Sequestering Soil Carbon in Irrigated Landscape Turned Dry Ecological Grazing

Site, Soil & Landform Description

Project Sites at:
Mystic Park-Tresco, Fish Point, Winlaton and Benjeroop, Northern Victoria

Project AoTGR1-167
Technical Report No. 2

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	Name	Position	Date
Author	K. Luitjes	Land Capability Specialist	24/06/2013
QA	L. North	Quality Manager	25/06/2013

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Prepared by

Sunraysia Environmental Pty Ltd

Project Manager: Kym Luitjes

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3 The Crescent
Mildura VIC 3500

Ph: 03 5023 3643
Fax: 03 5021 3440
Email: enquiries@sunenv.com.au
Website: www.sunenv.com.au

Executive Summary

This Action on the Ground (AotG) project is being undertaken to trial and demonstrate innovative on-farm practices to increase the sequestration of carbon in soil. These practices are centred on the conversion of flood irrigated cropping to dryland cell grazing on native forage, interspersed with protected biodiversity corridors.

The project sits within the Torrumbarry Irrigation District (TID) of northern Victoria, on the riverine plain between Kerang and Swan Hill. The core area of this trial area is based around the 1,250 ha *Five-on-Seven Grazing Block* west of Lake Tutchewop.

The study area occupies a plain of deposition from two sources and represents the eastern portion of the ancient Murray Gulf. The Riverine Plain within the Torrumbarry Irrigation District is comprised of sediments from two different stream systems – the Loddon system and the Murray–Goulburn system. The current active floodplain is flat with minor undulations and extends to the Mallee fringe. In places it is at least 5 km wide.

The trial sites sit across the junction of three bioregions; the Murray Fans Bioregion along the Murray River: the Victorian Riverina Bioregion which includes the tributaries to the Murray River; and to the east, the Murray Mallee Bioregion.

The bioregions consist of a number of landscape units, with two of these relating to the trial sites; Black Box Woodland and River Flat.

The trial sites are located within the geomorphic units known as; Areas of Inundation Away From Modern Channels, and Plains with Lakes and Depressions with Lunettes.

The climate is Mediterranean, with the average annual rainfall at Swan Hill, the nearest official weather station being 316 mm. Annual evaporation is approximately 1500 mm.

There are two soil classes associated with the trial sites; Grey and Brown Vertosols, cracking clays that are usually self-mulching and Red Sodosols, strong texture contrast soils with carbonates commonly present in the subsoil. There are soil transitions in the study area associated with the over-lapping sandier soils of the Mallee.

In these heavy-textured soils, structural development and cracking are such that entry of water is usually adequate for the pastures which are commonly grown. However, the clays swell when wetted, and this reduces the rate of water intake such that penetration is sometimes unsatisfactory. The surface soils contain appreciable exchangeable sodium. On application of water, dispersion of the clay occurs in the surface and the permeability of the soil may be greatly reduced.

In 1966, Skene & Sargeant found that the irrigated pastoral areas from Mystic Park to Fish Point were on heavy-textured soils, all of which had a potential salt hazard and were not readily leached of salt.

Table A provides a summary of the contextual settings of each trial site.

Table A Contextual Settings of the Trial Sites

Trial Sites	Land Form	Soil Class	EVC*	Bioregion	Landscape Unit
FPAG10 AB	Flat	Grey & Brown Vertosol	103	Murray Fans	River Flat
GMGP AG	Flat	Grey & Brown Vertosol	103	Murray Fans	River Flat
GMCO7 AG	Flat	Grey & Brown Vertosol	103, 812	Murray Fans	River Flat
JCRO2 AG	Flat	Grey & Brown Vertosol	103	Victorian Riverina	Black Box Woodland
FOSC2.1 Tresco Nth PG	Flat	Grey & Brown Vertosol/Red Sodosol	103, 829	Victorian Riverina	Black Box Woodland
FOSC7 Tresco West PB	Flat	Grey & Brown Vertosol	103	Victorian Riverina	Black Box Woodland
FOSC4.2 Oxley PG	Flat	Grey & Brown Vertosol	103	Victorian Riverina	Black Box Woodland
FOSC3.2 Tresco West PG	Flat	Grey & Brown Vertosol	103	Victorian Riverina	Black Box Woodland
Hawkins Flood Block Ref	Flat	Grey & Brown Vertosol/Red Sodosol	103	Murray Fans	River Flat
Mystic Park Forest Ref	Flat	Grey & Brown Vertosol	103, 829	Victorian Riverina	Black Box Woodland
KCLO3 PB	Flat	Grey & Brown Vertosol	103	Murray Fans	River Flat

*EVC: 103 – Riverine Chenopod Woodland; 812 – Grassy Riverine Forest/Riverine Swamp Forest Complex; 829 – Chenopod Grassland

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Appendices

1.0 Background

This Action on the Ground (AotG) project is being undertaken to trial and demonstrate innovative on-farm practices to increase the sequestration of carbon in soil. These practices are centred on the conversion of flood irrigated cropping land to dryland cell grazing on native forage, interspersed with protected biodiversity corridors.

The project comprises nine trial paddocks and two reference sites, each between 30 ha and 60 ha in size. The project is situated within the Torrumbarry Irrigation District (TID) of northern Victoria, on the riverine plain between Kerang and Swan Hill.

Situated across a project area 15 km wide by 20 km long, the core of this trial is the Five-on-Seven Grazing Block, west of Lake Tutchewop, with additional trial paddocks located north and east of Lake Tutchewop. The Five on Seven Block was reconfigured in 2012, and comprises over 20 cells for block grazing, together with a central biodiversity corridor. Sheep were introduced to the landscape in June 2012.

The location of the trial sites are shown in Figure 1, and listed in Table 1.

This report provides a description and contextual setting of the physical aspects of the trial sites, principally their geology, soils and landforms.

Table 1 Trial Sites

Trial Paddock	Location
FPAG10 AB	Fish Point
GMGP AG	Fish Point
GMCO7 AG	Fish Point
JCRO2 AG	Nth of Lake Tutchewop
FOSC2.1 Tresco Nth PG	Winlaton
FOSC7 Tresco West PB	West of Lake Tutchewop
FOSC4.2 Oxley PG	West of Lake Tutchewop
FOSC3.2 Tresco West PG	West of Lake Tutchewop
Hawkins Flood Block Ref	Benjeroop
Mystic Park Forest Ref	South west of Lake Tutchewop
KCLO3 PB	East of Lake Charm

AG - actively restored grazing; PG - passively restored grazing;
AB - actively restored biodiversity; PB - passively restored biodiversity

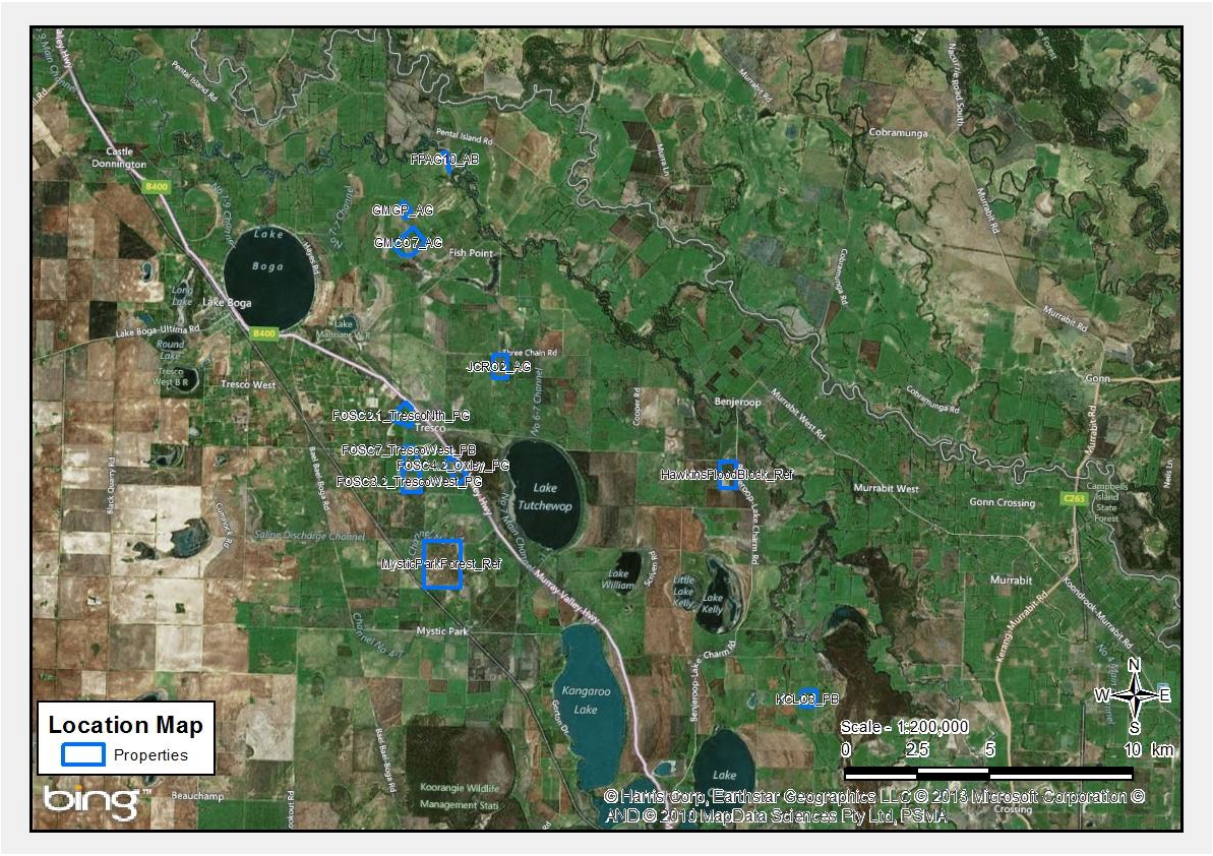

Figure 1: Trial Paddock Locations

2.0 Site Setting

The project area and the trial paddocks sit across a number of landscape and ecological features and groupings. For ease of interpretation, Table 2, on page 14, lists those features and groupings for each trial paddock.

2.1 Historical Use

Mystic Park and Fish Point Irrigation Areas were constituted as irrigation districts by the State Rivers and Water Supply Commission in 1922 and 1926 respectively. In their 1966 district soil survey, Skene & Sargeant found that:

> *"Most of the irrigation land supports only annual pastures while unirrigated saline areas are widespread. The salinity of the heavy-textured soils of the plains in the Mystic Park and Fish Point Irrigation Areas clearly presents difficulties to the establishment of irrigated pastures, and the risks involved in the irrigation of these lands have long been recognized."*

2.2 Geology

The study area occupies a plain of deposition and represents the eastern portion of the ancient Murray Gulf, which reached its greatest development in Miocene times. Limestone, marine sands and clays associated with the Miocene sea are overlain by lacustrine, fluviatile and aeolian deposits laid down during the alternatively wet and dry periods of the Pleistocene and later. These deposits are more than 100 m thick within the Swan Hill district and the formations are loosely compacted.

The lakes are considered to have developed as terminal basins during the final stages of prior stream activity. Macumber (1970) has proposed that some lake-lunette systems were created by deflation of salt-affected areas, and Lawrence (1971) has suggested the origin of lakes with saline water as points of ground water discharge.

Alluvial sediments fill the Murray Basin eastwards of the limits of the marine deposits of the Murravian Gulf. These comprise sands, silts and clays laid down during a long period, from the Oligocene to the Recent. Geological evidence suggests that in the Late Tertiary, rivers were flowing from the central and eastern highlands and had high discharges and considerable bed loads, with sizeable sand and gravel fractions.

In this way the deep lead systems were formed as described by Macumber (1968), who has traced the Loddon deep lead as far north as the Kerang Agricultural Research Farm.

The Riverine Plain within the Torrumbarry Irrigation District is comprised of sediments from two different stream systems – the Loddon system and the Murray–Goulburn system. South of the Pyramid Creek, the Riverine Plain is formed mainly from sediments of the Loddon system, constituting a zone of terminal deposition, with practically no aquifers. This area is generally referred to as the Tragowel clay plains.

North of the Pyramid Creek the sediments are predominantly those of the Murray-Goulburn system, although the lithology of the sediments of the treeless plain north of the Pyramid Creek is very similar to that of the sediments of the Tragowel Plains.

It can be concluded that the floodplain sediments through the Winlaton district are more related to the Loddon River (and to some extent the Avoca), than the Murray River. However the two are blended (DSE 2003).

2.3 Physiography & Topography

The study area is situated on a riverine plain traversed by the Murray River and its anabranch, the Little Murray River and its tributary the Loddon River, which joins the Little Murray upstream of Fish Point. The present flood plain of the Murray River, in places at least 5 km wide (Sergeant and Skene, 1965), includes a number of lakes, ox-bows and meander scrolls and extends to the Mallee fringe.

Maps of local landform features and spot levels for the local district indicate that the height of the floodplain above sea level ranges from 70 m to 74 m AHD, with local undulations within the sites of approximately 30 cm to 50 cm on land where there has been some aeolian influence. The maps are attached (Appendix 3).

The rivers have formed steep-sided channels approximately 6 m deep, and are essentially "rivers of transit" as, owing to the low rainfall and absence of defined watercourses, the local area contributes little runoff to their flow.

Associated with the lakes, a feature of the landscape are the aeolian formations known as lunettes; crescent-shaped ridges associated with the eastern periphery of lakes and dry lake beds, generally between 5 m and 10 m high. Lunettes typically occur at Lake Boga, Lake Charm, Kangaroo Lake and Lake Tutchewop, with crest levels of close to 80 m AHD. For reference, the highest point in the local landscape is 84 m AHD at Tresco.

2.4 Biodiversity Values

2.4.1 Bioregions

There are 27 bioregions in Victoria. The trial sites are located at the interface of three bioregions:

- Murray Fans Bioregion.
- Victorian Riverina Bioregion
- Murray Mallee Bioregion

The bioregions for the study area are shown in the appended map (Appendix 4).

The **Murray Fans Bioregion** is characterised by a flat to gently undulating landscape on recent unconsolidated sediments with evidence of former stream channels, braided old river meanders and palaeo channels and broad floodplain areas associated with major river systems and prior steams (known as braided / anastomosing streams).

Around 75 per cent of the Murray Fans Bioregion has been cleared. On freehold land farming is predominantly focused on mixed cropping and grazing. However some dairying and mixed farming as well as low intensity irrigation occurs on the southerly fringe of the Riverine plain.

Extensive tree clearing for agriculture on the more elevated sites and subsequent habitat fragmentation have resulted in removal of over 95 per cent of the native vegetation (DSE 2003).

The **Victorian Riverina Bioregion** is characterised by flat to gently undulating landscape on recent unconsolidated sediments with evidence of former stream channels and wide floodplain areas associated with major river systems and prior steams.

The **Murray Mallee Bioregion** is dominated by red-brown earths of the Woorinen Formation. The predominantly calcareous soils of aeolian origin occur as mixture of undulating plains interrupted by low longitudinal east-west trending dunes and intervening swales. Dunes may occupy up to 20 per cent of the landscape.

The Woorinen Formation mainly overlies a deep sandy marine deposit of the later Tertiary period known as the Parilla Sand as well as in some places, lacustrine clays of early Quaternary origin. The surface soils range in texture from sands to clays with the soil types varying with surface topography, the degree of undulation of the Parilla Sand base and the presence of lacustrine clay horizons.

Areas of low elevation are often subject to groundwater discharge from the saline Parilla Sand aquifer below and are characterised by scattered copi dunes and rises with laminated gypseous clay soils.

The Murray Mallee Bioregion is predominantly freehold land that is mostly cleared of native vegetation. The cleared land is use for agricultural production including dryland farming (grain and livestock grazing), and irrigated horticulture (vineyards, orchards and vegetables) (DSE 2003).

2.4.2 Ecological Vegetation Classes

A finer mapping unit for biodiversity is known as Ecological Vegetation Classes (EVC). There more than 800 EVC recognised in Victoria. A map showing the EVC within the study area is appended (Appendix 5). The EVC present in an area are the result of many factors interacting; principally soil and climate, but also slope, aspect, geology, flooding, altitude, groundwater, etc.

It must be noted that both Bioregion and EVC maps are not necessarily accurate at paddock scale. Bioregions have outliers in abutting Bioregions not represented at the mapping scale used. Furthermore there are often "transition zones" or "mosaics". Therefore many of the EVC are not unique to a particular Bioregion; some will predominate and some will be hardly represented.

The EVC can only be confirmed by on ground assessment. For blocks that have been totally cleared of native vegetation for intensive agriculture, the identity of the EVC prior to clearing would be difficult to verify.

The vegetation in the **Murray Fans Bioregion** is typically a mosaic of EVC including Plains Grassy Woodland, Pine Box Woodland, Riverina Plains Grassy Woodland and Riverina Grassy Woodland ecosystems (DSE Website 10/12/ 2012).

The vegetation in the **Victorian Riverina Bioregion** is dominated by a diverse range of EVC including Plains Grassy Woodland, Plains Grassland, Pine Box Woodland/Riverina Plains Grassy Woodland Mosaic, Riverine Grassy Woodland/Riverine Sedgy Forest/Wetland Mosaic, Plains Grassy Woodland/Gilgai Plains Woodland/Wetland Mosaic, Grassy Woodland and Wetland Formation ecosystems (DSE Website 10 Dec 2012).

Typical EVC in the **Murray Mallee Bioregion** are Chenopod Mallee, Woorinen Mallee, Woorinen Sands Mallee, Semi-arid Woodland, Semi-arid Chenopod Woodland, Plains Savannah and Ridged Plains Mallee (ARI 2003).

2.4.3 Public Land

Of significance to this project, the Mystic Park Bushland Reserve, identified in the trial as Mystic Park Forest Ref, a reference site, has been recommended to be added to a new national park as part of the *River Red Gum Forests Investigation – Final Report* (VEAC 2008). The new park with an area of 7,790 ha south east of Lake Tutchewop is known as the Leaghur-Koorangie National Park and consists of many existing smaller reserves and state forest.

The Mystic Park Bushland Reserve is located in the wetlands known as the Avoca Marshes that form part of the internationally significant Kerang Wetlands Ramsar site and consent was obtained from the relevant state agency to conduct the soil sampling.

2.4.4 Threatened Ecological Community

It is noted that the Buloke Woodlands of the Riverina and Murray-Darling Depression are listed as a *threatened ecological community* by the Australian Government under the *Environment Protection and Biodiversity Conservation Act 1999*. The same ecological community is also listed under the Victorian *Flora and Fauna Guarantee Act 1988*. Buloke Woodlands may occur in the study area but this can only be confirmed by field assessment.

2.5 Landscape Units

Skene and Sargeant, (1966) recognised six landscape units in the local Tresco-Mystic area and related them to soil types. Of the six, four are represented in the project area and three are represented in the trial sites as follows:

- Black Box Woodland (trial sites)
- Treeless Plain (project area)
- River Flat (trial sites)
- Lake/Lunette Complex (project area)

2.5.1 Black Box Woodland

The landscape unit of the Five on Seven Grazing Block at the core of the trial, this landscape unit delineates areas of low plain which formerly carried Black Box and, in places, a little Mallee. The depositional layers are principally aeolian, although it is probable that riverine layers are intermingled in some parts at least (Skene and Sargeant, 1966).

An extensive expanse of Black Box woodland in the Mystic Park area is very occasionally inundated by waters moving overland from the Avoca River. The Mystic Park occurrence of Black Box woodland corresponds to the Della soil association. There is only one important soil type, Della Clay. This is a grey, cracking clay which becomes yellowish or brownish, and slightly calcareous, between 10 cm and 30 cm. Most of the soils are saline (Skene and Sargeant, 1966).

2.5.2 Treeless Plain

A great part of the Riverine Plain which extends over much of northern Victoria is almost featureless and devoid of trees, except for Black Box and Red Gum in some of the shallow drainage ways. The treeless areas constitute a landscape unit commonly referred to as treeless plain. In Victoria, occurrences extend from Koyuga, near Tongala, to Kerang (Skene and Sargeant, 1966).

The treeless plain landscape unit encroaches into the southern part of the Mystic Park Irrigation Area, but it is a comparatively minor component of the general landscape pattern of the area. Meran sandy clay loam and Type 8 are the only components of the soil pattern, which is referred to as the Meran soil association.

Meran sandy clay loam occupies the fractionally higher and better drained parts of the plain. A shallow dull brown sandy clay loam overlies dark reddish brown heavy clay, but the surface is frequently windswept and the clay may be exposed. Calcium carbonate occurs below 35 cm, but usually only in small amounts (Skene and Sargeant, 1966).

Gypsum is commonly present. Type 8 is the duller member of the sequence and takes in grey-brown and grey profiles. It is of very small extent (Skene and Sargeant, 1966).

2.5.3 River Flat

The landscape unit of the Fish Point sites, the alluvial plains of the Murray and Little Murray Rivers constitute the river flat landscape unit. In most situations, this may be clearly recognized below the lower elements of the aeolian landscape. The river flats are below high flood level of the rivers and once were subject to recurrent flooding. Greater exploitation of the rivers for irrigation and installation of flood protection works now prevent this. The river flats have always been treeless except for scattered Black Box where they adjoin the aeolian landscape (Skene and Sargeant, 1966).

The surface of the flats is generally level, except for a few shallow depressions and low rises. Certain of the rises form discontinuous and indistinct natural levees adjoining the Murray River and its anabranch the Little Murray River. Other very low rises further removed from the rivers represent remnants of aeolian deposits superimposed on the alluvial layers (Skene and Sargeant, 1966).

Swan Hill clay is the most extensive soil type on the river flat landscape. This is a dark grey cracking medium clay which first becomes mottled with rusty shades, and then grades into strongly mottled yellow-brown and light grey light clay or fine sandy clay before 1.2 m.

Speewa clay is a somewhat similar clay soil, but occupies slightly lower situations. It differs from Swan Hill clay in that dominantly grey clay continues to 1.2 m, although the mottled lighter textures found in Swan Hill clay may occur before 2.1 m. Calcium carbonate is only occasionally present in these soil types and then as concretions in the deep subsoil.

Donnington clay is an extensive soil type and is also a dark grey cracking clay. A yellowish or brownish grey heavy clay in the subsoil continuing to 2.1 m distinguishes it from Speewa clay. Also slight calcium carbonate may be present throughout the subsoil. Donnington clay resembles Unit N, but is heavier-textured and less calcareous. It is probably formed on mixed aeolian and alluvial materials (Skene and Sargeant, 1966).

Fish Point clay is a minor occurrence where the river flats are intermingled with lunette ridges in the Fish Point Irrigation Area. It occurs with Donnington clay, but on slightly higher levels, and aeolian deposition has made a greater contribution to its profile features. The main difference is a brown subsoil clay and the more common occurrence of calcium carbonate and gypsum below 75 cm in Fish Point clay. Type 4 and Type 5 are formed on remnants of the aeolian landscape. Type 4 has about 10 cm of brown sandy clay loam over reddish brown medium clay becoming calcareous below 30 cm (Skene and Sargeant, 1966).

2.5.4 Lake/Lunette Complex

Lakes and drainage basins with associated crescent-shaped ridges or lunettes on their eastern perimeters are conspicuous features of the landscape in the Lake Boga locality. Here the lunettes extend into the Fish Point Irrigation Area. There are also several smaller occurrences of lunettes in the local area. The lunette soils which, in general, are moderately heavy brown soils have not been classified. The soils of two drained lake beds near Lake Boga have been classified as Lake Baker clay. The surface is a dark grey clay, characteristically strongly structured and friable due to a high organic matter content. This passes to yellowish grey clay (Skene and Sargeant, 1966).

2.6 Geomorphological Units

2.6.1 Northern Riverine Plain – Modern Floodplain

Meander Belt below Plain Level

The modern alluvial terraces and floodplains of today's active rivers carry young soils of varied texture and have been described as the late Quaternary Coonambidgal Formation. Source-bordering dunes are found along these channels, generally on their north-eastern sides. Several former but young courses of major rivers such as the Murray River are marked by inset terraces and extensive flood-plain meander belts with scrolls and oxbow lakes (DSE website 2013).

This grouping of geomorphological units describes the (generally) youngest spatial landscape features; the current floodplain of major streams. These units are generally incised into an alluvial plain with or without terraces. They are defined as being un-confined in the sense that they are not surrounded by upland and are formed on alluvial material (Coonambidgal Formation), part of the most recent alluvial landform complex (DSE website 2013).

Soils vary on the young unconsolidated regolith, from sands and loams, to clays where finer material has accumulated. Major soils include sodic, grey texture contrast soils (grey Sodosols) and cracking clay soils (Vertosols) (DSE website 2013).

The texture contrast soils have slightly acidic sandy clay loam surfaces over grey light clays that increase in sodicity with depth. Minor carbonate occurs in the subsoil. The cracking clays are acidic at the surface with light clays clearly changing to heavy clay subsoils that can be more acidic at depth, with very few carbonate nodules. Depths for all soils are generally in excess of 2 m (DSE website 2013).

Vegetation may also change with climate (drier to the north) though Red Gums are a major overstorey species. Vegetation communities along these floodplains include a variety of woodlands including; Plains Woodland, Drainage-line Woodland, Salt Paperbark Woodland, Lignum Swampy Woodland, Riparian Woodland, Creek line Sedgy Woodland and Riverine Chenopod Woodland for example (DSE website 2013).

Flooding provides a significant hazard for this unit especially in urban areas along the rivers and creeks. Shrink-swell behaviour of cracking clays around these urban areas may also be a relevant factor in residential development and selection of footings that will accommodate clay expansion and contraction (DSE website 2013).

Areas of Inundation Away From Modern Channels

Several former courses of the major rivers, such as the Murray River, are marked by extensive meander belts and source-bordering dunes. Commonly these have associated Red Gum forests in shallow depressions below the plains, such as the Gunbower Forest, or on broad, occasionally inundated fans such as the Loddon Fan. These younger incised channels were formerly referred to as ancestral rivers (DSE website 2013).

Soils vary on these plains, where regolith, consisting of sands, loams and clays has accumulated. The major soils include sodic, grey texture contrast soils (grey Sodosols) and cracking clay soils (Vertosols) (DSE website 2013).

The texture contrast soils have slightly acidic sandy clay loam surfaces over grey light clays that increase in sodicity with depth. Minor carbonate occurs in the subsoil. The cracking clays are acidic at the surface with light clays clearly changing to heavy clay subsoils that can be more acidic at depth and very few carbonate nodules. Depths for all soils are generally in excess of 2 m (DSE website 2013).

Vegetation is dominated by Red Gums as the major overstorey species. Vegetation communities along these floodplains include a variety of woodlands including Plains Woodland and Drainage-line Woodland. Flooding provides a hazard for this unit but usually only after the modern channels have flooded (DSE website 2013).

Lakes and Basins with Lunettes

Lakes, swamps and depressions with bordering lunettes are found across the plain. Deflation of lake floor sediments to produce lunettes has provided depositional sequences recording lake and climatic changes over as much as the past 50 000 years, as demonstrated at the Kerang lakes and elsewhere in the Mallee (DSE website 2013).

2.6.2 Northern Riverine Plain – Older Alluvial Plain

Plains with Leveed Channels, Sometimes Source Bordering Dunes

Plains with largely inactive leveed channels of various ages are a characteristic of earlier stream deposition that predates the present flood plains. These are referred to here as the prior stream plains. They emanated from the foothills at about the same location as each of the present streams but, unlike the present streams, the stream pattern traversing the plain is distributary and/or divergent. The prior streams and associated levees are generally recognizable features on aerial photographs and contour maps, and are seen as low winding ridges up to 2 km wide and up to 3 m above the level of the surrounding flood plain (DSE website 2013).

Initially the prior streams incised the sediments on the plains during prolonged wet periods, when little erosion was occurring in the uplands. During later dry periods, erosion increased in the uplands and deposited sediments within the incision. Eventually these streams filled the incision with sediment, which then spilled over the plain. Coarse material was deposited nearest to the stream channel forming levees with finer material overflowing onto the plain. In this way prior streams built up levees and clayey flood plains.

Eventually the streams abandoned these courses and new courses developed in the lower land between the ridges. Stream deposition initially continued when the wetter period returned, but eventually the uplands were stabilized, and stream incision again occurred, generally outside the previous meander path. A thin layer of wind-blown calcareous clay called "parna" is believed to mantle much of the prior stream plains east of the Loddon River (DSE website 2013).

The real extent of the prior stream plains associated with each catchment appears to be related to its area and rainfall, with those associated with the Murray River being the most extensive, followed in order by the Goulburn, Campaspe, Loddon and Avoca Rivers (DSE website 2013).

Prior to European settlement the vegetation on the prior stream plains was mainly plains grassy woodland with other woodland complexes but this is mainly cleared and much is now irrigated. The little tree vegetation that remains includes Black Box (*E. largiflorens*) and Buloke (*Allocasuarina luehmannii*). The original grassland vegetation included Spear Grass (*Austrodanthonia* spp.) and Wallaby grass (*Austrostipa* spp.) with Common Rush (*Juncus polyanthemus*) in wetter areas (DSE website 2013).

Pasture is predominant on the more clayey soils with horticulture on the lighter textured soils. The soils are mainly red, brown and yellow texture contrast soils (Sodosols), with grey cracking clays (Vertosols) occupying poorly drained areas. Salinity is an ever increasing problem in the irrigation districts and is associated with shallow water tables; often less than 2 m deep. High sodicity in deep subsoil and soil physical properties such as hard setting surfaces in some Sodosols and high dry bulk densities in some Vertosols may also adversely affect yield in cropping areas (DSE website 2013).

Plains without Leveed Channels

Plains without leveed channels are the most extensive component of the Northern Riverine Plains west of the Campaspe River. The topography is very gentle to almost level with a low northerly gradient northward towards the Murray River. Much is treeless and like the plains with leveed channels, they are mainly comprised of alluvial sediments belonging to the Shepparton Formation, but differ in that leveed prior stream channels are absent.

They are comprised of alluvial sediments that may represent the far flood plains of the plains with leveed channels, or the alluvial plains pre-dating these. In the northern and western parts of the plains there are well-defined shallow drainage depressions. Plains with terminal lakes and drainage basins with lunettes occur towards the most northerly extent of the plains associated with the Loddon and Avoca Rivers. It is likely that most of these lakes and basins were formed as a result of past ground-water discharge from saline aquifer systems, with deflation of the dry lake beds during drier periods forming the lunettes downwind.

Prior to European settlement, woodland complexes and grasslands were the dominant vegetation types with wetlands comprising River Red Gum (*Eucalyptus camaldulensis*), Black Box (*E. largiflorens*) and Lignum (*Muehlenbeckia cunninghamii*) in the creek-lines and swampy areas (DSE website 2013).

On the plains without leveed channels associated with the Avoca, Loddon and Campaspe catchments, the soils are mostly shallow red and brown Sodosols with occurrences of red, brown and grey Vertosols. The major problems associated with the Sodosols are their hard setting surfaces, while all soils tend to have high sodicity in the deep subsoil.

Most of the land is used for grazing, but there are areas under irrigation. Gilgais, a mosaic of mounds and hollows, are common features of the Vertosols prior to cultivation (DSE website 2013).

Plains with Lakes and Depressions with Lunettes, e.g. Lake Tutchewop

Plains with lakes, basins and lunettes occur predominantly within the older alluvial plains and comprise lakes and basins with lunettes of various sizes and complexity as well as the plains within which they occur. Example of lakes and their associated streams include Lake Bael Bael, Lake Cullen, Kangaroo Lake and Lake Tutchewop (Avoca River), and Reedy, Middle and Third Lake and Lake Charm (Loddon River). These units adjoin older alluvial plains as well as modern flood plains, or as isolated units in the plain ridge complex (DSE website 2013).

The dry lake beds are dominated by organic rich fine sediments on which cracking clay soils, often self-mulching, (Vertosols) and Sodosols have evolved. The lunettes vary in composition according to the nature of the lake sediments, and can range from fine sands to clayey and calcareous (DSE website 2013).

Depending on their water supply and salinity, the lakes and basins may be used as water storages, conservation areas, including wildlife habitats, and salt mining. The surrounding plains are mostly used for dryland grazing (DSE website 2013).

2.6.3 North Western Dunefields and Plains – Calcareous Dunefields

Hummocky Dunes Sub-Dominant

Clusters of sub-round dunes occur on an undulating plain in the south-eastern Mallee, extending north-easterly from Beulah West to Swan Hill, a distance of some 130 km (DSE website 2013).

The northern boundary abuts linear dunefields and is thus clear. This boundary appears to approximate to the local southern limit of the Blanchetown Clay. The southern and eastern boundaries are irregular, but clearly defined from riverine plains of the Richardson and Avoca Rivers. Alluvial terraces also cross the unit from south east to North West along the Tyrrell and Lalbert Creeks (DSE website 2013).

The plains on which the dunes occur are generally subdued with weakly-developed stranded ridges (DSE website 2013).

Low hummocky dunes occupy about one quarter of the unit. On subdued plains they tend to occur in clusters which may be as much as 3 km across. The pattern may reflect variation in the clay content of the underlying weathered Parilla Sand (DSE website 2013).

Gilgaied clays (Vertosols) are the most widespread soils, occupying the broad subdued plains, the elongated plains between stranded ridges and the lower slopes of dunes and ridges. Medium-textured Calcarosols occur on the upper slopes of dunes and ridges (DSE website 2013).

Agricultural production is lowered on the clay soils by limited penetration of rainwater and by inherent salinity and sodicity of the gilgai puffs. These effects increase with increasing aridity towards the north. The wind erosion hazard is high only on upper western dune slopes. Seepage salinity has not been noted (DSE website 2013).

2.7 Vegetation

The landscape units described above originally carried their own distinctive vegetation. However, this has been greatly modified by clearing for agricultural purposes and now only remnants remain.

Woodland, predominantly Black Box (*Eucalyptus largiflorens*) but with some Buloke (*Allocasuarina luehmannii*), Belah (*Casuarina pauper*), and Needlewood (*Hakea tephrosperma*), was associated with much of the flatter country adjoining the mallee dunes.

The river flats near Swan Hill contrast with river flats elsewhere along the Murray River in that the former were always treeless, except for a few scattered River Red Gum (*E. camaldulensis*) along the river banks. The ground cover consisted of native grasses and sedges, with Nardoo (*Marsilea drummondii*) growing in seasonally waterlogged areas.

The present plant cover variously reflects the hand of man. The effects of sowing of pastures is reflected in the presence of either annuals such as Wimmera Rye Grass (*Lolium rigidum*), or perennial pastures based on Perennial Rye Grass (*L. perenne*), White Clover (*Trifolium repens*) and Strawberry Clover (*T. fragiferum*).

The volunteer pastures mostly comprise native and introduced grasses including Rye Grasses, Barley Grass (*Hordeum murinum*) and various medics such as Burr Medic (*Medicago polymorpha* var. *vulgaris*) and Barrel Medic (*M. truncatula*).

Halophytic species commonly found on the very saline areas are Seablite (*Suaeda maritima*), Black Roly Poly (*Bassia quinquecuspis*), Samphire (*Crithmum maritimum*), Salt Bush (*Atriplex* spp.) Ice Plant (*Mesembryanthemum crystallinum*) and Pigface (*Sarcozona praecox*). Sea Barley Grass (*Hordeum hystrix*) occurs on the moderately salt-affected soils.

Dillon Bush (*Nitraria billardierei*) occurs on the treeless plain, with Lignum (*Muehlenbeckia florulenta*) in swampy depressions.

2.8 Climate

Since 1996, when recordings commenced at Swan Hill airport, the nearest official weather station, the average annual rainfall has been 316 mm. Prior to 1996 the official weather station was in Swan Hill. Winter rainfall is less than summer rainfall, however the rainfall varies considerably from year to year, the recent highest and lowest values being 582 mm in 2010 and 171 mm in 2006. The rainfall in summer and autumn is more erratic than in winter and spring. Note that an unofficial figure for the long term average annual rainfall at Lake Boga is 335 mm.

Annual evaporation is approximately 1500 mm for Swan Hill. The ratio of rainfall to evaporation (P/E) illustrates the general aridity of the climate. There is a complete dominance of evaporation over rainfall in all months of the year. In June and July the rainfall is about three-quarters of the potential evaporation. From November to April, rainfall is only one-fifth of the potential evaporation (Skene and Sargeant 1966).

Temperatures fall below 0 deg C on an average of 1.8 days in August and 0.5 days in September. The mean maximum temperature is 14.6 deg C in July and 32.9 deg C in January, while the mean minimum is 3.6 deg C in July and 16.0 deg C in February. The mean number of days where the temperature is greater than 35 deg C is 33.0.

The windiest month is October and the least windy is May, with the dominant wind directions being from the south and south east in the morning and from the south west and west in the afternoon.

Table 2 Contextual Settings of the Trial Paddocks

Trial Sites	Land Form	Soil Class	EVC*	Bioregion	Landscape Unit
FPAG10 AB	Flat	Grey & Brown Vertosol	103	Murray Fans	River Flat
GMGP AG	Flat	Grey & Brown Vertosol	103	Murray Fans	River Flat
GMCO7 AG	Flat	Grey & Brown Vertosol	103, 812	Murray Fans	River Flat
JCRO2 AG	Flat	Grey & Brown Vertosol	103	Victorian Riverina	Black Box Woodland
FOSC2.1 Tresco Nth PG	Flat	Grey & Brown Vertosol/Red Sodosol	103, 829	Victorian Riverina	Black Box Woodland
FOSC7 Tresco West PB	Flat	Grey & Brown Vertosol	103	Victorian Riverina	Black Box Woodland
FOSC4.2 Oxley PG	Flat	Grey & Brown Vertosol	103	Victorian Riverina	Black Box Woodland
FOSC3.2 Tresco West PG	Flat	Grey & Brown Vertosol	103	Victorian Riverina	Black Box Woodland
Hawkins Flood Block Ref	Flat	Grey & Brown Vertosol/Red Sodosol	103	Murray Fans	River Flat
Mystic Park Forest Ref	Flat	Grey & Brown Vertosol	103, 829	Victorian Riverina	Black Box Woodland
KCLO3 PB	Flat	Grey & Brown Vertosol	103	Murray Fans	River Flat

*EVC: 103 – Riverine Chenopod Woodland; 812 – Grassy Riverine Forest/Riverine Swamp Forest Complex; 829 – Chenopod Grassland

3.0 Soils

There are two soil classes associated with the trial sites; Grey and Brown Vertosols, cracking clays that are usually self-mulching and Red Sodosols, strong texture contrast soils with carbonates commonly present in the subsoil.

In the district soil surveys undertaken by Skene & Sargeant (1966) and Sargeant, Newell & Walbran (1978), local names were given to soils which had a group of common characteristics. The soils of the trial sites comprise the following:

Boga Clay Loam; a grey saline soil type occupying broad, shallow depressions and low plain in the mallee plain landscape unit which occurs extensively in the Mystic Park area. The original vegetation was predominantly mallee with Black Box a minor component.

Della Clay; a grey, cracking clay which becomes yellowish or brownish, and slightly calcareous between 10 cm and 33 cm, the soil type of the almost level plains of the Black Box woodland landscape unit, which occurs extensively in the Mystic Park irrigation area. Most areas of Della Clay are either saline or potentially saline. The Mystic Park State Forest, a trial reference site is all Della Clay and is extensively timbered with Black Box.

Although not mapped in the 1966 district soil survey, the limited field investigation indicates that the soils of the Fish Point sites are Donnington Clay.

The soil type map is attached (Appendix 1).

3.1 Permeability

In the heavy-textured soils (Della Clays), structural development and cracking are such that entry of water is usually adequate for the pastures which are commonly grown on these soils. However, the clays swell when wetted, and this reduces the rate of water intake such that penetration is sometimes unsatisfactory.

3.2 Salinity

It is very evident that soil salinity is a major potential issue of the trial area. In 1966, Skene & Sargeant found that the irrigated pastoral areas from Mystic Park to Fish Point were on heavy-textured soils, all of which had a potential salt hazard and were not readily leached of salt. They described the situation as follows:

3.2.1 Fish Point Area

About one third of the irrigated pasture land in the Fish Point Irrigation Area is salt affected. The saline soils are those furthest from the Little Murray River. Nearer the river, there is little surface salting, although all of the subsoils are moderately saline and the risk of salinity developing is present.

3.2.2 Mystic Park-Tresco Area

This irrigation area presents a picture of extensive soil salinity in both its

irrigated and unirrigated parts. More than 80 per cent is either highly saline or potentially saline. Della clay and Boga clay loam are highly saline in all but a few situations.

3.3 Sodicity & Dispersion

The surface soils of Boga clay loam and Della clay contain appreciable exchangeable sodium. On application of water, dispersion of the clay occurs in the surface and the permeability of the soil may be greatly reduced. However, if gypsum is incorporated in the surface, dispersion can be prevented and leaching can proceed.

4.0 Conclusions

Scattered across a significant area (15 km by 20 km), the trial sites are underlain by alluvial sediments associated with the Murray River, its anabranch the Little Murray and the Loddon River. Described as Riverine Plain, there are two geomorphic units; the Modern Floodplain and the Older Alluvial Plain.

With the exception of the lunettes, the relief of this land is quite flat, varying between 70 m and 74 m AHD. Height variation across the trial sites is generally 30 cm to 50 cm.

In a biodiversity context, the project area is situated at the boundary of three bioregions, with two present on the trial sites; the Murray Fans and the Victorian Riverina. Within these bioregions there are three landscape units represented across the trial sites; Black Box Woodland, Treeless Plain and River Flat.

While there are a number of soil types that have historically been named for local differentiation, the soils of the trial sites fall broadly into two groups under the Australian Soil Classification. The most common are the grey cracking clays known, as Vertosols. Less common are the texture contrast soils known as Red Sodosols.

Due a combination of tree clearing and a natural lack of trees, the remnant vegetation across the trial sites to the north and west of Lake Tutchewop is predominantly native or improved grasses. Across the Five on Seven Block, the grasses are interspersed with isolated Black Box and Mallee, and in the Mystic Park Bushland Reserve, the vegetation is Black Box Woodland with interspersed Mallee and grasses.

5.0 References

DSE website accessed December 2012 and January 2013 http://www.dse.vic.gov.au/conservation-and-environment/native-vegetation-groups-for-victoria/victorias-bioregions#muf

Sargeant I.J., Newell J.W. and Walbran W.I. *Soils and Land Use in the Torrumbarry Irrigation District, Victoria*. Research Project Series no. 49, 1978. Department of Agriculture, Melbourne.

Skene J.K.M. and Sargeant, I.J. *Soils and Land Use near Swan Hill, Victoria*. Technical Bulletin no. 20, 1966. Department of Agriculture, Melbourne.

VEAC 2008. *River Red Gum Forests Investigation – Final Report.* Victorian Environmental Assessment Council, Melbourne.

White M., Oates A., Barlow T., Pelikan M., Brown J., Rosengren N., Cheal D., Sinclair S. and Sutter G. *The Vegetation of North West Victoria – A Report to the Wimmera, North Central and Mallee Catchment Management Authorities.* (2003) Arthur Rylah Institute for Environmental Research

Appendix 1

District Soil Survey - Soil Type Map

SOIL ASSOCIATION MAP
SWAN HILL AREA
COUNTY OF TATCHERA
VICTORIA

SCALE OF MILES
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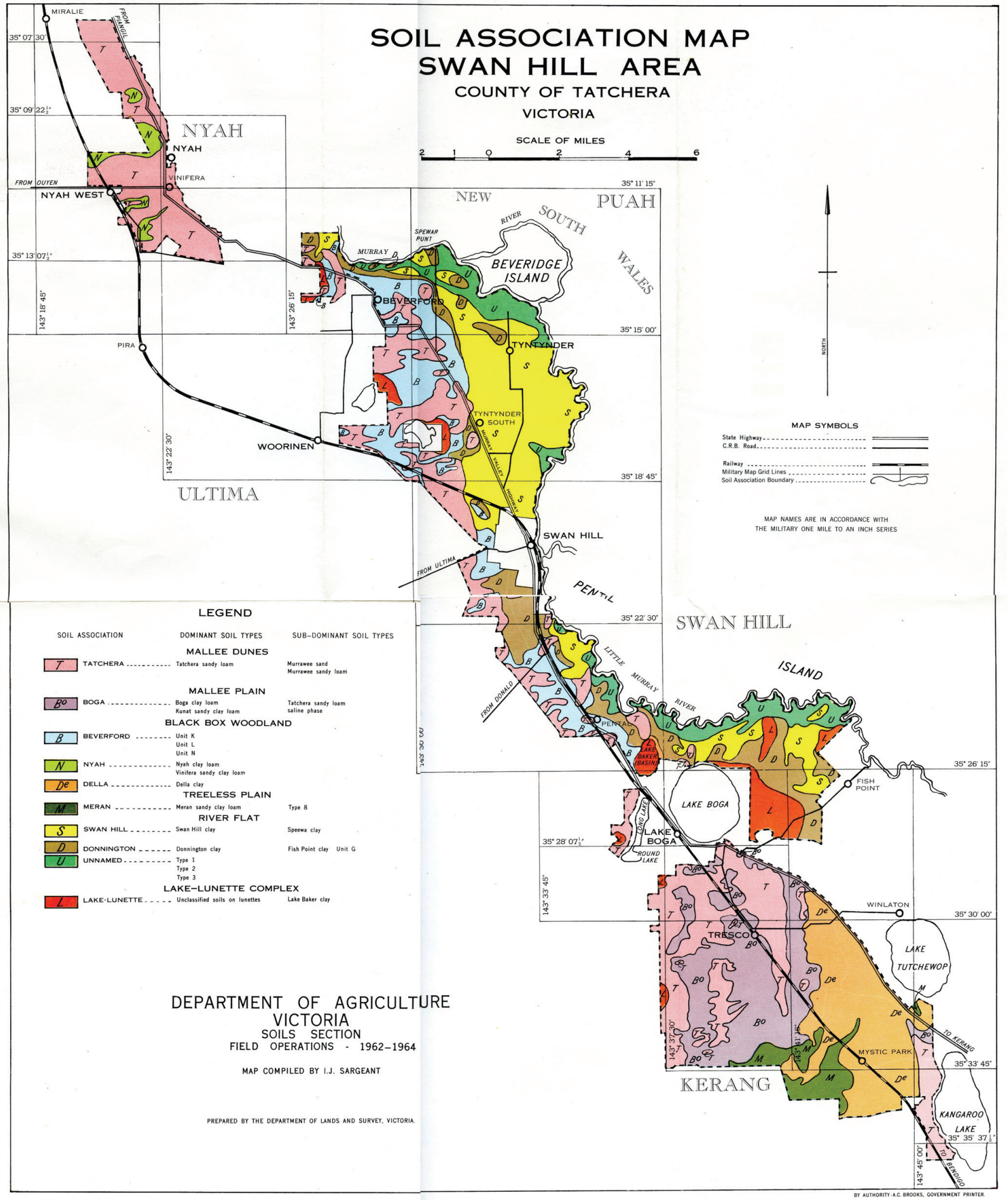


MAP SYMBOLS

State Highway
C.R.B. Road
Railway
Military Map Grid Lines
Soil Association Boundary

MAP NAMES ARE IN ACCORDANCE WITH THE MILITARY ONE MILE TO AN INCH SERIES

LEGEND

SOIL ASSOCIATION	DOMINANT SOIL TYPES	SUB-DOMINANT SOIL TYPES
MALLEE DUNES		
T TATCHERA	Tatchera sandy loam	Murrawee sand Murrawee sandy loam
MALLEE PLAIN		
Bo BOGA	Boga clay loam Kunat sandy clay loam	Tatchera sandy loam saline phase
BLACK BOX WOODLAND		
B BEVERFORD	Unit K Unit L Unit N	
N NYAH	Nyah clay loam Vinifera sandy clay loam	
De DELLA	Della clay	
TREELESS PLAIN		
M MERAN	Meran sandy clay loam	Type 8
RIVER FLAT		
S SWAN HILL	Swan Hill clay	Speewa clay
D DONNINGTON	Donnington clay	Fish Point clay Unit G
U UNNAMED	Type 1 Type 2 Type 3	
LAKE-LUNETTE COMPLEX		
L LAKE-LUNETTE	Unclassified soils on lunettes	Lake Baker clay

DEPARTMENT OF AGRICULTURE
VICTORIA
SOILS SECTION
FIELD OPERATIONS - 1962-1964

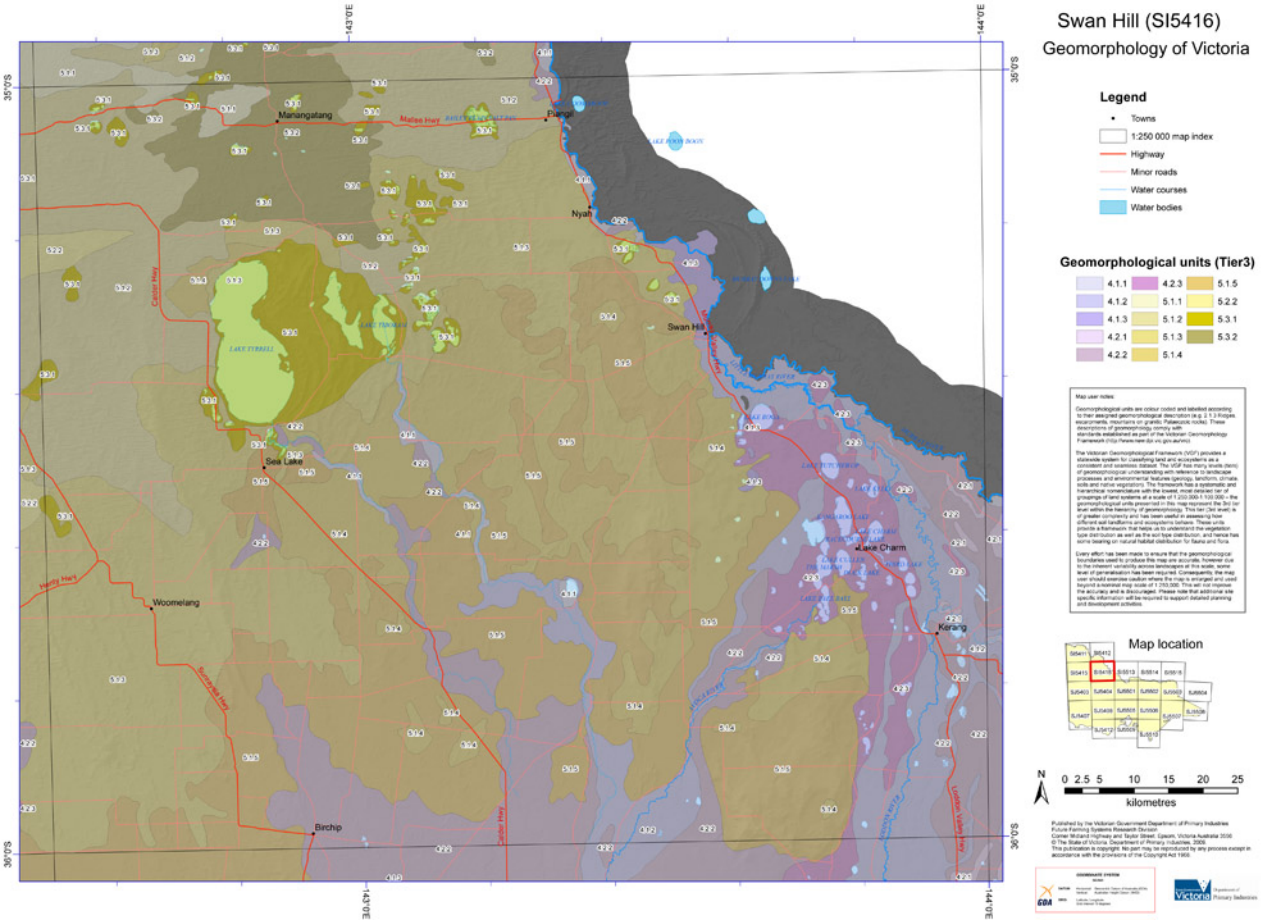
MAP COMPILED BY I.J. SARGEANT

PREPARED BY THE DEPARTMENT OF LANDS AND SURVEY, VICTORIA.

BY AUTHORITY A.C. BROOKS, GOVERNMENT PRINTER.

Appendix 2

Geomorphology

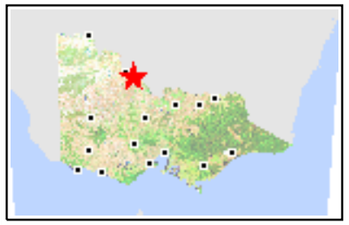

Swan Hill (SI5416)
Geomorphology of Victoria
Legend
Towns
1:250 000 map index
Highway
Minor roads
Water courses
Water bodies
Geomorphological units (Tier3)
4.1.1
4.1.2
4.1.3
4.2.1
4.2.2
4.2.3
5.1.1
5.1.2
5.1.3
5.1.4
5.1.5
5.2.2
5.3.1
5.3.2
Map user notes
Map location
0 2.5 5 10 15 20 25
kilometres
Manangatang
Piangil
Nyah
Swan Hill
Sea Lake
Lake Charm
Woomelang
Kerang
Birchip
143°0'E
144°0'E
35°0'S
36°0'S

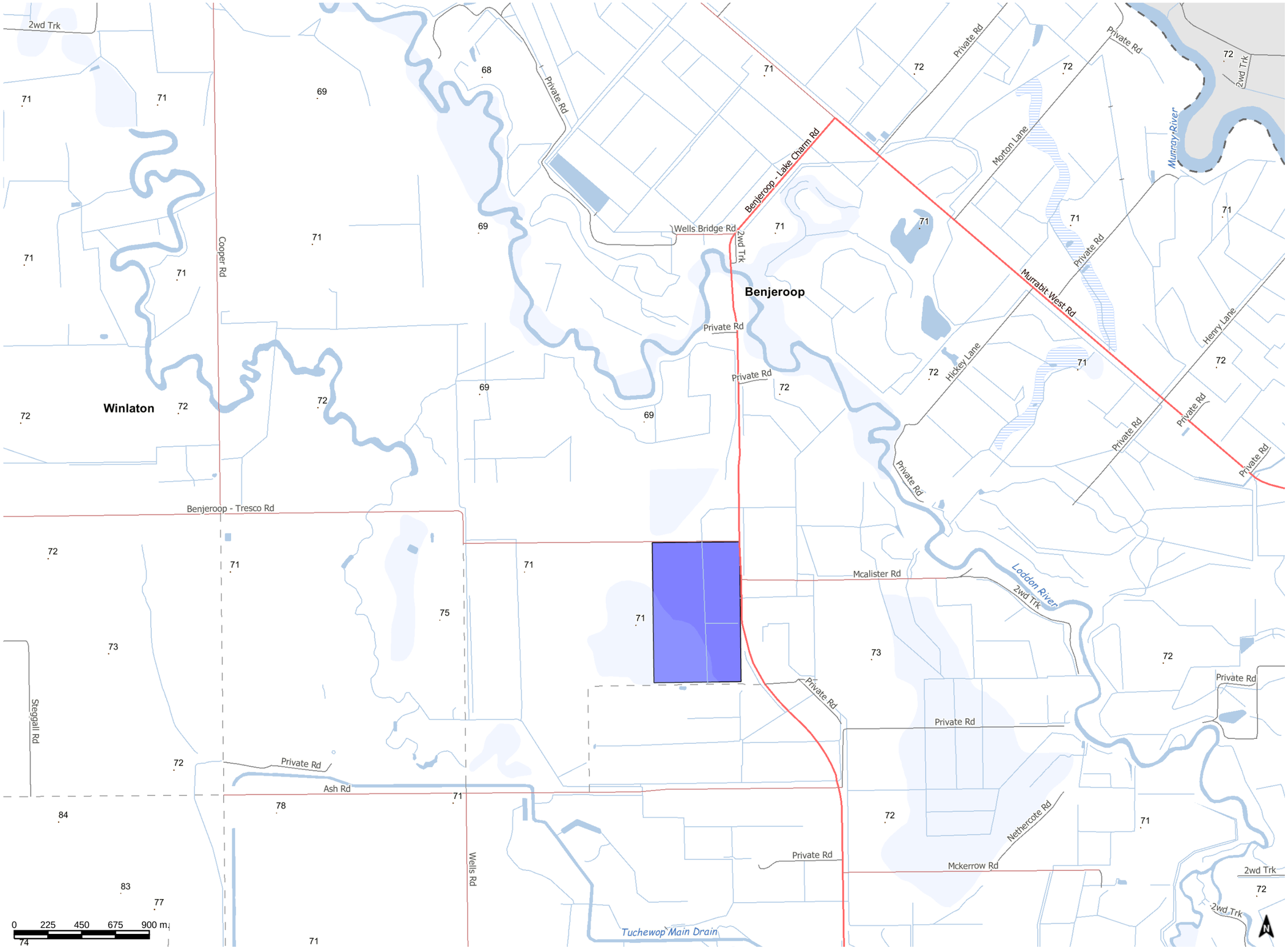
Appendix 3

Features and Spot Heights

Spot Heights - Benjeroop

Department of Sustainability and Environment





ROADS
- Freeway
- Highway
- Main Road
- Secondary Road
- Local Road
- 2WD (Unsealed)
- 4WD Only
- Walking or Cycle Track

WATERCOURSES

UNNAMED DRAINAGE LINES

WATERBODIES
- Watercourse Area
- Permanent Waterbody
- Wetland Area
- Inundation Area

BUILT UP AREAS

Map Scale 1:25,000

Biodiversity Interactive Map A3 Landscape

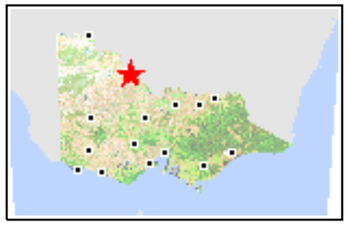
Produced on Thu Feb 21 15:40:29 EST 2013

GDA Vicgrid94

State Government Victoria

Spot Heights - Fish Point

Department of Sustainability and Environment



ROADS
- Freeway
- Highway
- Main Road
- Secondary Road
- Local Road
- 2WD (Unsealed)
- 4WD Only
- Walking or Cycle Track

WATERCOURSES
- UNNAMED DRAINAGE LINES

WATERBODIES
- Watercourse Area
- Permanent Waterbody
- Wetland Area
- Inundation Area

BUILT UP AREAS

Pental Island Rd
Private Rd
Little Murray River
Lette Lane
Mccoy Lane
Vains Rd
Rob Roy Rd
No 7/7 Channel
Tripcony Rd
Lakeside Dr
Lake Boga
Fish Point
2Wd Trk
Fish Point Rd
Winlaton Rd
Herbie Lane
Davies Rd
No 6/7 Channel
Weame Rd

0 225 450 675 900 m.

Biodiversity Interactive Map A3 Landscape

Map Scale 1:25,000

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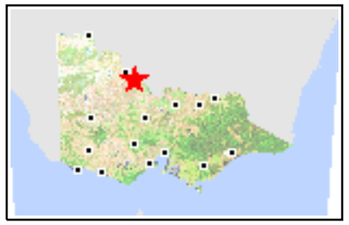
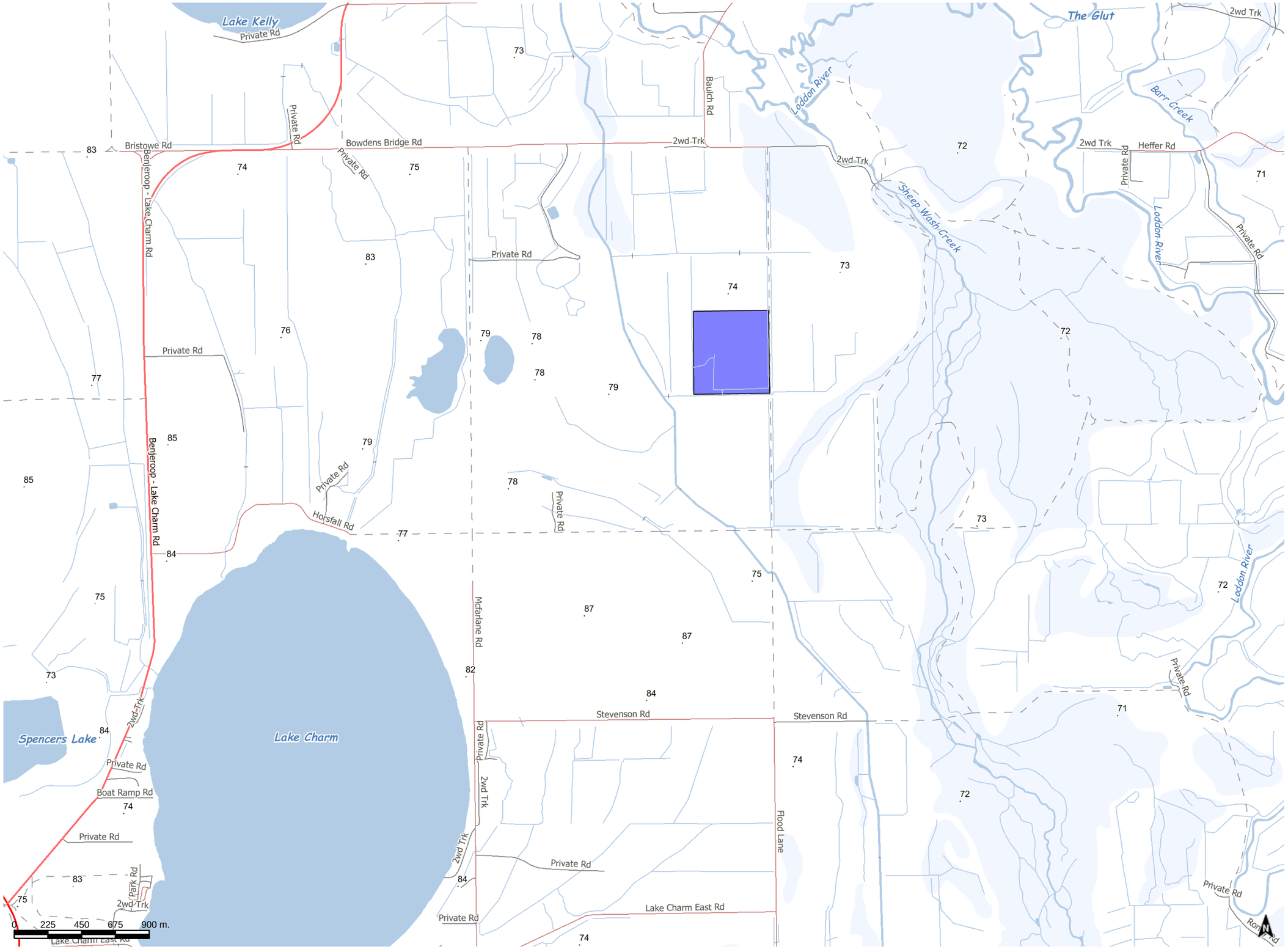
GDA Vicgrid94

State Government Victoria

Spot Heights - Lake Charm

Department of Sustainability and Environment





ROADS
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- Highway
- Main Road
- Secondary Road
- Local Road
- 2WD (Unsealed)
- 4WD Only
- Walking or Cycle Track

WATERCOURSES

UNNAMED DRAINAGE LINES

WATERBODIES
- Watercourse Area
- Permanent Waterbody
- Wetland Area
- Inundation Area

BUILT UP AREAS

Biodiversity Interactive Map A3 Landscape

Map Scale 1:25,000

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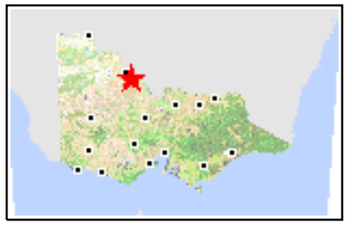
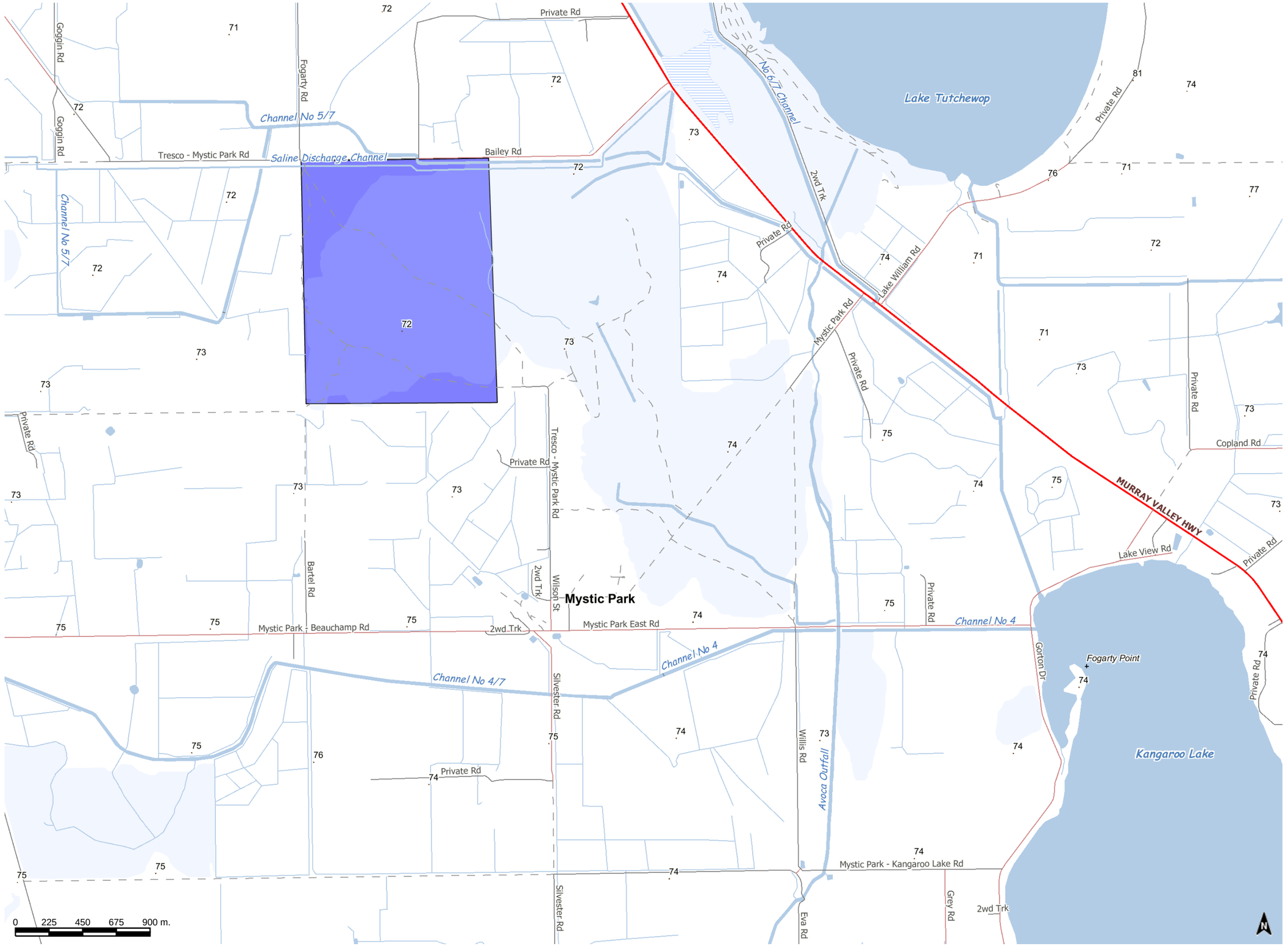
GDA Vicgrid94

State Government Victoria

Spot Heights - Mystic Park

Department of Sustainability and Environment





ROADS
- Freeway
- Highway
- Main Road
- Secondary Road
- Local Road
- 2WD (Unsealed)
- 4WD Only
- Walking or Cycle Track

WATERCOURSES

UNNAMED DRAINAGE LINES

WATERBODIES
- Watercourse Area
- Permanent Waterbody
- Wetland Area
- Inundation Area

BUILT UP AREAS

Map Scale 1:25,000

Biodiversity Interactive Map A3 Landscape

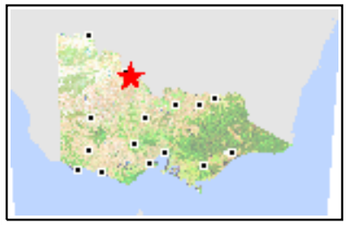
Produced on Thu Feb 21 15:38:48 EST 2013

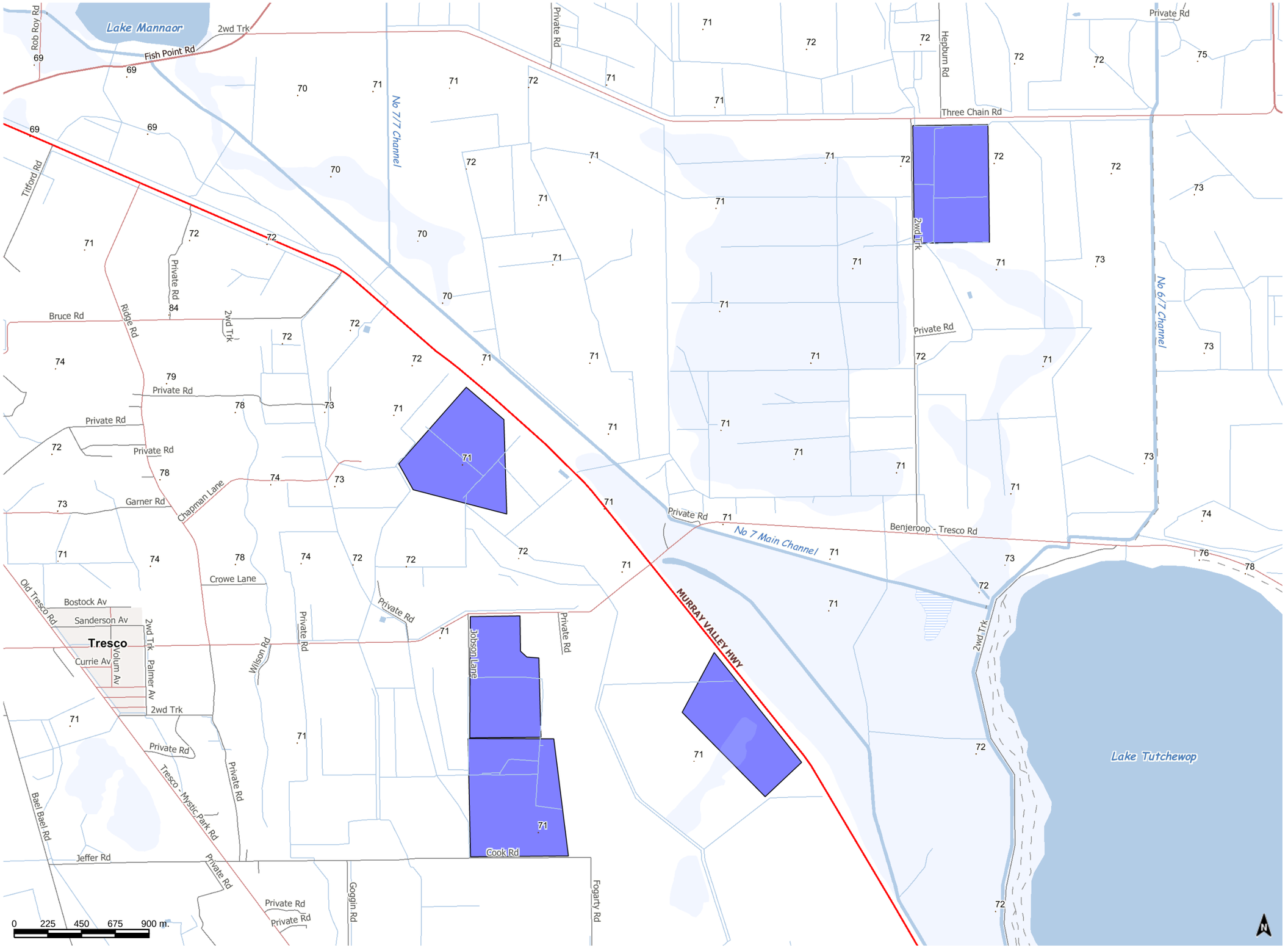
GDA Vicgrid94

State Government Victoria

Spot Heights - Tresco

Department of Sustainability and Environment





ROADS
- Freeway
- Highway
- Main Road
- Secondary Road
- Local Road
- 2WD (Unsealed)
- 4WD Only
- Walking or Cycle Track

WATERCOURSES

UNNAMED DRAINAGE LINES

WATERBODIES
- Watercourse Area
- Permanent Waterbody
- Wetland Area
- Inundation Area

BUILT UP AREAS

Map Scale 1:25,000

Biodiversity Interactive Map A3 Landscape

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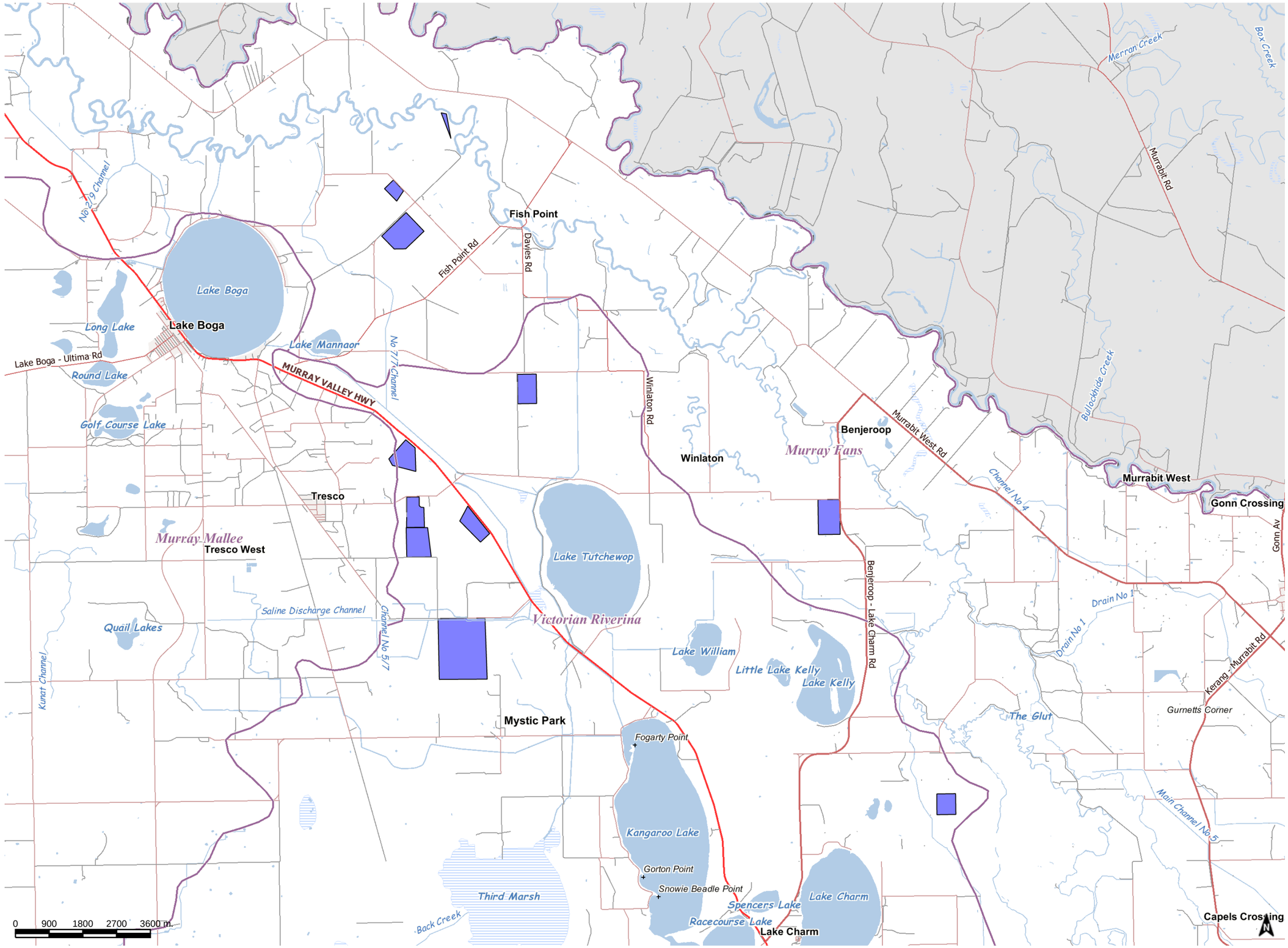
GDA Vicgrid94

State Government Victoria

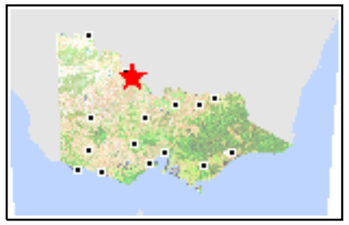
Appendix 4

Bioregions

Bioregions



Department of Sustainability and Environment



BIOREGION BOUNDARY

ROADS
- Freeway
- Highway
- Main Road
- Secondary Road
- Local Road
- 2WD (Unsealed)

WATERCOURSES
- Major Watercourse
- Minor Watercourse

WATERBODIES
- Watercourse Area
- Permanent Waterbody
- Wetland Area

BUILT UP AREAS

Map Scale 1:100,000

Biodiversity Interactive Map A3 Landscape

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GDA Vicgrid94

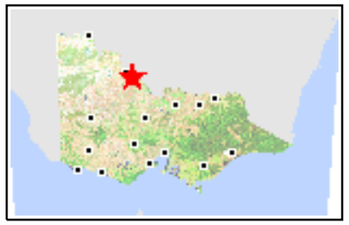
State Government Victoria

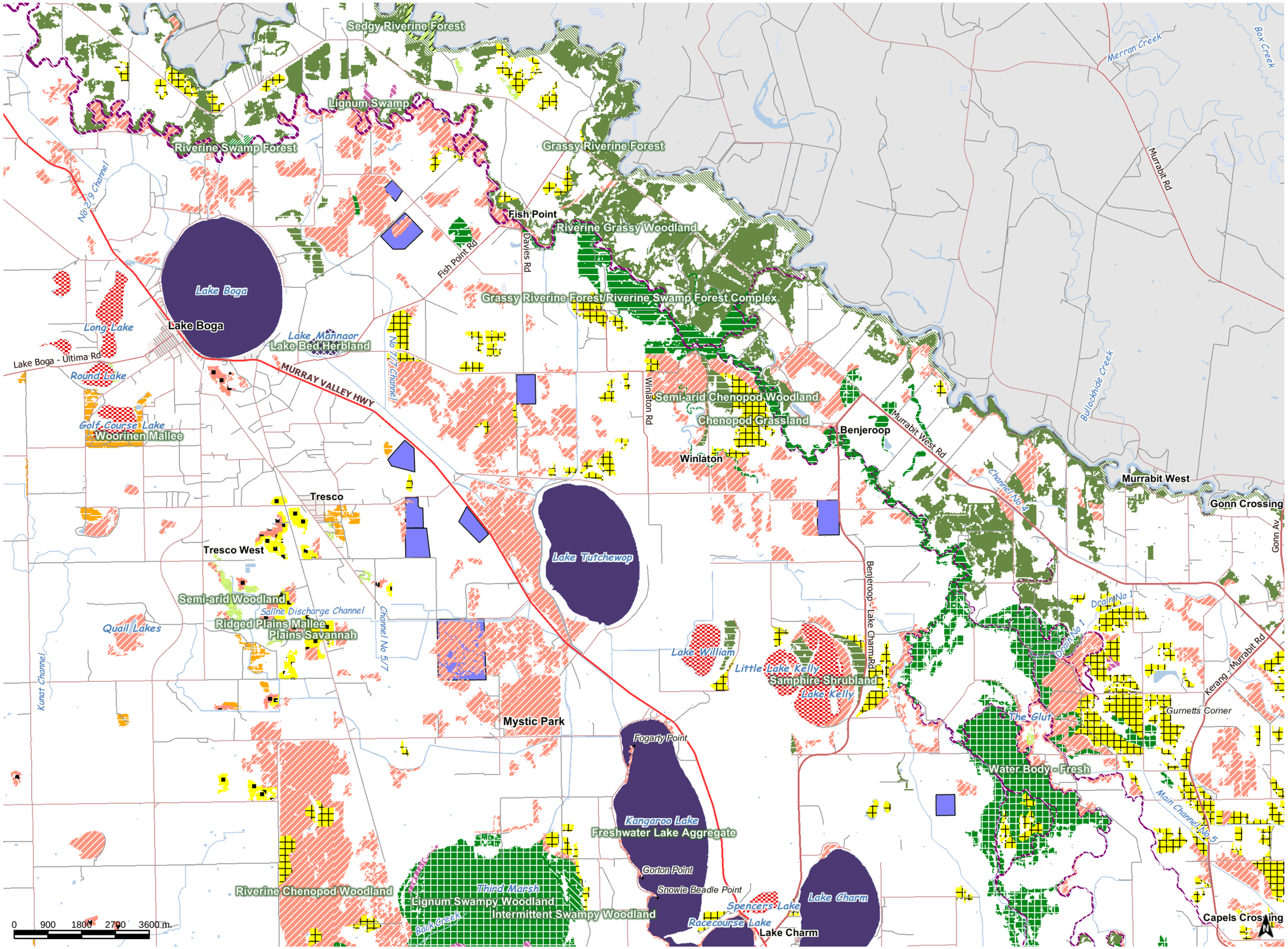
Appendix 5

Extant Ecological Vegetation Classes (EVC)

EVC 2005

Department of Sustainability and Environment





ROADS
- Freeway
- Highway
- Main Road
- Secondary Road
- Local Road
- 2WD (Unsealed)

WATERCOURSES
- Major Watercourse
- Minor Watercourse

ECOLOGICAL VEGETATION CLASSES
- 812 Grassy Riverine Forest/Riverine Swamp Forest Complex
- 813 Intermittent Swampy Woodland
- 823 Lignum Swampy Woodland
- 816 Sedgy Riverine Forest
- 97 Semi-arid Woodland
- 104 Lignum Swamp
- 992 Water Body - Fresh
- 718 Freshwater Lake Aggregate
- 107 Lake Bed Herbland
- 829 Chenopod Grassland
- 826 Plains Savannah
- 101 Samphire Shrubland
- 103 Riverine Chenopod Woodland
- 96 Ridged Plains Mallee
- 824 Woorinen Mallee
- 295 Riverine Grassy Woodland
- 98 Semi-arid Chenopod Woodland
- 106 Grassy Riverine Forest

WATERBODIES
- Watercourse Area
- Permanent Waterbody
- Wetland Area

BUILT UP AREAS

Biodiversity Interactive Map A3 Landscape

Map Scale 1:100,000

Produced on Thu Feb 21 15:28:59 EST 2013

GDA Vicgrid94

State Government Victoria