure of the upper and mid-storey is sufficient to convey the character of the EVC. Ground-storey is likely dominated by exotic species
- 3 (Medium) – Riparian zone consists of fragmented EVCs. Upper and mid-storey convey the character of the EVC. Ground-storey weeds are present
- 4 (High) – Riparian vegetation is relatively intact with structural elements present with high connectivity
- 5 (Very high) – Riparian vegetation is intact with all structural components present and very high connectivity

Although this method was originally designed for assessing riparian vegetation, here we adopted it for rapidly assessing native vegetation of all types to convey the character of the broader landscape.

As only native vegetation which met patch criteria (as determined by the definition provided in the *Guidelines for the removal, destruction and lopping of native vegetation*) was scored following this method, no areas were given a score of one in these assessments. Nonetheless, vegetation which met the criteria for a score of one was widespread throughout the PSPs, representing the most abundant category. Patches assessed via this method fell into either category two or three, with no patches given a score of four or five. This is reflective of the highly degraded and fragmented nature of most of the vegetation encountered throughout the three PSPs.

Rapid vegetation assessment limitations:

As we were only able to gain access to a selection of properties, the remainder were rapidly assessed from a distance (with the aid of aerial imagery). As such, Vegetation Vision scores represent best estimates which may require revision should site access be granted. Furthermore, this method only allowed for the mapping and scoring of vegetation patches which were assessable from the nearest fence line or road and thus should in no way be viewed as an exhaustive inventory of patch values within the PSPs. Additionally, closer inspection may reveal other ecological values such as the presence of threatened species, which are difficult to detect at a distance.

Native vegetation distribution:

Native vegetation was most abundant within Devon Meadows PSP area with 54 ha of native vegetation patches mapped (**Error! Reference source not found.**). This is compared with 16 ha Clyde South PSP area and 6 ha in and Casey Fields PSP area. The dominant EVC identified throughout the study area was Heathy Woodland EVC 48, with all Heathy Woodland identified falling within the Devon Meadows PSP area. Native vegetation patches within the Clyde South and Casey Fields South PSP areas predominantly consisted of fragmented linear strips of swamp scrub on roadsides and fence lines, plains grassy wetland occurring in

narrow strips within drainage lines and sedge wetland occurring in low-lying intermittently wet areas. One notable exception to this is a long corridor of native vegetation (Heathy Woodland and Plains Grassy Woodland mosaic) following the railway line in the Clyde South PSP area.

Mapped current wetlands:

As mentioned earlier, the definition of a patch of native vegetation given within the *Guidelines for the removal, destruction and lopping of native vegetation* (DELWP 2017) includes:

- Any mapped wetland including the Current Wetlands map, available in the DELWP systems and tools

As such, these have been included on the native vegetation mapping in **Error! Reference source not found.**. For the purposes of potential v egetation removal as part of future Melbourne Water works, these wetlands are considered as native vegetation patches unless:

- The mapped wetland (or part thereof) is covered by a hardened, man-made surface, such as a roadway, or

The mapped wetland does not support wetland values, evidenced by:

- Part or all the wetland not currently supporting any wetland values at the location
- It being highly unlikely to support wetland values in the future (given ongoing approved uses on and around the land in question)

The mapped wetland is permanent, deep water meaning that:

- The waterbody does not support any native vegetation
- It is highly unlikely to support native vegetation in the future

(DELWP 2018)

For a mapped wetland to be considered for exclusion from a native vegetation removal assessment under these conditions evidence must be provided to DELWP Native Vegetation Regulation and written agreement obtained. Whilst these assessments were outside the scope of this assessment, it should be kept in mind for future works which may impact mapped wetlands throughout the PSP areas.

Of the three PSP areas Clyde South had the greatest area of mapped wetlands, at 24 ha. This was followed by Devon Meadows at 5 ha and Casey Fields at 3 ha.

Recommendations:

Although much of the vegetation mapped as part of these assessments falls outside of the waterway buffers, this information is of use as it provides a strategic overview of ecological values, potential habitat corridors and patches which may allow for enhancement and extension as part of future works. It should however be stressed that most properties throughout the three PSP areas were inaccessible. Where possible, values have also been mapped utilising aerial imagery and via rapid roadside assessments. Nonetheless, there are likely further native vegetation values present throughout the PSP areas than those shown in **Error! Reference source not found.**.

Native vegetation throughout the three PSP areas was primarily of low or moderate quality. The highest quality patches noted were the Heathy Woodland and Plains Grassy Woodland mosaic running along the railway line in Clyde South and some sections of Heathy Woodland and Swampy Riparian Woodland located at 1934 South Gippsland Highway, Devon Meadows and on the adjacent parcel. Where practicable, these higher quality remnant patches should be retained and prioritised for enhancement and expansion of habitat corridors with other patches.

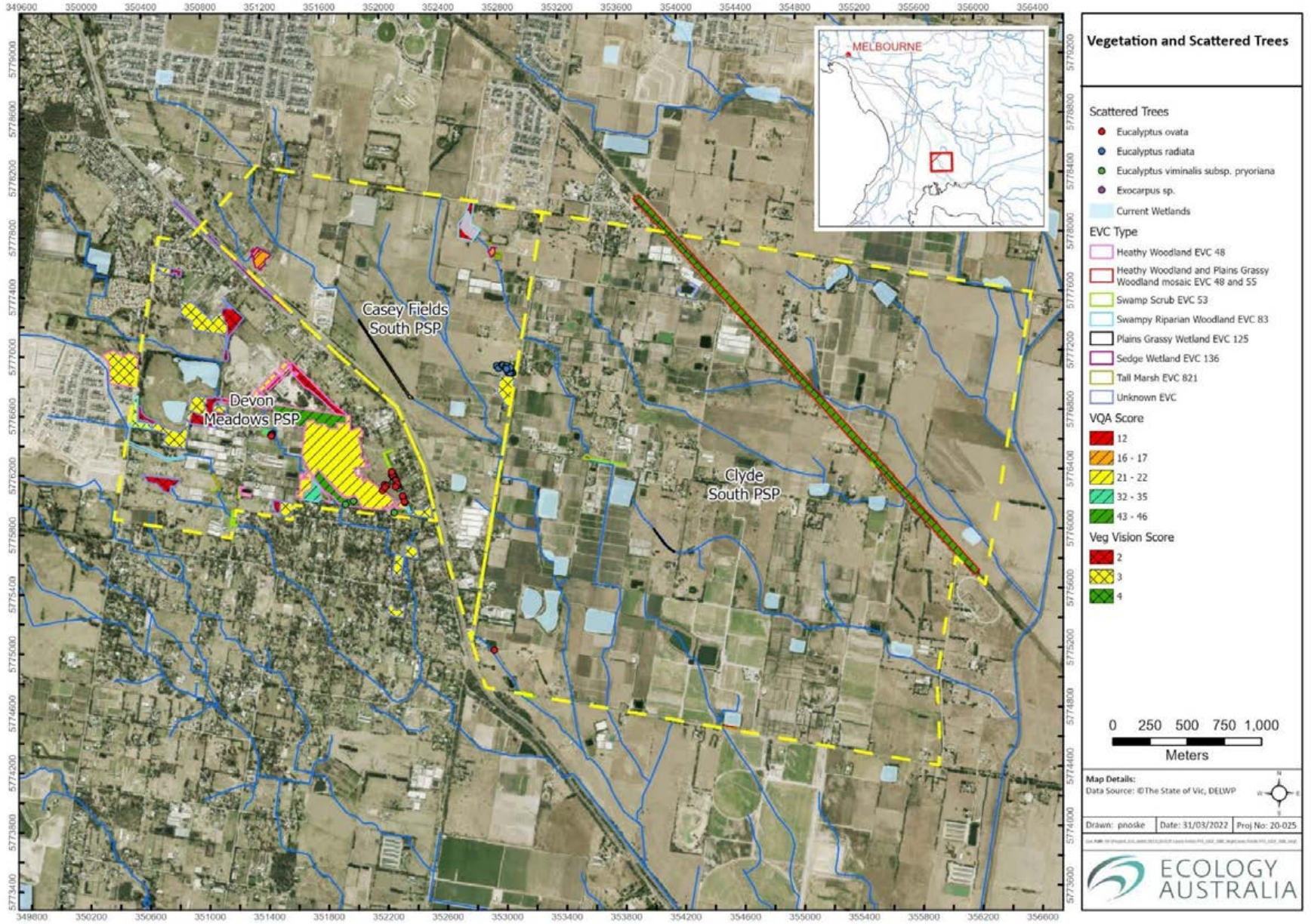


Figure 40. Native vegetation patches and scattered trees recorded within the three PSP areas. Mapped wetlands as per the DELWP current wetlands layer are also shown.

10.3 Threatened ecological communities

No threatened ecological communities were detected during field surveys. A prior desktop review using the Protected Matters Search Tool indicated that within a 5 km radius the following ecological communities may occur:

- Natural Damp Grassland of the Victorian Coastal Plains (Critically endangered)
- Subtropical and Temperate Coastal Saltmarsh (Vulnerable)
- Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains (Critically endangered)
- White Box - Yellow Box - Blakely's Red Gum Grassy Woodland and Derived Native Grassland (Critically endangered)

Natural Damp Grassland of the Victorian Coastal Plains and Subtropical and Temperate Coastal Saltmarsh were both deemed unlikely to occur within the three precincts due to the distance of the study area from the coastal plains and a lack of tidal influences. Seasonal Herbaceous Wetlands (Freshwater) of the Temperate Lowland Plains and White Box - Yellow Box - Blakely's Red Gum Grassy Woodland and Derived Native Grassland were deemed to have some likelihood of occurring within the study area. These communities were not detected during field surveys. This is likely due to the long history of agriculture and land clearing throughout the PSP areas which would have disproportionately affected the arable land on which these communities naturally occur.

10.4 Threatened species

As part of the desktop assessment, the likelihood of presence (LOP) for threatened flora and fauna species within the PSP areas was determined.

Threatened species records within 5 km of the PSP areas were obtained from the Victorian Biodiversity Atlas (VBA) (2021). Records of EPBC Act-listed species with modelled habitat within 5 km of the study area were also obtained utilising the Protected Matters Search Tool (DAWE 2021). Seven flora species were deemed to have a moderate LOP (with none deemed to have a high LOP). Five fauna species were deemed to have a moderate or greater LOP. They are as follows:

Flora species:

Flora species with a moderate LOP within the study area:

- River Swamp Wallaby-grass (*Amphibromus fluitans)*
- Pale Swamp Everlasting (*Coronidium gunnianum)*
- Matted Flax-lily (*Dianella amoena)*
- Yarra Gum (*Eucalyptus yarraensis*)
- Purple Blown-grass (*Lachnagrostis semibarbata* var. *semibarbata*)
- Swamp Fireweed (*Senecio psilocarpus*)
- Swamp Everlasting (*Xerochrysum palustre*)

Fauna species:

Fauna species with a moderate or greater LOP within the study area:

- Southern Brown Bandicoot (*Isoodon obesulus obesulus*)
- Growling Grass Frog (*Litoria raniformis*)
- Hardhead (*Aythya australis*)
- White-throated Needletail (*Hirundapus caudacutus*)
- Little Eagle (*Hieraaetus morphnoides*)

For definitions of each LOP classification see Appendix A Table 8.

Southern brown bandicoot and growling grass frog are the two threatened fauna species most likely to have a presence and could be impacted by development within or adjacent to waterways/ drainage lines. Hardhead, is a waterfowl species, that is likely to use the farm dams with open water and are quite mobile so there may be some reduction in presence in the local area upon increasing urbanisation. Little eagle is a raptor that is unlikely to have suitable nesting sites in the study area however it may forage over the agricultural landscape. Both these species are unlikely to significant population impacts from development within the study area.

While the field survey did not find any threatened flora species (listed above) their presence within the study area could not be ruled out based on potential habitat that has not had field survey.

Whilst undertaking field assessments, any threatened species encountered were noted. Three threatened species were recorded from the study area (two flora species and one fauna species). However, as will be discussed further below, the two threatened flora species were non-indigenous to the area and thus do not represent significant findings in terms of the local flora.

The limited number of threatened species found during these surveys is attributable both to the low number of properties accessible during these surveys, and the highly degraded nature of much of the vegetation present throughout the three precincts. Furthermore, only incidental faunal species records were made during these surveys. Further targeted surveys are necessary for species of interest such as growling grass frog *Litoria raniformis*, which was deemed as having moderate LOP throughout the three precincts in the desktop study (Section 6).

The restricted nature of the field surveys represents a limitation of the findings of this report. A precautionary approach including further targeted surveys prior to the commencement of works is recommended, with a particular focus on species identified as having a moderate or high likelihood of presence in the desktop review. For a comprehensive list of threatened species which have been recorded within the vicinity of the study area or have modelled habitat within the vicinity of the study area, see Section 6.

Threatened flora species detected during field surveys:

No *EPBC Act*-listed flora species were detected during field surveys, however, two *FFG Act*-listed threatened flora species were detected. These species are discussed further below.

Spotted gum *Corymbia maculata*:

Spotted gums are listed as vulnerable in Victoria and were encountered during field surveys. However, in Victoria spotted gums are only indigenous to the Mottle Ranges in the far east. They are a commonly planted ornamental species which has naturalised throughout much of the rest of the state, and thus in this instance are non-indigenous to the local area and were not mapped. Furthermore, as planted vegetation they are exempt from the need for a permit to clear under Clause 52.17 of the Casey Planning Scheme.



Figure 41. Planted spotted gums noted from a property in Clyde South



Figure 42. Planted windbreak of giant honey-myrtle noted from a property in Clyde South

Giant honey-myrtle *Melaleuca armillaris* subsp. *armillaris*

Planted windbreaks of giant honey-myrtle were noted from several properties throughout the PSPs. Giant honey-myrtle is listed as endangered within Victoria, however, as with spotted gums, it is indigenous only in the far east of the state and elsewhere has been planted or escaped cultivation and become naturalised. As such and given that they are also exempt from the need for a permit to clear under Clause 52.17 of the Casey Planning Scheme, this distribution of this species also was not mapped throughout the PSPs.

Threatened fauna species detected during field surveys:

One threatened fauna species was incidentally encountered during field surveys – the white throated needletail *Hirundapas caudacutus*. This species is listed as vulnerable under the *FFG* and *EPBC Acts*. As a listed migratory and marine species, it also garners further protection under the *EPBC Act*.

White-throated needletail *Hirundapas caudacutus*

The white-throated needletail was recorded once from the study area flying overhead at 76 Devon Road, Devon Meadows. White-throated needletails are an almost exclusively aerial species in Australia. As such, habitat descriptions for the species are varied, with it having been recorded flying above a diverse range of habitat types (Coventry 1989). In this instance, the individual was recorded flying above a landscape consisting of market gardens and farm dams adjacent to remnant heathy woodland.



Figure 43. White-throated needletail in flight (Source: eBird n.d.)

Potential significant impacts

Given their mainly airborne nature, there are few threats to white-throated needletails in Australia. However, the species is threatened in Australia by the use of insecticides (leading to a reduction in invertebrate prey and potential secondary poisoning) and a reduction in roosting sites due to clearing of forest and woodland habitat (Tarburton 2014). Though it has been noted that there is also the constant threat of collision with wind turbines, windows, lighthouses and overhead wires, this is unlikely to threaten the species as a whole (DAWE n.d.).

Although specifications of Melbourne Water's plans within the PSP areas have not yet been released, it appears unlikely that activities would have a significant impact on this species, as per the Matters of National Environmental Significance Significant Impact Guidelines 1.1 (Department of Environment 2013). The exception to this may be in the case of significant clearing of woodland or forest habitat (which may provide potential roosting locations for the species). However, given the already low extent of remnant woodland and forest habitat along waterways within the PSPs, this is of low likelihood.

Other flora and fauna species recorded during surveys

A total of 125 flora taxa were recorded during field surveys across the three PSP areas. Sixty-nine of these were of exotic origin and a further nine were native species occurring outside of their natural range or of uncertain origin. Thirty-three fauna species were recorded during surveys, these were primarily of native origin, with only five exotic species recorded. Twenty-six of these species were birds, in addition to four mammals, two amphibians and one reptile. The high proportion of bird species recorded reflects a bias towards records of this lifeform during incidental surveys, but also reflects the habitat value of the many farm dams present throughout the study area, with most bird species

sighted at said dams. Comprehensive lists of all flora and fauna recorded throughout the study area during the March field surveys can be found in Appendix D.

10.5 Habitat values

During the desktop assessment component, growling grass frogs (GGF) and southern brown bandicoots (SBB) were identified as having moderate and high LOPs in parts of the study area. These assessments were based upon records held within Victorian Biodiversity Atlas (VBA) (DELWP 2021), habitat modelling obtained through the Protected Matters Search Tool (PMST) (DAWE 2021) and an assessment of other landscape factors such as available habitat likely present within the study area and links to known populations.

The distribution of potential GGF and SBB habitat encountered throughout the study area was mapped during field surveys. This mapping gives an indication of areas or vegetation types of possible habitat significance which may require consideration for protection or replacement during future planning.

Growling grass frog habitat

GGFs are associated with permanent or semi-permanent waterbodies that are either still or very slow flowing. Ideally these waterbodies contain a diverse range of aquatic vegetation including emergent, submerged, and floating vegetation. The range of aquatic vegetation is particularly important during breeding events. In addition to the aquatic requirements of the pools themselves, relatively open terrestrial habitat is required adjacent to waterbodies. The terrestrial habitat is used to overwinter or when temporary pools dry up. The terrestrial surrounds are also used for feeding (DEPI 2013).

On properties surveyed throughout the three precincts, the primary source of potential GGF identified was farm and irrigation dams, although these were of varying habitat value. Areas deemed to have moderate habitat value tended to exhibit abundant fringing vegetation throughout different stratum, as well as sometimes also containing submergent aquatic vegetation (Figure 44). Areas of lower habitat value tended to be dams with little to no fringing or submergent aquatic vegetation (Figure 45). It is worth noting that vegetation did not always have to be native to be considered of habitat value for GGFs. Lesser reed-mace was frequently encountered as a fringing species of dams which provided cover potentially suitable for GGFs. No habitat was considered of high habitat values, primarily due to the lack of appropriate vegetation across all stratum (with a conspicuous lack of floating and submergent vegetation at most sites).

Another source of potential transitory GGF habitat identified during site visits throughout the three precincts were drainage lines. Drainage lines act as a dispersal pathway for GGFs when conditions become unsuitable at their current wetland and they look to move elsewhere. The increasing fragmentation of habitats and loss of dispersal corridors has been identified as a key cause of decline in amphibian populations (DEPI 2013). As such, suitable habitat links should be protected and enhanced where practicable.



Figure 44. Dam in Devon Meadows deemed as having moderate GGF habitat values. This example is fringed with common spike-sedge and lesser reed-mace. Submergent blunt pondweed *Potamogeton ochreatus* is also present here.



Figure 45. Dam in Clyde South deemed as having low GGF habitat values due to the absence of emergent, floating or submergent vegetation.

Growling grass frog habitat distribution

GGF habitat was mapped across the three PSPs during field visits (where access could be granted) and via aerial imagery where site access could not be gained and waterbodies could not be assessed from neighbouring properties (**Error! Reference source not found.**). Across the three PSPs, h abitat was considered to be either of low or moderate quality for GGFs. As discussed above, areas deemed to be of low habitat quality still exhibited some structural features necessary to support GGFs (e.g. the presence of a waterbody), but tended to lack sufficient vegetative features to aid in the protection of GGFs from predators (i.e. fringing, aquatic, submergent and floating vegetation) (DELWP 2017)

Throughout the three PSPs, 68 ha of low quality GGF habitat was identified. 49 ha of this was located within Clyde South PSP area, 9 ha within Casey Fields South PSP area and 10 ha within Devon Meadows PSP area. Moderate quality GGF habitat was less abundant, with only 20 ha present across the three PSPs. Clyde South PSP contained the largest area of moderate quality GGF habitat at 15 ha, followed by Casey Fields South and Devon Meadows (at 3 ha each).

Clyde South PSP area is also of strategic landscape importance given its location adjacent to Conservation Area 36. Conservation Area 36, which is located directly northeast of Clyde South, has been identified as significant as it contains GGF populations and high quality GGF habitat (DEPI 2013).

GGF habitat throughout the PSPs was composed primarily of farm irrigation dams, wetlands and drainage lines. It is worth noting that although only habitat which supported a waterbody or drainage line was mapped, GGFs also periodically make use of open, terrestrial habitats adjacent to waterbodies to overwinter and feed (DELWP 2017). As such, the true extent of potential GGF habitat throughout the PSP areas is likely greater when considering this form of intermittently used habitat.

The future Regional Parklands and adjoining Melbourne Water retarding basin (Graham Road Retarding Basin) on the eastern edge of Clyde South PSP, if implemented with carefully considered design, may support a further habitat node for landscape connectivity of GGF habitat.

Within the PSP areas, drainage lines provided potential habitat corridors between permanent and semi-permanent wetland habitats. This is important, given that GGF populations often act as interconnected metapopulations, moving through the landscape when the current habitat being used becomes unsuitable. The ability to move through the landscape has been shown to have strong impacts on the persistence of GGF populations.



Figure 46. Drainage line in Casey Fields South which may act as a potential GGF dispersal corridor

However, within the PSP areas, these drainage lines tended to be narrow and surrounded by densely grazed pasture (as in Figure 46). This likely lowers the habitat suitability for GGFs as they are threatened both by grazing damage to wetland margins and decreases in water quality (DELWP 2017).

Recommendations

No records of GGFs are contained within the VBA for the study area. However, this is likely reflective of low survey and recording effort due to a large proportion of land in the three precincts being private and often agricultural in nature. Given the proximity of the precincts to known GGF populations, and the abundance of potential habitat and habitat corridors (in particular for Clyde South), further targeted GGF surveys are recommended to inform planning decisions within the PSP areas.

Further recommendations for the promotion and conservation of potential GGF populations within the PSP areas include:

- Fencing of strategically important drainage lines to preclude grazing and improve habitat structure and water quality within potential GGF corridors
- Revegetation of drainage lines and dams to improve structural heterogeneity and provide habitat for all life stages of GGFs
- Development of future drainage strategies should incorporate additional viable breeding and movement corridors (appropriate bathymetry, hydrology and vegetation) for GGF within the study area.

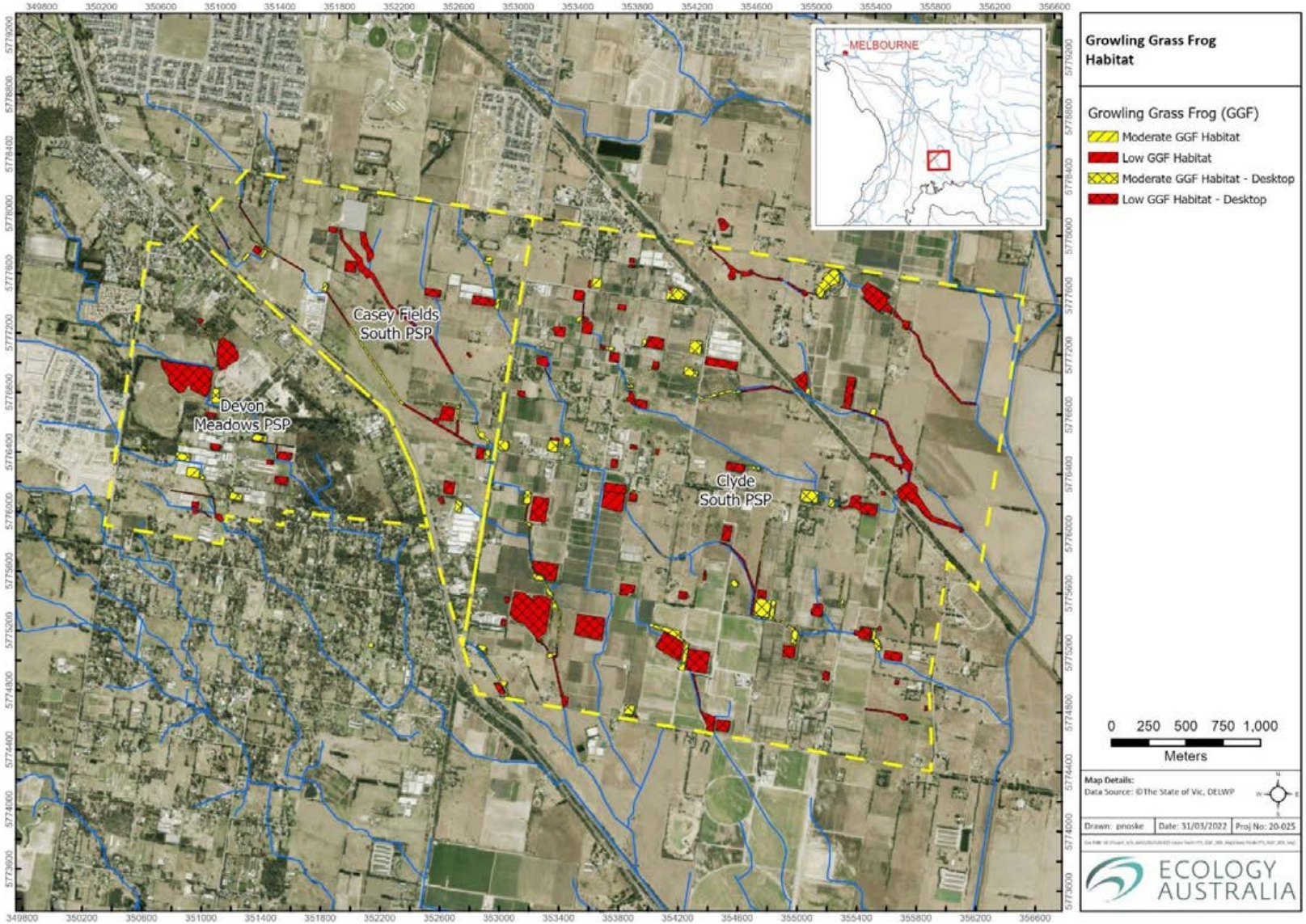


Figure 47. Distribution of GGF habitat throughout the three PSPs. Cross hatching indicates habitat which has been rapidly assessed via aerial imagery, whereas single-hatched lines indicate habitat which was ground-truthed in the field.

Southern brown bandicoot habitat

The SBB is known to use a range of habitats ranging from sedgelands and heathlands through to open forests (DAWE 2021). The upper stratum of the habitat can be low or tall woodland, but the critical factor in what is considered good SBB habitat is a dense groundcover. Suitable habitat will contain an understory with 50–80% foliage density in the height range of 0.2–1 m. The distinction between native and non-native vegetation is not important for the bandicoot, and often species like Blackberry (*Rubus* spp.) provides good habitat as it can form dense stands.

Mapping of potentially suitable SBB habitat along waterways and on adjacent land was undertaken during field surveys. Due to the highly degraded nature of much of the vegetation throughout the precincts, non-native vegetation comprised a large portion of potential SBB habitat. A common example of this were dense stands of Blackberry (**Error! Reference source not found.**). Patches of suitable habitat encountered were generally small and highly fragmented, often running along fence or drainage lines. Nonetheless they may still allow for some mobility of the species throughout the landscape.

Other examples of potentially suitable SBB habitat which were composed predominantly of native species included dense stands of common reed, *Juncus* spp. or austral bracken (with austral bracken generally seen growing in association with heathy woodland vegetation).



Figure 48. A dense stand of blackberry growing beneath swamp paperbark which may act as a potential SBB habitat corridor. This was noted from a roadside surveyed in Clyde South.



Figure 49. Dense stand of austral bracken (growing amongst other heathy woodland vegetation) which offers high habitat value for SBB. This was noted from a property surveyed at 1934 South Gippsland Highway, Devon Meadows.

Southern Brown Bandicoot habitat distribution

SBB habitat was also mapped across the three PSPs during field visits (where access could be granted) and via aerial imagery where site access could not be gained and vegetation could not be assessed from neighbouring properties.

Across the three PSP areas, Devon Meadows exhibited the most potential for SBB habitat, with 37 ha of potential SBB habitat identified (**Error! Reference source not found.**). This was primarily due to a high-quality site located at 1934 South Gippsland Highway, Devon Meadows, which contained the most extensive remnant vegetation assessed throughout the three PSP areas. This property contained significant SBB habitat values due to the presence of a dense understorey of austral bracken (and blackberry in some areas) throughout much of the site (Figure 49).

Across the three PSP areas, 69 ha of potential SBB habitat was identified. Twenty-four hectares of this was deemed high quality SBB habitat, 21 ha of this from Devon Meadows and 3 ha from Casey Fields South. Moderate quality SBB habitat was most abundant, with 38 ha across the three PSP areas. Clyde South PSP area contained the largest area of moderate quality SBB habitat at 17 ha, followed by Devon Meadows and Casey Fields South (14 ha and 8 ha, respectively). A further 7 ha of low quality SBB habitat was identified throughout the three PSP areas. Four hectares of this was located within Clyde South PSP, and 3 ha within Devon Meadows PSP area.

Clyde South and Casey Fields South PSP areas contained relatively little potential SBB habitat due to the lack of remnant vegetation throughout the precinct. Additionally, intensive grazing and cropping throughout the precinct has given rise to a short, simplified vegetation structure which does not provide the necessary cover for SBBs (50–80% foliage density in the height range of 0.2–1 m).

SBB habitat throughout the three PSP areas is highly fragmented in nature, likely impeding SBB movement throughout the area. The Sub-regional Species Strategy for the Southern Brown Bandicoot Supplement: Habitat Connectivity (DEPI 2014) outlines that habitat connectivity corridors will be created in Devon Meadows (and Botanic

Ridge to the west) by revegetation to enable movement from a significant SBB population at the Royal Botanic Gardens Cranbourne (RBGC) into neighboring suburbs and rural areas to the south of the Urban Growth Boundary. The Sub-regional Species Strategy outlines that as part of this commitment the Victorian Government (acting through Melbourne Water and other government organisations) is responsible for the creation and enhancement of SBB habitat within drainage corridors throughout the Devon Meadows PSP.

Recommendations

- Retain and expand upon current SBB habitat present throughout PSP areas, with particular focus given to Devon Meadows as the most significant precinct in terms of existing SBB habitat and habitat links
- Ecology Australia (2008) noted that SBB within the former Koo Wee Rup Swamp area are often restricted to small, isolated or loosely connected patches of remnant vegetation, often on private land, reserves, road corridors and waterways. Bandicoot-friendly design of waterways throughout the precincts may therefore provide a rare opportunity to increase habitat connectivity between these isolated patches, particularly given that SBB are already known to utilise these riparian zones.
- Where removal of dense patches of exotic species is planned, consider implementing this in a staged manner where native SBB habitat species are planted and allowed to establish prior to the removal of exotic species. This is significant given that potential SBB habitat throughout the PSP areas was often provided by dense stands of exotic species such as Blackberry
- Emphasize retention of native vegetation where possible over clearing and replanting. Optimal SBB habitat is characterised by a dense lower stratum (in the 0.2-1 m height range). As such, revegetation sites will take some time to reach this density and provide adequate cover. In some cases, supplementation of existing native vegetation patches with infill planting may also be beneficial to increase vegetation density.

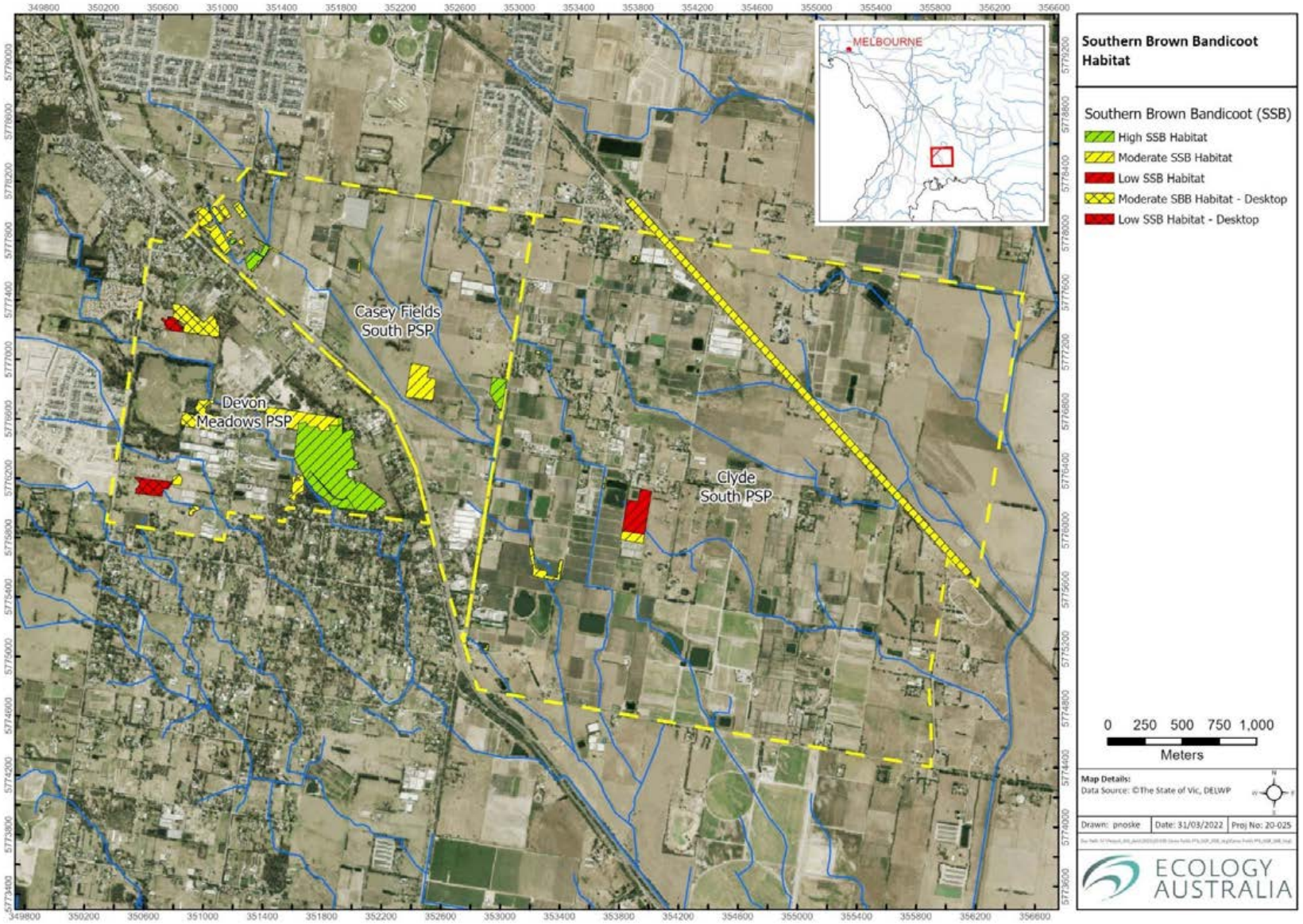


Figure 50. Distribution of SSB habitat throughout the three PSPs. Cross-hatching indicates habitat which has been rapidly assessed via aerial imagery, whereas single-hatched lines indicate habitat which was ground-truthed in the field.

11 Recommendations

Across the study area, both geomorphic and vegetation values were found to be limited. All the waterways assessed on the ground within the study area are anthropogenic drains. Many of these drains are discontinuous and drain to local dams. The PSPs cover an area that once comprised Koo Wee Rup Swamp and as a result, all drainage across the site is the result of human modification.

From a geomorphic perspective, risks associated with development across the site appear to be minor. No significant areas of erosion were observed during site assessments. According to the soil mapping for the area, the development site overlays a small band of sodic soil. At present, only small reaches of two drains intersect this soil type. In the field, these reaches did not reveal characteristics usually associated with disturbed sodic soils such as tunnelling. This risk should be kept in mind for future development and disturbance of this soil type should be limited. Similarly, mapping of potential acid sulfate soils shows the PSP areas are not considered to be at risk.

Vegetation along waterways was generally comprised exotic species with some common native species which are frequently found in modified waterway or wetland settings. Vegetation along the waterways was also in poor condition. In areas where vegetation met the criteria to be considered a native vegetation patch, rapid condition assessments were undertaken. These assessments found that most patches were in poor to moderate condition. The highest quality patches noted were the Heathy Woodland and Plains Grassy Woodland mosaic running along the railway line in Clyde South and some sections of Heathy Woodland and Swampy Riparian Woodland located at 1934 South Gippsland Highway, Devon Meadows and on the adjacent parcel.

Habitat suitability to Southern brown bandicoot and Growling grass frog was mapped as a part of this project. Across the PSP areas there was 37 ha of potential southern brown bandicoot habitat which was rated as high suitability. Patches of moderate and low suitability habitat were also mapped. Potential growling grass frog habitat consisted of patches of both low and moderate suitability. At present, there are no records of GGFs contained within the VBA for the study area. This is likely reflective of low survey and recording effort due to a large proportion of land in the three precincts being private and often agricultural in nature.

Based on these key findings we recommend:

1. Waterways are suitable to be developed as constructed waterways. Future constructed waterways should resolve the discontinuous network of waterways and dams across the PSP areas and provide an opportunity to improve values.
2. High quality patches of Heathy Woodland and Swampy Riparian Woodland located at 1934 South Gippsland Highway, Devon Meadows should be retained and prioritised for enhancement.
3. Patches of high-quality Heathy Woodland and Plains Grassy Woodland mosaic running along the railway line in Clyde South should be retained.
4. High suitability southern brown bandicoot habitat at 1934 South Gippsland Highway, Devon Meadows and the adjacent property should be retained and prioritised for the enhancement and expansion of habitat corridors.

5. Targeted surveys of growling grass frog should be undertaken to inform future decisions about the management and improvement of low and moderate suitability habitats that have been identified across the PSP areas.

11.1 Limitations

The assessment of geomorphology and vegetation values within the PSP areas is a preliminary assessment. Recommendations have been made based on sites that were visited during field visits. Access across the three PSP areas was limited, particularly within the Clyde South PSP area. Most waterways within this PSP area were not able to be surveyed in the field. Based on the desktop assessment, it is not expected that geomorphic forms and processes at sites that could not be visited are substantially different than those that could be accessed. There is a higher level of uncertainty relating to the assessment of vegetation values. The assessment of vegetation values is a high-level preliminary assessment of sites that could be accessed in the field. It is important to note that vegetation surveys were conducted at the beginning of Autumn which is not the most ideal timing to identify all possible values. More detailed vegetation assessments should be undertaken in the design of drainage assets for the area.

11.2 Opportunities

Four key opportunities associated with future development have been identified during this assessment.

1. Without active management, it is assumed that headwater streams will be lost in the course of development. Converting these areas to constructed waterways provides an opportunity to retain more water in the landscape through design. Additionally, the replacement of drains with constructed waterways provides opportunity to enhance vegetation values across the PSP areas. Native vegetation which is currently along waterways but in poor condition could be replicated with improved condition, structure, and diversity as a part of the construction of new waterways.

2. This provides an opportunity to progress towards the performance objectives for rivers within the Westernport and Mornington Peninsula region as laid out in the Melbourne Water (2018) Healthy Waterway Strategy. Nine key values are identified for rivers, including several environmental values (birds, fish, frogs, macroinvertebrates, platypus and vegetation) as well as amenity, community connection and recreation. Performance objectives which may be progressed by these works include the establishment and maintenance of continuous vegetation buffers, maintenance of high-quality vegetation, increased access to and along waterways, reduced nutrient and sediment runoff from rural land and conservation of water dependent species and communities.

3. Growling grass frogs have not been identified within the PSP areas, although this may be due to a low surveying effort. Across the three PSP areas many patches of low and moderate habitat suitability have been mapped. Development of the area could provide an opportunity to improve the habitat suitability by considering:

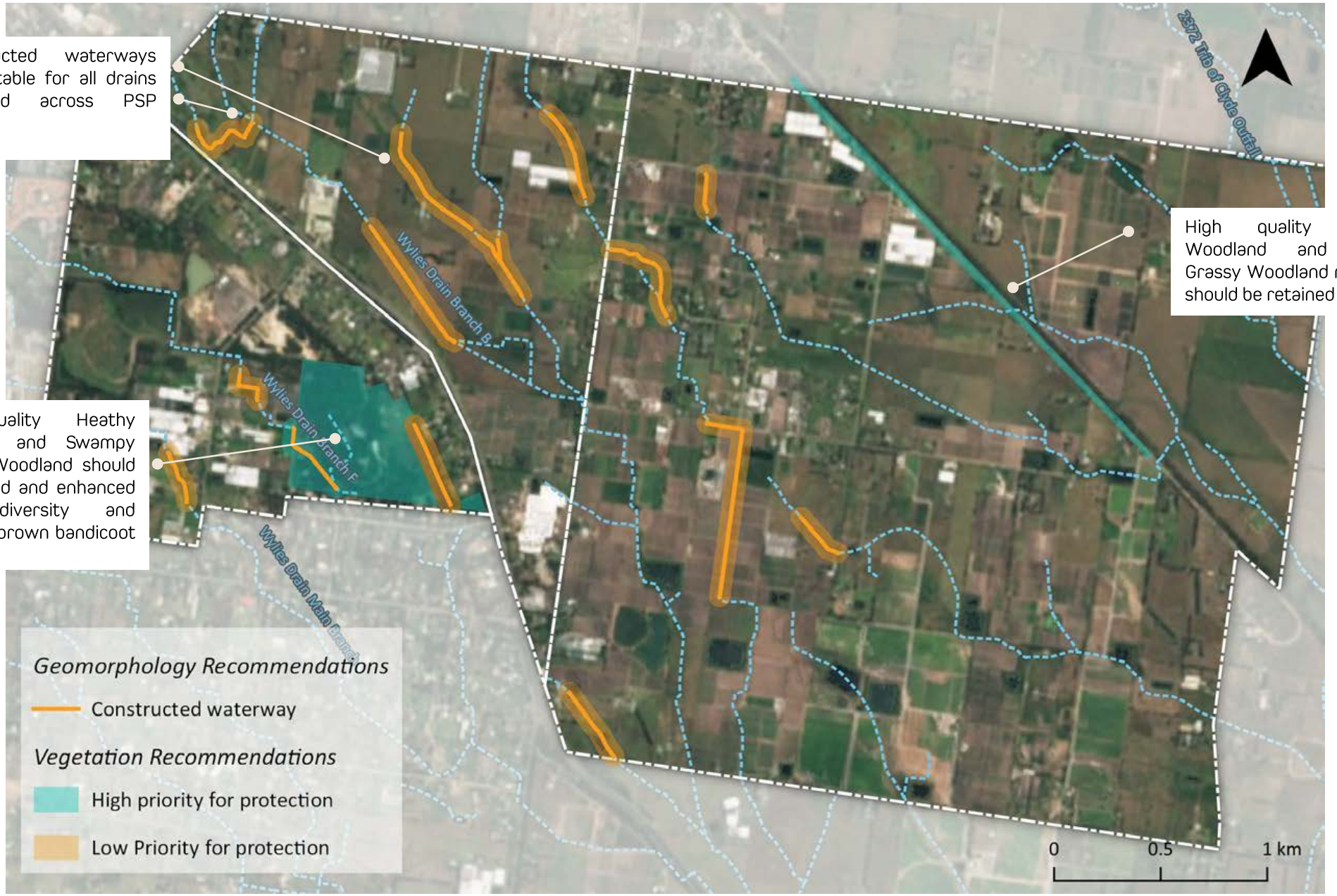
a. Fencing of strategically important drainage lines to preclude grazing and improve habitat structure and water quality within potential GGF corridors
b. Revegetation of drainage lines and dams to improve structural heterogeneity and provide habitat for all life stages of GGFs
c. Development of future drainage strategies should incorporate additional viable breeding and movement corridors (appropriate bathymetry, hydrology and vegetation) for GGF within the study area.

4. Parts of the PSP area contain high and moderate suitability habitat for southern brown bandicoot, totalling up to 69 ha. Development of waterways across the site provides an opportunity to create corridors – through the improvement of existing high-quality sites and considered revegetation of new waterway corridors to enable movement of the population at the Royal Botanic Gardens in Cranbourne. The creation of habitat connectivity corridors in Devon Meadows was identified in the Sub-regional Species Strategy for the Southern Brown Bandicoot Supplement: Habitat Connectivity (DEPI 2014).

Constructed waterways are suitable for all drains assessed across PSP areas.

High quality Heathy Woodland and Plains Grassy Woodland mosaic – should be retained

High quality Heathy Woodland and Swampy Riparian Woodland should be retained and enhanced for biodiversity and Southern brown bandicoot habitat.



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APPENDICES

Appendix A: Methods

Geomorphology

Streamology undertook a PSP and reach specific assessment to consolidate existing knowledge and information and identify representative locations for the field assessment components. Specific focus for this assessment was on the following physical form components:

- Characteristics (values, form, and process of the waterway),
- Existing waterway condition,
- Likely stressors (with reference to excess stormwater runoff from urban development), and
- Trajectory of change.

The data review of available spatial data for the desktop assessment included;

- MW Physical Form Framework
- RiverStyles mapping
- Surface geology
- Geomorphological management units
- Australian Soil Classification soil mapping

Flora and Fauna

Flora and fauna data review

Ecology Australia undertook a review of online databases and previous reports to inform the design of survey methods and identify rare or threatened species or communities likely to occur within the study area. This review compiled information from the following sources:

- Flora and fauna records within 5 km of the study area held in DELWP's Victorian Biodiversity Atlas (VBA) online database (DELWP 2021a). VBA records were limited to those occurring post-1980 as the intense development of the area after this point reduces the usefulness of older historic records
- Aquatic fauna records from the catchments within and surrounding the study area held in the VBA and Melbourne Water Fish Database
- Broader catchment-based VBA and Melbourne Water Fish Database searches for Dwarf Galaxias
- Records of ecological communities and flora and fauna species listed under the EPBC Act within a 5 km radius of the study area using the EPBC Protected Matters Search Tool (PMST) (DAWE 2021)
- Vegetation assessment with reference to Melbourne Strategic Assessment mapping and timestamping of vegetation
- Department of Environment, Land, Water and Planning NatureKit interactive map for Ecological Vegetation Class (EVC) mapping/modelling (DELWP 2021b) of the area (both extant and pre-1750)
- Relevant GIS data and aerial photography
- Desktop assessment for suitable Southern Brown Bandicoot habitat with reference to the Biodiversity Strategy

- Desktop assessment for potential Growling Grass Frog habitats; covering waterways, mapped drainage lines and farm dams
- Desktop assessment of potential Dwarf Galaxias habitat suitability including connectivity of waterbodies, waterways, drains, dams and low-lying areas
- Review of relevant national, state and local legislation and policies, including Melbourne Water strategies
- Review of relevant publicly available reports and technical reports provided by the client for the study area and surrounds.

Review of relevant reports

Relevant reports that were reviewed include:

- Casey Planning Scheme – zones and overlays
- Biodiversity Conservation Strategy Melbourne Strategic Assessment
- City of Casey Biodiversity Strategy
- Casey Growth Area Planning – assessment of the risk to water dependant environmental values from the development of the Casey Growth Area (Part A – Clyde Creek/ Western Outfall Drain and Muddy Gates Drain. (SKM 2012)
- Casey Growth Area Planning – assessment of the risk to water dependant environmental values from the development of the Casey Growth Area (Part B – Wylies Drain) (SKM 2012a)
- Casey Growth Area Planning – Issues Paper (SKM 2012b)
- Casey Growth Area Planning – Risk assessment Summary Report (SKM 2012c)
- Sub-regional Species Strategy for the Southern Brown Bandicoot (DEPI 2013)
- Sub-regional Species Strategy for the Southern Brown Bandicoot, supplement: Habitat connectivity, Melbourne Strategic Assessment (DEPI 2014)
- Implementation Plan for the Southern Brown Bandicoot Sub-regional Species Strategy (DELWP 2016)
- Botanic Ridge Precinct Structure Plan (amended 2017) (VPA 2012)
- Biodiversity Assessment Report, revised – Botanic Ridge – PSP10 (Practical Ecology 2010)
- Significant impact guidelines or the vulnerable Growling Grass Frog (*Litoria raniformis*) (Commonwealth of Australia 2009)
- Growling Grass Frog Masterplan for Melbourne's Growth Corridors, Melbourne Strategic Assessment (DELWP 2017a)
- Sub-regional species strategy for the Growling Grass Frog (DEPI 2013b)
- Growling Grass Frog Habitat Design Standards, Melbourne Strategic Assessment (DELWP 2017b)
- Growling Grass Frog Crossing Design Standards, Melbourne Strategic Assessment (DELWP 2017c)
- Botanic Ridge Native Vegetation Plan December 2012 (GAA 2012)

- Cranbourne East Precinct Structure Plan, Flora and Fauna existing conditions (Golder Associates 2007)
- Cranbourne East Precinct Structure Plan (including Cranbourne East Native Vegetation Precinct Plan) (GAA 2010)

Likelihood of presence

Species which are listed as threatened under the EPBC Act (1999) or FFG Act (1988) were assessed for likelihood of presence within the study area. Determining likelihood of presence is a subjective process which considers the following:

- Documented habitats and ecological requirements for relevant species
- Presence of suitable habitat within the study area, based on a brief site assessment
- Attributes of suitable habitat, including size, shape and landscape context
- Number, age and distribution of previous records, taking into account the likely survey history in terms of intensity and frequency.

A general description of the likelihood classifications is provided in Table 8.

EVC mapping and vegetation quality assessments

Where site access could be arranged, vegetation assessments were undertaken in the riparian areas, as well as throughout the remainder of the property to give a broader understanding of the landscape ecological values.

Vegetation was first categorised as native or non-native in line with Clause 73.01 of the *Guidelines for the removal, destruction and lopping of native vegetation* (DELWP 2017) which defines native vegetation as 'plants that are indigenous to Victoria, including trees, shrubs, herbs, and grasses'. The Guidelines further classify native vegetation as either a patch or a scattered tree (DELWP 2017).

A patch of native vegetation is defined as:

- An area of vegetation where at least 25% of the total perennial understorey plant cover is native; or
- Any area with three or more native canopy trees where the drip line of each tree touches the drip line of at least one other tree, forming a continuous canopy; or
- Any mapped wetland including the Current Wetlands map, available in the DELWP systems and tools.

Where vegetation met the requirements to be considered a patch (and was able to be accessed and assessed via a site walk-through) vegetation quality assessments were undertaken to determine the condition of said vegetation, including the presence of habitat zones.

Scattered trees (native canopy trees that do not form part of a patch) present on properties surveyed were also mapped as part of these assessments.

Table 8. Description of likelihood classifications

Likelihood	Definition
Not Likely	Study area is located outside the known geographic range for the taxon or does not contain necessary landscape features and/or habitats documented for that taxon.
Low	Study area lies within, or on the edge, of the geographic range for the taxon, and supports major habitat elements, but is lacking in one or more critical features, or is located within a landscape that will most likely preclude occupancy or regular use. Historic records may be supported by more recent records within 5 km of the study area.
Moderate	The location and geographic features of the study area match that which is known for the taxon. Habitat shares numerous floristic, structural or physical similarities with documented habitats, but may be limited with regard to one or more known ecological requirements (e.g. size, landscape context or critical resources). Historic and contemporary records occur within 5 km of the study area and/or the broader region.
High	Location of the study area lies within the known range and distribution for the taxon. Habitats present within the study area match that documented for the taxon with regard to floristics and/or structure and satisfy the known ecological requirements. Multiple historic and recent records within the surrounding landscape indicate occurrence or regular use of the area.
Known	Taxon recorded within the study area during the current assessment or other recent assessment.

Appendix B: Hydrologic modelling

Source hydrologic model has been used to simulate rainfall-runoff model over the Casey Field project area to investigate the hydrologic characteristics of the catchment. The objective of the modelling is to understand the catchment response to rainfall-runoff and quantify flow time series data at different flow sites, which will be used to simulate different hydraulic characteristics in the project area.

Source

Source is a computer-based application software that can be used for both catchment and river modelling. It has become the adopted tool for managing Australia's scarce and highly variable water resources. It is based on modern tools and the best available research as Australia's National Hydrological Modelling Platform. It has been applied and validated by many water experts not only in Australia but also in many different countries with a wide-range of real-water situations.

In this project, Source 5.12.0 is used where a range of rainfall-runoff models (e.g., Observed Runoff, AWBM, GR4J, SMARG, Sacramento etc.) are available. In this version of the software, rainfall and potential evapotranspiration can be defined, faster and more reliable numerical solutions are incorporated with defining an appropriate rainfall-runoff model, and hydrographs can be extracted at hydrologic junction (i.e., flow site).

The modelling starts with defining the catchments from Digital Elevation Model (DEM). The process is then to define the functional units from land cover/use dataset and rainfall-runoff model with inputting required data and parameterisation.

Elevation data and catchment delineation

For terrain setup, Shuttle Radar Topography Mission (SRTM) 30 m data were used covering the areas Casey Field, Devon Meadows and Clyde South PSP. Prior to use this data in the model, required DEM pre-processing such as 'Fill Sink' operation was carried out to remove small imperfections (i.e., sink) in the data. The extent of the DEM was retained wider than the project area to ensure rainfall and evapotranspiration data availability. Figure 51 shows the terrain data in ArcGIS view.

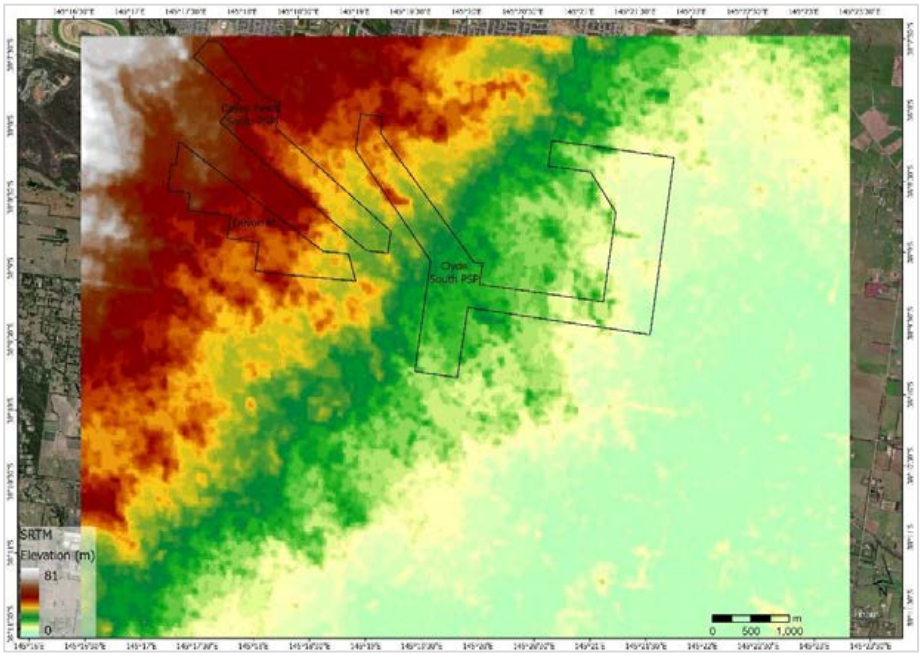


Figure 51. SRTM elevation map of the Casey Fields, Devon Meadows and Clyde South PSP areas

Model setup

Network Delineation

As the initial process of model setup, a DEM based catchment with an appropriate and representative hydrological network generation was introduced as in Figure 53. The minimum sub-catchment area for this network was applied as 0.5 m^2, which produced the following sub-catchments with a hydrological network (Figure 53).

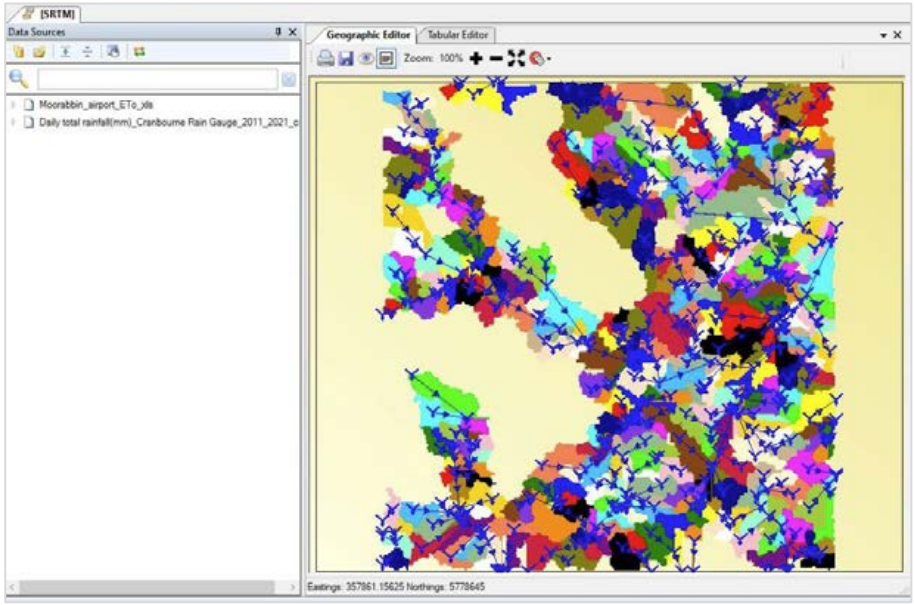


Figure 53. Sub-catchment and hydrological network of the model in Source view

Functional units

As in Figure 52, a total of 2,577 blocks of individual functional units that represent five different types of land covers (Park, natural, pasture and grassland, developed and farming site) were captured from the Land use dataset. The land use dataset was developed by the Spatial Information Sciences Group of the Agriculture Victoria Research in the Department of Economic Development, Jobs, Transport, and Resources in 2017 survey.

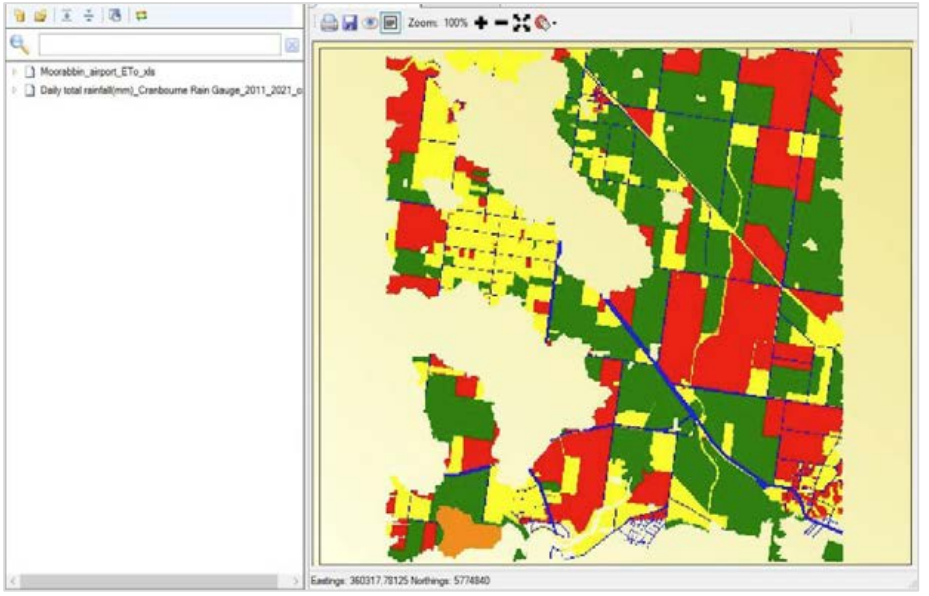


Figure 52. Functional units map in the model area

Rainfall-runoff model and dataset

We used the GR4J rainfall-runoff model in this project. The model is one of the simplest hydrological models of Source with only two water stores (production and routing) and four parameters. A study carried out by Zhang, Waters et al. (2013) depicted that this GR4J model performs better than other rainfall-runoff models- Australia Water Balance Model (AWBM) and Sacramento in terms of computational efficiency.

In the preparation phase of the model, it requires two time series datasets- 1) Rainfall and 2) Evapotranspiration as in Figure 54. Further with the preparation phase, the model needs to have parameter values set and, in this case, we used the default parameters set in the model. The Source includes two baseflow filter parameters (*k* and C), which do not affect the total flow, but do determines slow and quick flow. The parameters can be left at their default values of 0 or can be changed with some sensible values. In this regard, we inputted 0.95 for *k* and 0.15 for C in our Source model.



Figure 54. Rainfall-runoff time-series at Cranbourne rain gauge in Source view (top), evapotranspiration (ETo) time-series at Moorabbin airport in Source view (bottom)

Results

Source model is capable to generate downstream flow at different hydrologic junctions created in the hydrological network. In this project, the main objective was to generate a similar kind of flow time series data at the stormwater outlet (i.e., one of the nodes in the hydrological network) and then use this time series data in a 2D hydraulic model (HEC-RAS) as one of the boundary conditions. Now, the Source generated flow time series data at four flow sites is presented below. Note that the Devon Meadows area has got two flow sites whereas other two areas (Casey Field and Clyde South PSP) has got one flow site.

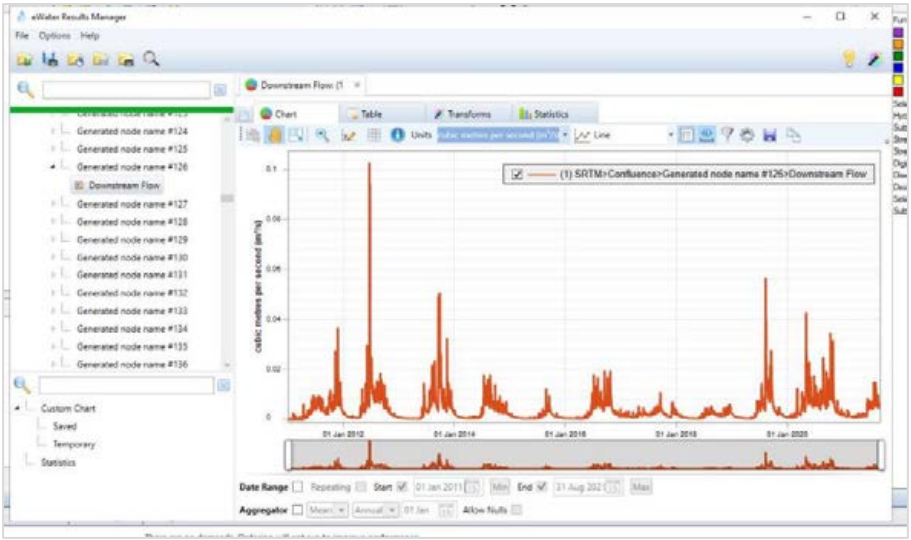


Figure 55. Flow time series at flow site – 126 in the Devon Meadows model area

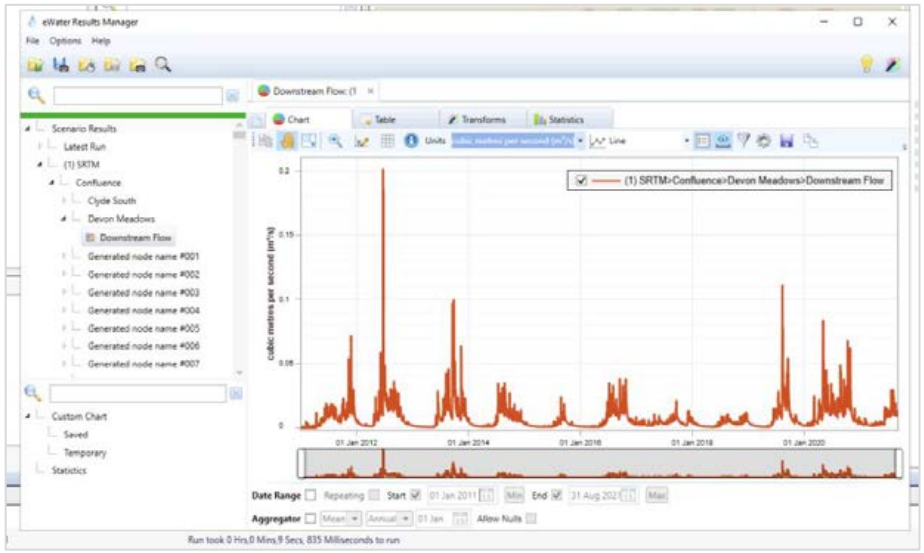


Figure 56. Flow time series at Devon Meadows flow site

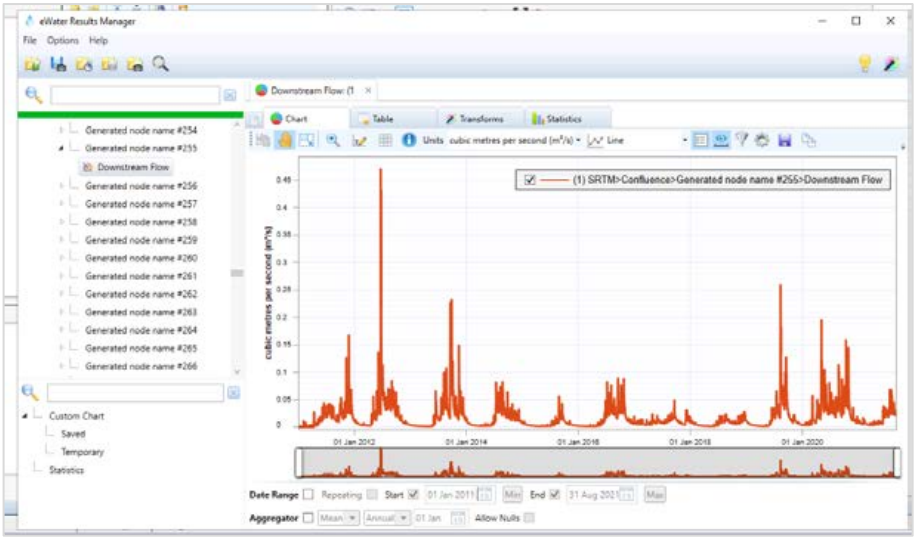


Figure 57. Flow time series at flow site – 255 in the Clyde South model area

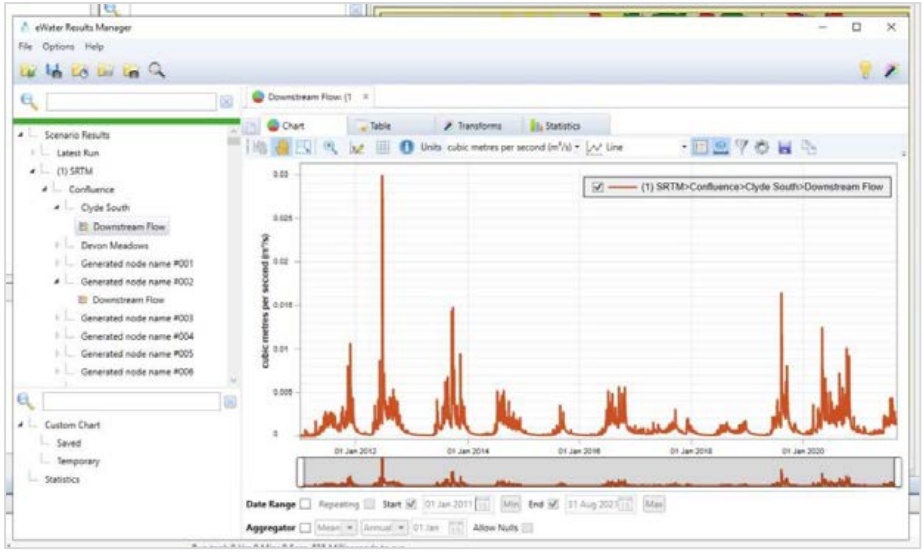


Figure 59. Flow time series at Clyde South model area

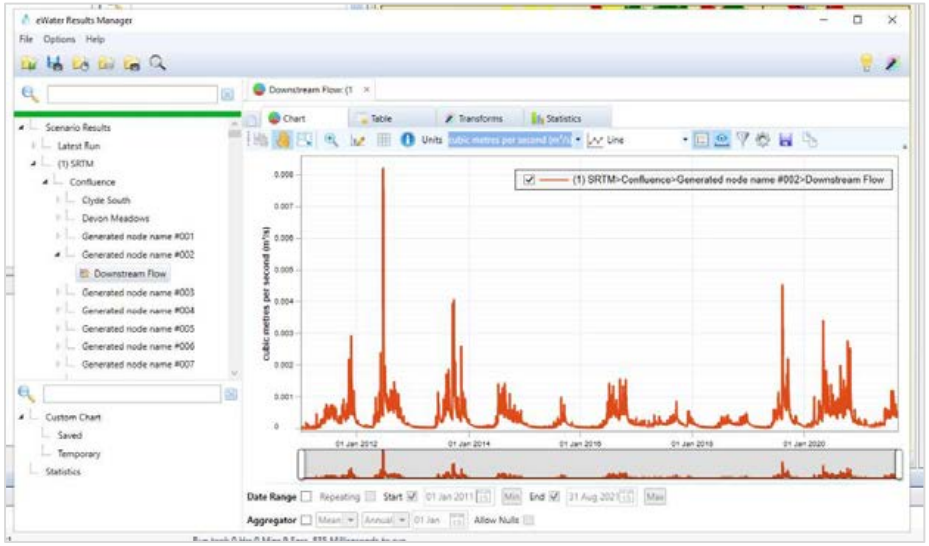


Figure 58. Flow time series at flow site - 2 in the Casey Fields model area

References

Zhang, X., D. Waters and R. Ellis (2013). Evaluation of Simhyd, Sacramento and GR4J rainfall runoff models in two contrasting Great Barrier Reef catchments. 20th International Congress on Modelling and Simulation, Adelaide, Australia.

Appendix C: Hydraulic modelling

HEC-RAS 2D has been applied to investigate different hydraulic parameters such as velocity and shear stress in current and developed conditions on the site.

HEC-RAS

The US Army Corps of Engineers has developed HEC-RAS, which is a peer-reviewed and widely accepted computer program used for different hydraulic investigations. The widely applied reasons of this program include modelling water flows through rivers, channels and creeks and their adjacent floodplain. Many government agencies and private firms across the world has accepted this program. In this project, we used HEC-RAS 6.0 version which has very updated modelling features available. The modelling starts with defining the terrain by elevation data (LiDAR), adding flow series and drawing geometry for three individual sites: 1. Devon Meadows, 2. Casey Field and 3. Clyde South PSP. The process is then to generate hydraulic characteristics at current and developed condition.

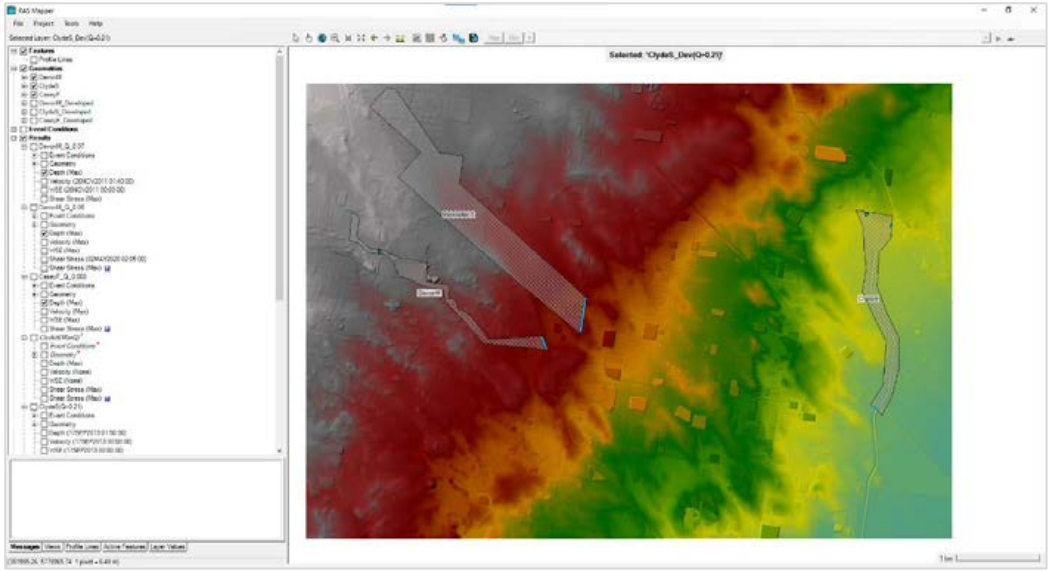


Figure 60. Elevation map of the project sites in HEC-RAS view

Elevation data

For terrain setup into the model, high resolution (1m) LiDAR data collected by Victorian Department of Environment, Land, Water and Planning (DELWP) for the project titled '2017-18 Greater Melbourne LiDAR Project' were used. The LiDAR was captured between December 2017 and April 2018. The horizontal and vertical spatial accuracy of the data are 0.2m and 0.1m respectively. **Error! Reference source not found.** shows the elevation data in HEC-RAS view

Model setup

Mesh

As the beginning process of model setup, a 2D mesh covering the stream network that was generated from Source model was introduced as in Figure 61, Figure 62 and Figure 63 for Devon Meadows, Casey Field and Clyde South PSP, respectively. The grid size for this mesh was applied as 1 m for all the three regions. This produced a total of 298487 cells in Devon Meadows, 1462969 cells in Casey Field and 472391 cells in Clyde South PSP areas. The maximum, minimum and average cell size for Devon Meadows is 3.64 m^2, 0.52 m^2 and 1.01 m^2, whereas they are 2.50 m^2, 0.49 m^2 and 1.00 m^2 for Casey Field and 4.48 m^2, 0.51 m^2 and 1.00 m^2 for Clyde South PSP.



Figure 62. Mesh grid map of the model (Devon Meadows)

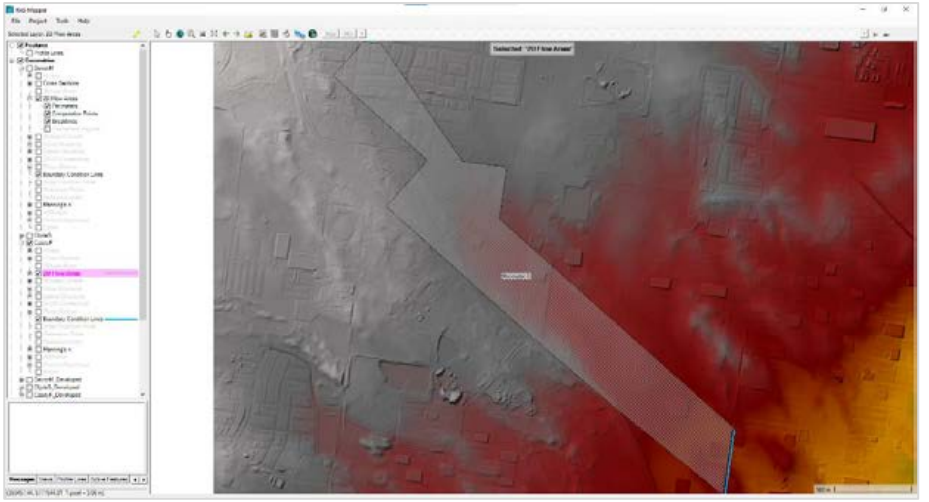


Figure 63. Mesh grid map pf the model (Casey Fields)

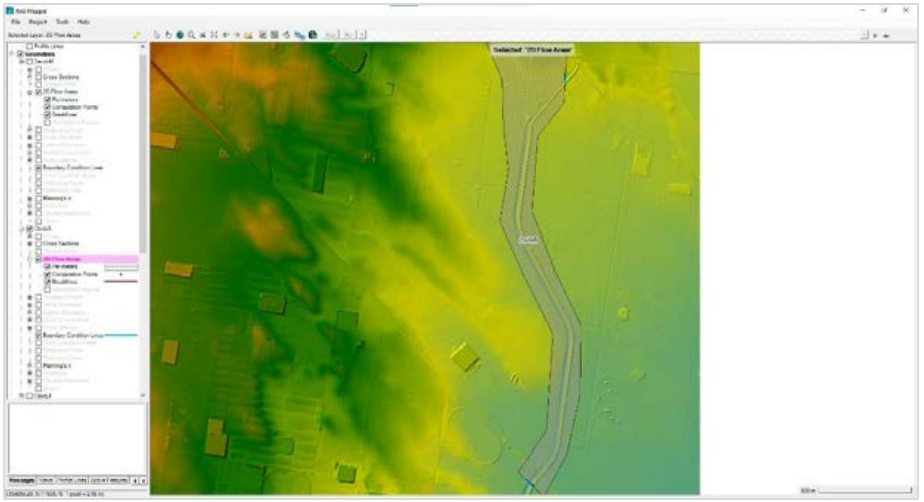


Figure 61. Mesh grid map of the model (Clyde South)

Boundary conditions

The upstream boundaries for three regions were set up as per the Source generated hydrologic nodes (**Error! Reference source not found.**, **Error! Reference source not found.** and **Error! Reference source not found.**). The energy slopes used in the flow hydrographs is 0.001. A downstream boundary condition with slopes of 0.008, 0.014 and 0.0013 for Devon Meadows, Casey Field and Clyde South PSP were considered

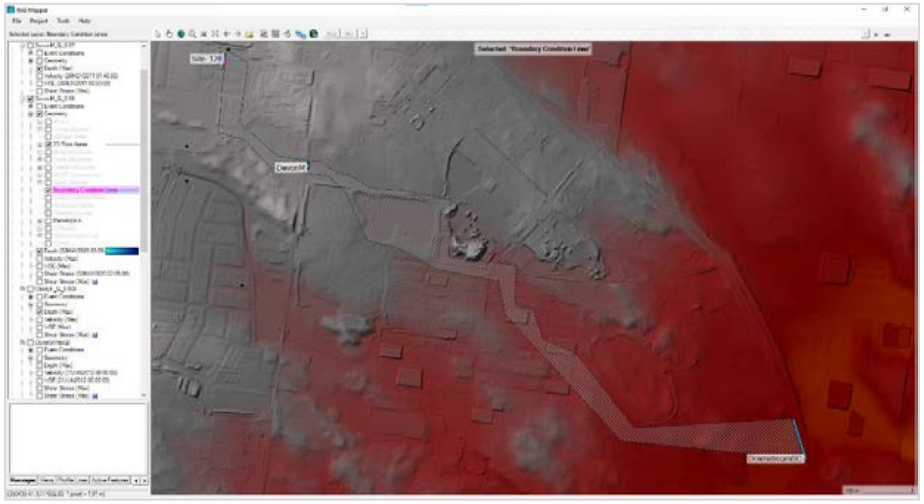


Figure 65. Model geometry showing the location of upstream (site 126 and DevonM) and downstream boundary (DownstreamBC) condition in the Devon Meadows area.

at the end of the mesh representing their normal depth.

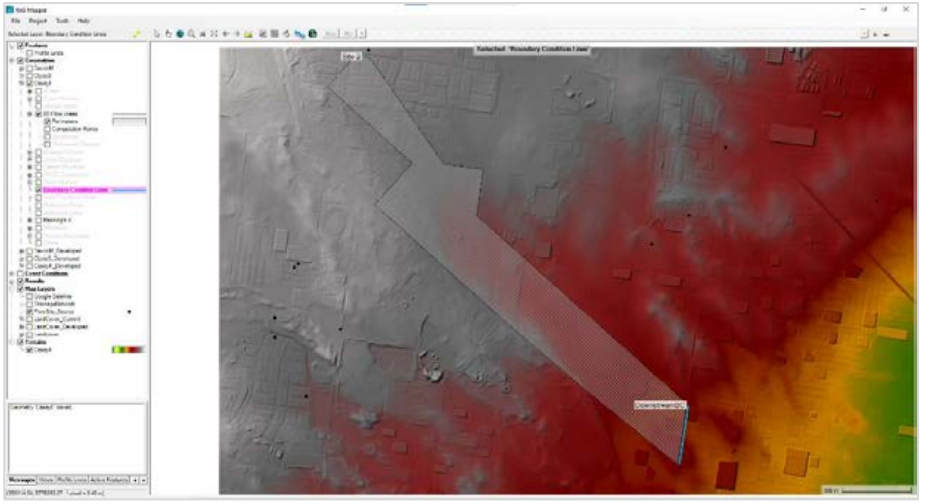


Figure 64. Model geometry showing the location of upstream (site 2) and downstream (DownstreamBC) boundary conditions in the Casey Fields area.

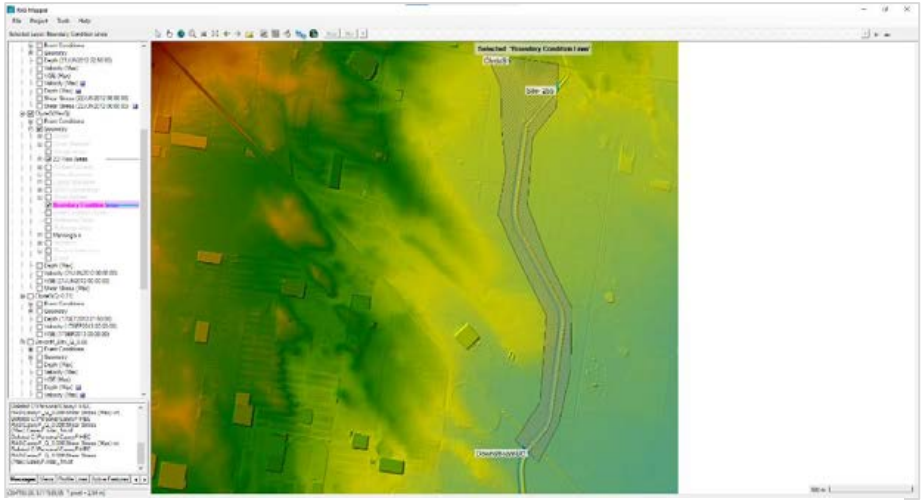


Figure 66. Model geometry showing the location of upstream (site 255 and ClydeS) and downstream boundary conditions in the Clyde South area.

Roughness

According to the current landcover of the project area, the roughness (Manning's n) values (Table 9) were determined and applied in the hydraulic model setup for current condition scenario. The roughness (Manning's n) values were changed for some specific land covers to estimate the developed scenario in the model (Table 9). Figure 67 shows the map view of the landcover in the model area.



Figure 67. Land cover map of the model area

Table 9. Roughness (Manning's n) values

Landcover	Field photo	Manning's n (current)	Manning's n (developed)	Photo source	Manning source
Developed site		0.08	0.08	MetroMap	Ladson, Lang et al. (2003)
Farming site		0.04	0.03	Field visit	Chow (1959)

Landcover	Field photo	Manning's n (current)	Manning's n (developed)	Photo source	Manning source
Natural site		0.05	0.03	Field visit	Chow (1959)
Pasture and grass land		0.03	0.02	Field visit	Papaioannou, Efstratiadis et al. (2018)

Results

We ran the model with peak flow at each upstream boundary model site for the three model areas. We had two individual modelling plans for each site. One plan demarcates the current condition whereas another estimates the developed condition. Now three types of hydraulic outputs (depth, velocity and shear stress) for each site at current and developed conditions are described below.

Devon Meadows

At peak flows of 0.043 m^3s^{-1} at flow site- 126 and 0.084 m^3s^{-1} at site DevonM.

Figure 68. Different hydraulic characteristics in the Devon Meadows model area

Maximum depth (m)		Maximum velocity (ms^{-1})		Maximum shear stress (Nm^{-2})	
Current condition	Developed condition	Current condition	Developed condition	Current condition	Developed condition
0.26	0.27	1.36	1.64	46.86	38.56

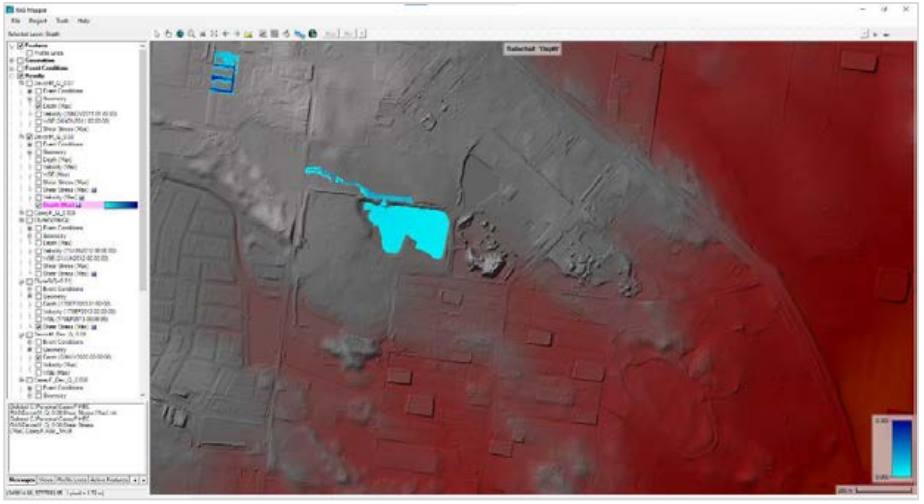


Figure 69. Maximum depth (m) in Devon Meadows under current conditions.

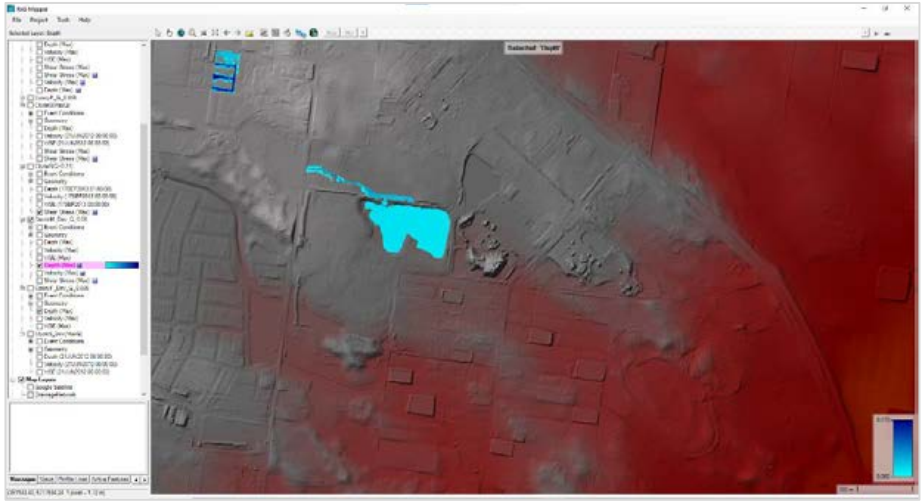


Figure 70. Maximum depth (m) in Devon Meadows under developed conditions.

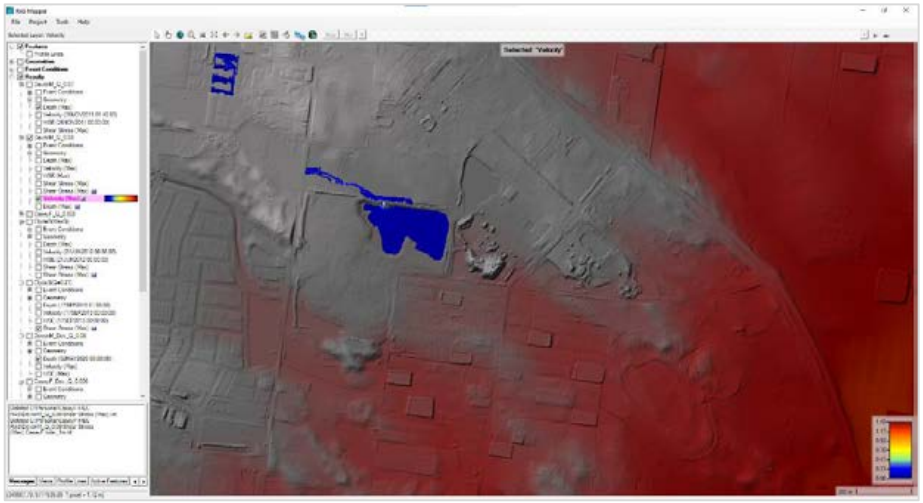


Figure 72. Maximum velocity (m/s^{-1}) in Devon Meadows under current conditions



Figure 73. Maximum shear stress (Nm^{-2}) layer in Devon Meadows model area under current conditions.



Figure 71. Maximum velocity (m/s^{-1}) in Devon Meadows under developed conditions



Figure 74. Maximum shear stress (Nm^{-2}) layer in Devon Meadows model area under developed conditions.

Devon Meadows

At peak flow of 0.008 m^3s^{-1} at flow site- 2.

Table 10. Different hydraulic characteristics in the Casey Fields model area

Maximum depth (m)		Maximum velocity (ms^{-1})		Maximum shear stress (Nm^{-2})	
Current condition	Developed condition	Current condition	Developed condition	Current condition	Developed condition
0.7	0.7	0.25	0.35	5.39	5.53

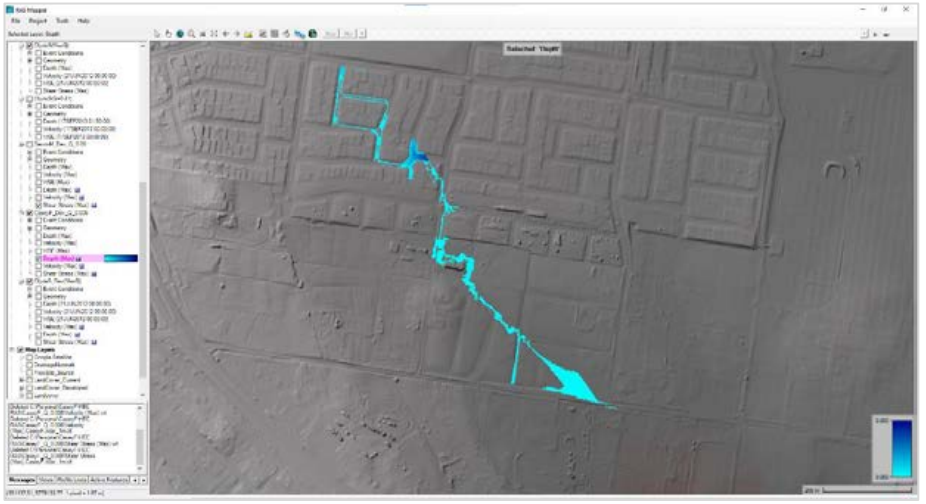


Figure 75. Maximum depth (m) in Casey Fields area under current conditions

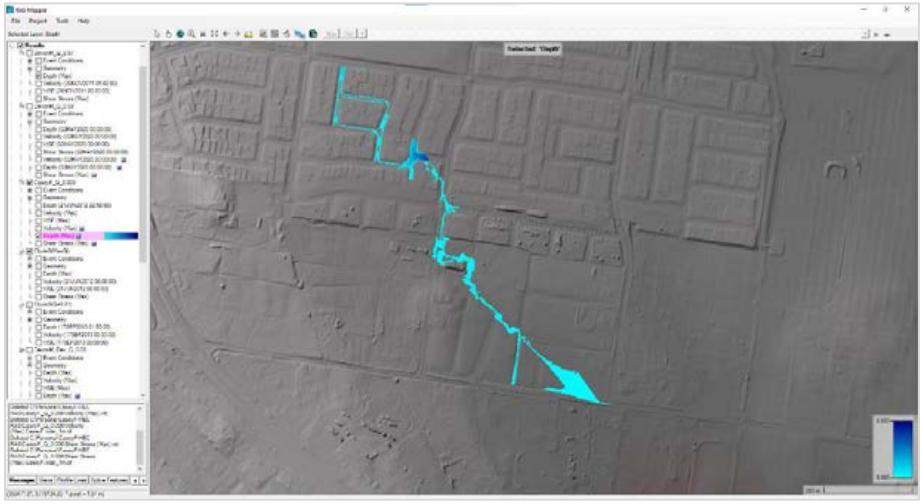


Figure 76. Maximum depth (m) in Casey Fields area under current conditions

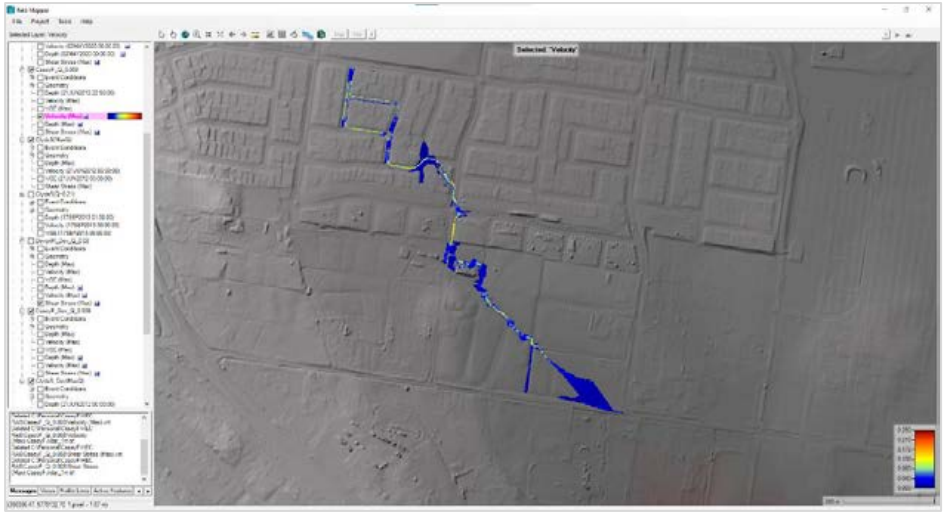


Figure 77. Maximum velocity (ms^{-1}) layer in Casey Field model area at current condition.

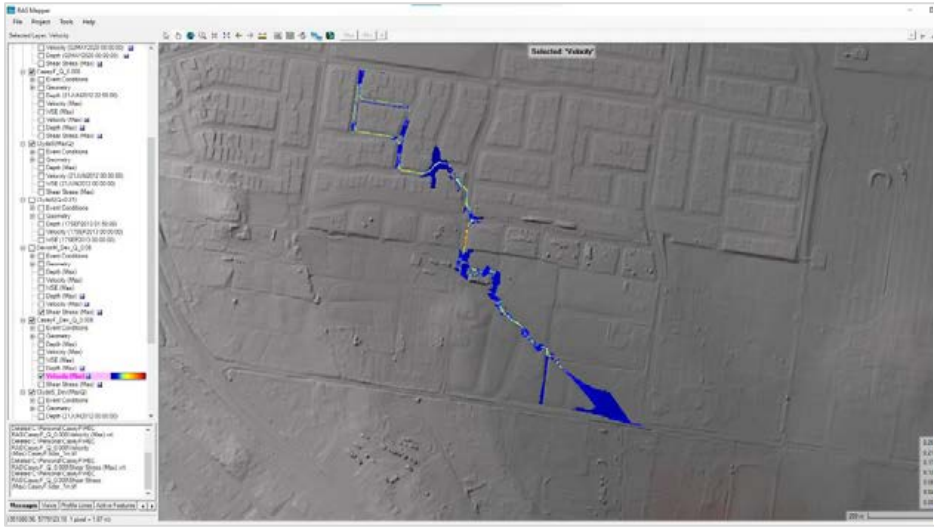


Figure 78. Maximum velocity (ms^{-1}) layer in Casey Field model area at developed condition.



Figure 79. Maximum shear stress (Nm^{-2}) layer in Casey Field model area at current condition.

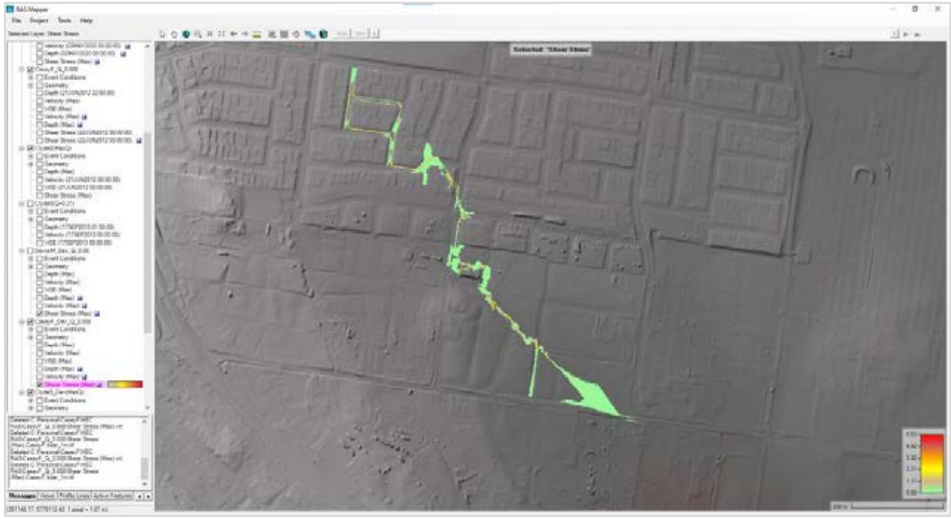


Figure 80. Maximum shear stress (Nm^{-2}) layer in Casey Field model area at developed condition.

Clyde South

At peak flow of 0.03 m^3s^{-1} at ClydeS and 0.47 $m^3s^{-}1$ at flow site- 255.

Table 11. Different hydraulic characteristics in Clyde South

Maximum depth (m)		Maximum velocity (ms^{-1})		Maximum shear stress (Nm^{-2})	
Current condition	Developed condition	Current condition	Developed condition	Current condition	Developed condition
0.44	0.44	0.9	1.03	89.48	90.22

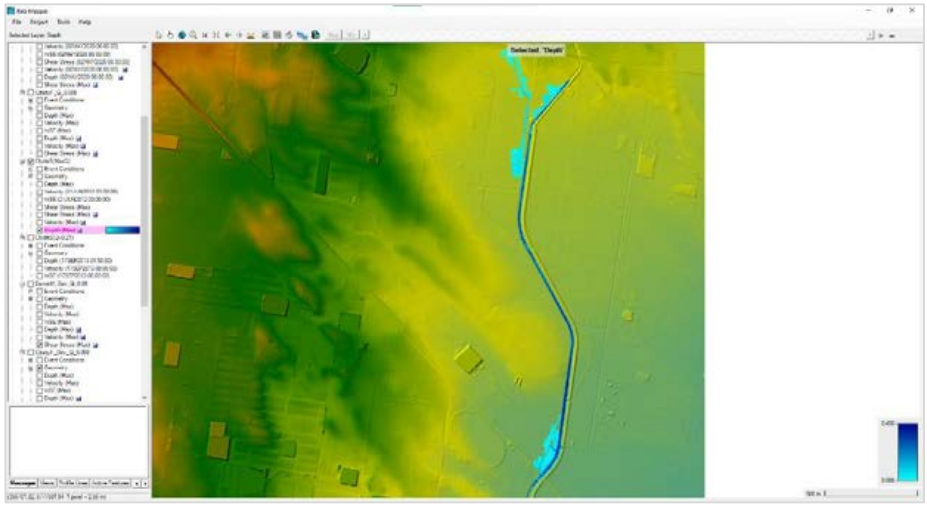


Figure 81. Maximum depth(m) layer in Clyde South PSP model area at current condition.

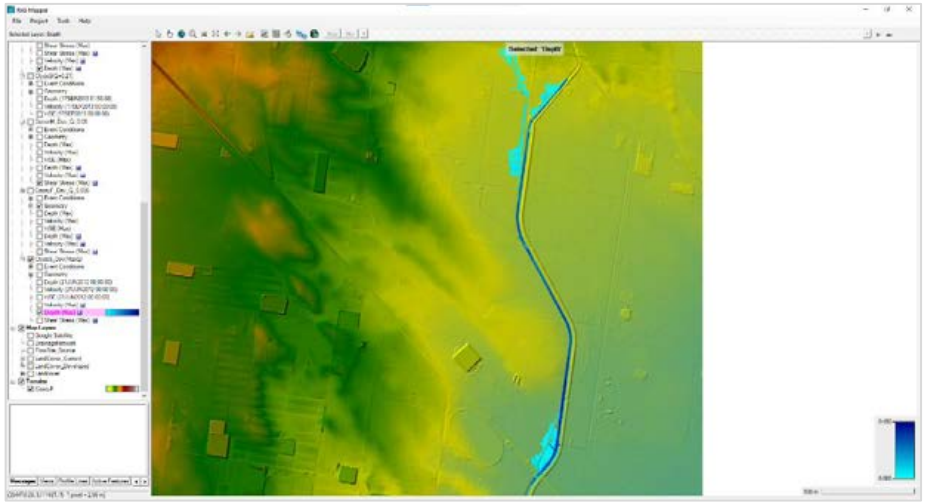


Figure 82. Maximum depth(m) layer in Clyde South PSP model area at developed condition.

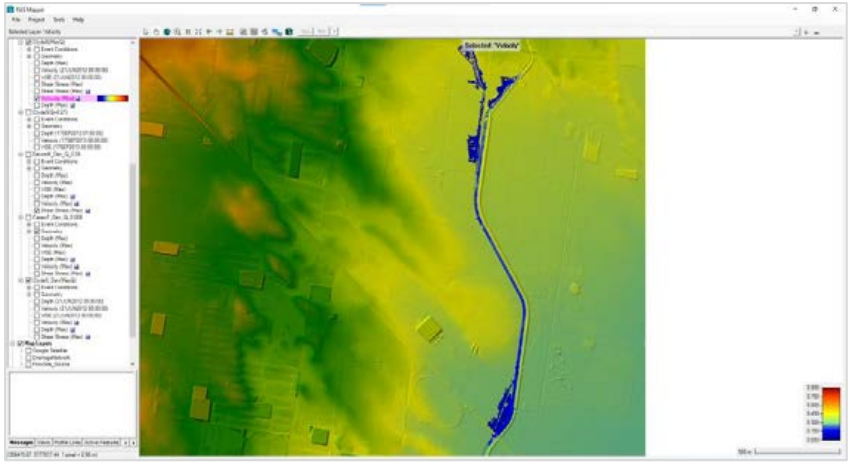


Figure 83. Maximum velocity(ms^{-1}) layer in Clyde South PSP model area at current condition.

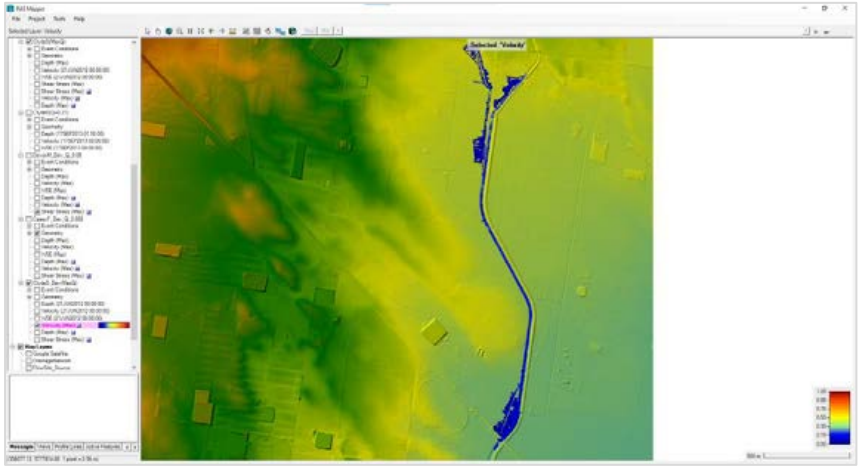


Figure 84. Maximum velocity(ms^{-1}) layer in Clyde South PSP model area at developed condition.

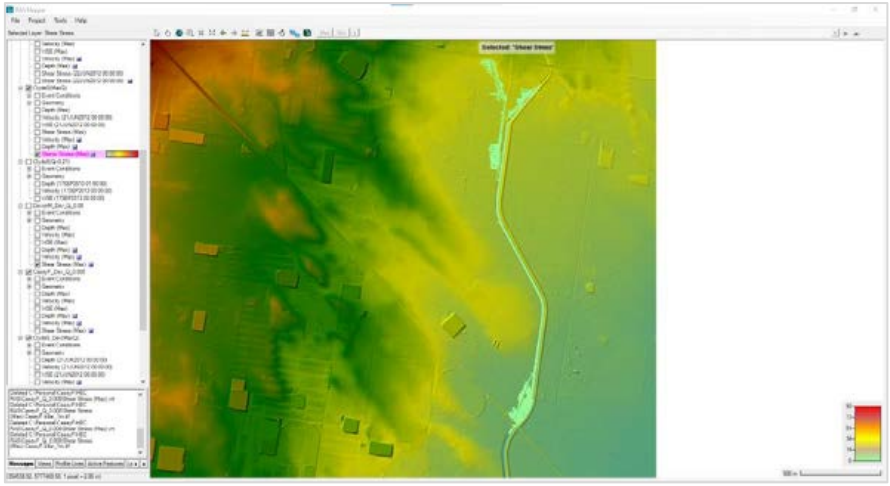


Figure 85. Maximum shear stress (Nm^{-2}) layer in Clyde South PSP model area at current condition

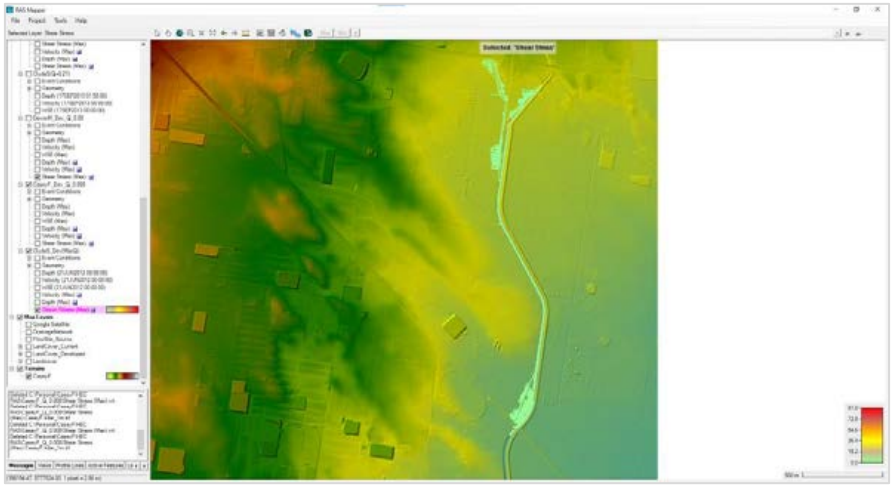


Figure 86. Maximum shear stress (Nm^{-2}) layer in Clyde South PSP model area at developed condition

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Appendix D: Field survey flora and fauna records

Table 12. Vascular flora species recorded within study area - Casey Fields South, Clyde South and Devon Meadows PSP areas, March 2022.

Key

*	Exotic species
#	Species native to Victoria though not indigenous within study area
en	Listed under the FFG Act as endangered in Victoria
vu	Listed under the FFG Act as vulnerable in Victoria
P	Protected flora species under the FFG Act
C	Species listed as Regionally Controlled under the CaLP Act
R	Species listed as Restricted under the CaLP Act
W	Weed of National Significance

Status	Scientific name	Common name
	Acacia dealbata	Silver Wattle
# P	*Acacia longifolia subsp. longifolia*	Sallow Wattle
P	*Acacia mearnsii*	Black Wattle
	Acacia melanoxylon	Blackwood
*	*Acetosella vulgaris*	Sheep Sorrel
*	*Agapanthus praecox subsp. orientalis*	Agapanthus
*	*Agrostis capillaris*	Brown-Top Bent
	Alisma plantago-aquatica	Water Plantain
	Alternanthera denticulata s.s.	Lesser Joyweed
*	*Anthoxanthum odoratum*	Sweet Vernal-Grass
P	*Azolla rubra*	Pacific Azolla
*	*Bromus catharticus*	Prairie Grass
P	*Cassinia longifolia*	Shiny Cassinia
#	*Cassinia sifton*	Drooping Cassinia
*	*Cenchrus clandestinus*	Kikuyu
*	*Centaurium erythraea*	Common Centaury
	Centella cordifolia	Centella

Status	Scientific name	Common name
*	*Chenopodium album*	Fat Hen
*	*Chlorophytum comosum*	Spider Plant
* C	*Chrysanthemoides monilifera*	Boneseed
* C	*Cirsium vulgare*	Spear Thistle
*	*Coprosma repens*	Mirror Bush
*	*Cortaderia selloana*	Pampas Grass
# vu	*Corymbia maculata*	Spotted Gum
*	*Cotula coronopifolia*	Water Buttons
	Crassula helmsii	Swamp Crassula
*	*Cynodon dactylon var. dactylon*	Couch
*	*Cyperus eragrostis*	Drain Flat-Sedge
	Cyperus spp.	Flat Sedge
*	*Dactylis glomerata*	Cocksfoot
	Daviesia ulicifolia	Gorse Bitter-Pea
* C	*Dittrichia graveolens*	Stinkwort
#	*Dysphania pumilio*	Clammy Goosefoot
*	*Echinochloa spp.*	Barnyard Grass
*	*Ehrharta erecta*	Panic Veldt-Grass

Status	Scientific name	Common name
	Eleocharis acuta	Common Spike-Sedge
	Eleocharis sphacelata	Tall Spike-Sedge
*	*Epilobium hirsutum*	Great Willow-Herb
	Epilobium spp.	Willow Herb
*	*Erigeron bonariensis*	Flaxleaf Fleabane
#	*Eucalyptus botryoides*	Southern Mahogany
	Eucalyptus cephalocarpa s.s.	Mealy Stringybark
	Eucalyptus ovata	Swamp Gum
	Eucalyptus viminalis subsp. pryoriana	Coast Manna-Gum
P	*Euchiton involucratus s.s.*	Star Cudweed
*	*Euphorbia peplus*	Petty Spurge
	Ficinia nodosa	Knobby Club-Sedge
*	*Fumaria bastardii*	Bastard'S Fumitory
* C	*Genista linifolia*	Flax-Leaf Broom
*	*Geranium molle*	Dove'S Foot
	Geranium spp.	Crane'S Bill
*	*Gomphocarpus physocarpus*	Balloon Cotton-Bush
*	*Hakea salicifolia subsp. salicifolia*	Willow-Leaf Hakea
*	*Helminthotheca echioides*	Ox-Tongue
*	*Holcus lanatus*	Yorkshire Fog
*	*Hordeum hystrix*	
	Hypericum gramineum	Small St John'S Wort
*	*Hypochaeris radicata*	Flatweed
	Isolepis inundata	Swamp Club-Sedge
	Juncus amabilis	Hollow Rush
	Juncus pallidus	Pale Rush
	Juncus procerus	Tall Rush
	Juncus sarophorus	Broom Rush
	Juncus subsecundus	Finger Rush
	Juncus vaginatus	Clustered Rush

Status	Scientific name	Common name
	Lachnagrostis filiformis s.s.	Common Blown-Grass
*	*Lactuca serriola*	Prickly Lettuce
	Lamiaceae spp.	Labiate
	Lemna spp.	Duckweed
*	*Leontodon saxatilis subsp. saxatilis*	Hairy Hawkbit
	Lepidosperma spp.	Sword Sedge
	Leptospermum continentale	Prickly Tea-Tree
*	*Lolium perenne*	Perennial Rye-Grass
*	*Lolium spp.*	Rye Grass
*	*Lotus corniculatus var. corniculatus*	Bird'S-Foot Trefoil
*	*Lysimachia arvensis var. arvensis*	Scarlet Pimpernel
	Lythrum hyssopifolia	Small Loosestrife
*	*Malva parviflora*	Small-Flower Mallow
# en	*Melaleuca armillaris subsp. armillaris*	Giant Honey-Myrtle
#	*Melaleuca ericifolia*	Swamp Paperbark
P	*Melaleuca squarrosa*	Scented Paperbark
*	*Mentha pulegium*	Pennyroyal
	Mentha spp.	Mint
	Microlaena stipoides var. stipoides	Weeping Grass
*	*Modiola caroliniana*	Red-Flower Mallow
*	*Nasturtium officinale*	Watercress
	Oxalis spp.	Wood Sorrel
	Paspalidium spp.	Panic Grass
*	*Paspalum distichum*	Water Couch
	Persicaria decipiens	Slender Knotweed
#	*Persicaria lapathifolia*	Pale Knotweed
*	*Phalaris aquatica*	Toowoomba Canary-Grass
	Phragmites australis	Common Reed
*	*Phytolacca octandra*	Red-Ink Weed

Status	Scientific name	Common name
*	*Pinus radiata*	Radiata Pine
#	*Pittosporum undulatum*	Sweet Pittosporum
*	*Plantago lanceolata*	Ribwort
*	*Polygonum aviculare s.s.*	Hogweed
*	*Polypogon monspeliensis*	Annual Beard-Grass
#	*Portulaca oleracea*	Common Purslane
	Potamogeton cheesemanii	Red Pondweed
	Potamogeton ochreatus	Blunt Pondweed
*	*Prunus spp.*	Prunus
	Pteridium esculentum subsp. esculentum	Austral Bracken
*	*Quercus spp.*	Oak
*	*Ranunculus sceleratus subsp. sceleratus*	Celery Buttercup
*	*Raphanus raphanistrum*	Wild Radish
* C	*Rosa rubiginosa*	Sweet Briar
* C	*Rubus anglocandicans*	Common Blackberry

Status	Scientific name	Common name
*	*Rumex conglomeratus*	Clustered Dock
* R	*Salix alba*	White Willow
* R	*Salix X pendulina*	Weeping Willow
	Solanum laciniatum	Large Kangaroo Apple
*	*Solanum nigrum s.s.*	Black Nightshade
*	*Sonchus asper s.s.*	Rough Sow-Thistle
*	*Sonchus oleraceus*	Common Sow-Thistle
*	*Stachys arvensis*	Stagger Weed
*	*Symphyotrichum subulatum*	Aster-Weed
P	*Taraxacum spp.*	Dandelion
*	*Trifolium fragiferum var. fragiferum*	Strawberry Clover
*	*Trifolium repens var. repens*	White Clover
*	*Typha latifolia*	Lesser Reed-Mace
*	*Ulmus spp.*	Elm
*	*Vicia sativa subsp. sativa*	Common Vetch
*	*Zantedeschia aethiopica*	White Arum-Lily

Table 13. Fauna species recorded within study area - Casey Fields South, Clyde South and Devon Meadows PSP areas, March 2022.

Key

*	Exotic species
vu	Listed under the FFG Act as vulnerable in Victoria
VU	Listed under the EPBC Act as nationally vulnerable

Status	Scientific name	Common name
	Anas gracilis	*Grey Teal*
	Anas superciliosa	*Pacific Black Duck*
*	*Oryctolagus cuniculus*	*European Rabbit*
	Tachybaptus novaehollandiae	*Australasian Grebe*
	Hirundo neoxena	*Welcome Swallow*
	Rhipidura albiscapa	*Grey Fantail*
	Anthochaera carunculata	*Red Wattlebird*
	Poliocephalus poliocephalus	*Hoary-Headed Grebe*
	Anthochaera chrysoptera	*Little Wattlebird*
*	*Equus caballus*	*Horse*
	Phalacrocorax sulcirostris	*Little Black Cormorant*
	Vanellus miles	*Masked Lapwing*
	Anhinga novaehollandiae	*Australasian Darter*
	Elseyornis melanops	*Black-Fronted Dotterel*
	Corvus spp.	*Ravens And Crows*
	Egretta novaehollandiae	*White-Faced Heron*
	Ocyphaps lophotes	*Crested Pigeon*

Status	Scientific name	Common name
*	*Acridotheres tristis*	*Common Myna*
VU vu	*Hirundapus caudacutus*	*White-Throated Needletail*
*	*Vulpes*	*Red Fox*
*	*Ovis aries*	*Sheep*
	Poodytes gramineus	*Little Grassbird*
	Limnodynastes tasmaniensis	*Spotted Marsh Frog*
	Porphyrio melanotus	*Australasian Swamphen*
	Pseudechis porphyriacus	*Red-Bellied Black Snake*
	Crinia signifera	*Common Froglet*
	Manorina melanophrys	*Bell Miner*
	Rhipidura leucophrys	*Willie Wagtail*
	Falco berigora	*Brown Falcon*
	Malurus cyaneus	*Superb Fairy-Wren*
	Gymnorhina tibicen	*Australian Magpie*
	Grallina cyanoleuca	*Magpie-Lark*
	Threskiornis molucca	*Australian White Ibis*