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Stockland Development Pty Ltd

# Vincentia Development Site

## Aquatic Studies

Report

January 2006

INFRASTRUCTURE | MINING & INDUSTRY | DEFENCE | PROPERTY & BUILDINGS | ENVIRONMENT

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# 1. Introduction

## 1.1 Background

GHD Pty Ltd was commissioned by Stockland Developments Pty Ltd to undertake investigations into aquatic environments downstream of the proposed Vincentia development site (hereafter referred to as the "site"). The site is located at the corner of The Wool Road and Jervis Bay Road, Vincentia NSW (Figure 1). Stockland is seeking approval for a residential subdivision and concept approval for a district town centre across the 127 hectare (ha) site. This document will form part of the supporting documentation for the Stockland proposal.

## 1.2 Aquatic environments

Drainage in the Vincentia area is divided into three main catchments, the largest being in the north. The northern catchment covers over half of the Vincentia locality and drains into environmentally sensitive areas. Two smaller catchments occur in the east and the west. The western catchment has no well-defined watercourses, while the eastern catchment drains directly into Jervis Bay (SCC 1996). The Vincentia site is a part of the western catchment area.

Three watercourses flow through the Vincentia development site in a northerly direction, discharging into two wetlands which are located directly to the north. Wetlands No. 325 and No. 324, were former SEPP 14 Wetlands before being incorporated into the Jervis Bay National Park (JBNP) (Figure 2). These both drain into Moona Moona Creek and subsequently into Jervis Bay Marine Park (SCC 1996).

## 1.3 Purpose

The purpose of this report is to compile and summarise existing data to provide an outline of the aquatic components and processes of the surrounding ecological systems in particular the wetlands, the saltmarsh and mangrove environments of Moona Moona Creek and the Jervis Bay Marine Park as they relate to the site.

The report will:

- Describe the nature and extent of current downstream habitats from the site to Jervis Bay Marine Park;
- Provide baseline data for ongoing monitoring of the wetlands during construction and post development and provide information for the development of the Environmental Management Plans;
- Describe of the potential effects of the proposed development on downstream habitats from the site to Jervis Bay Marine Park; and
- Provide recommendations for the management of onsite activities to mitigate downstream effects on aquatic habitats.

This report forms part of a range of studies that are aimed at providing baseline information on the aquatic environment on the site and the downstream environment. These reports include:

- Water Sensitive Urban Design Study (Forbes Rigby Pty Ltd);
- Baseline Surface Water Quality Monitoring Program (Forbes Rigby Pty Ltd); and
- Monitoring of Saltmarsh Vegetation in Moona Moona Creek, Jervis Bay (Dr N Saintilan, Australian Catholic University).


Study Area

**VERSION: 19/1/06**

**PROJECT NO: 21-14337**

0 0.5 1 1.5
Kilometres

N

GHD
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Client: Stockland Developments Pty Ltd

Project: **Stockland Proposal**

Figure 1 Site Location


Quadrat
Survey transect

**VERSION: 24/5/05**

**PROJECT NO: 21-13727**

0 200 400 600
Metres

N

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Project: **Vincentia Aquatic Assessment**

Figure 2 Survey Site Locations

# 2. Methodology

## 2.1 Desktop Assessment

A desktop assessment involving a review of available literature and data was undertaken to provide baseline data on the nature and extent of the aquatic ecological systems surrounding the site. The literature review was undertaken with a detailed knowledge of the extent and nature of the proposed development to allow a better understanding of the potential causal links between the development and likely impacts on the downstream ecosystems.

## 2.2 Baseline Surveys

Baseline surveys were undertaken to determine the character, species composition and current condition of the downstream wetlands. The degree and extent of the current impacts associated with the adjacent urbanisation at Collingwood Beach (Wetland 324) compared to that of a lower level of development (Wetland 325) was assessed.

### 2.2.1 Background

The two former SEPP 14 Wetlands No. 325 and 324 which are located downstream of the site are likely to currently be impacted upon by differing levels of disturbance from existing landuses. Wetland 324 adjoins the Collingwood Beach urban development area which was established in the 1980s, whilst Wetland 325 is not bordered by development other than the Huskisson Sewerage Treatment Plant and dirt roads and tracks. These two wetlands are directly downstream of the proposed Stockland development.

The freshwater areas within the upper reaches of the two wetlands were assessed in this study concurrently with the long-term monitoring program within the saltmarsh / mangrove communities of the more northerly sections which are being undertaken by Dr Neil Saintilan.

Traditionally, vegetation characterisation, water quality and macroinvertebrate assessment of a wetland area is used to provide indicators as to wetland health and baseline data for ongoing monitoring (Novo Eco Consultancy & SWC Consultancy 2000). However, the lower south-western reaches of the wetlands currently contain no free water. This may be attributable to the extended dry period being experienced across NSW or more likely these wetlands are only intermittently inundated during rain events.

Baseline surveys were undertaken to:

- Determine the species composition of each of the wetlands;
- Measure the current condition of the two wetlands through characterisation of vegetation; and
- Collect data prior to construction of the proposed Stockland residential and commercial development up stream.

It was envisaged that these data would provide a basis from which to:

- Predict responses to upstream changes; and
- Develop measurable goals for wetland management during construction and operation.

### 2.2.2 Vegetation Survey

The boundaries of the wetlands were identified through aerial photograph interpretation and the use of satellite imagery. The most south-westerly freshwater end of the wetlands was chosen for these surveys as saltmarsh / mangrove monitoring was being undertaken in the north-easterly section.

The vegetation within each of the wetlands was characterised through quadrat-based field surveys. The sampling design was aimed at assessing vegetational changes along a 100 metre (m) transect from the edge towards the central wetland area. This design was also aimed at detecting changes associated with edge effects as a consequence of differing neighbouring landuse.

At four sites within each wetland, two on the eastern boundary and two on the northern side, three 20 m x 20 m quadrats were placed at intervals of 20 m perpendicular to the edge of the wetland, ie. over 100 m in total (Figure 2). All vascular plant species within the quadrats were identified and recorded together with the height and percentage cover of the dominant species within each structural layer.

Vegetation communities were described and named according to height, percentage cover and dominant species at the subject site in accordance with Specht (1981). Plant species names follow Harden (1992, 1993, 2000, 2002) or more recent naming conventions as provided by the Sydney Royal Botanic Gardens. Species that could not to be identified in the field or which were likely to have conservation significance were retained for identification by the National Herbarium at the Sydney Royal Botanic Gardens.

### 2.2.3 Analysis

In order to determine differences between the wetlands univariate measurements were used to summarise the attributes of each wetland. Shannon-Weaver Indices were used to calculate the species diversity within the eastern and western sampling sites of each of the wetlands. Two sample T-tests were used to compare differences between the numbers of species on the eastern side compared to the western side within each

wetland ($P < 0.05$). The significance of differences between the numbers of weed species was calculated by Chi-square analysis ($P < 0.05$).

## 2.3 Limitations

There are limitations to the efficacy of all studies and these are most commonly as a result of limited temporal and spatial replication. The baseline studies were undertaken over a five day period during summer across relatively small areas of the entire wetlands. Although summer is considered to be an acceptable time for most ecological assessments it will nonetheless limit the numbers of species recorded as some species are cryptic and can only be recorded during flowering (which may occur in other times of the year). Consequently this study was not designed to record every species but instead to allow data to be collected which characterised the nature of each wetland. These data will provide baseline information to be used in ongoing surveys during and post-construction on the Stockland development site.

Conclusions drawn as to the impacts on the wetlands associated with the proposed development were based on the assumption that the Water Sensitive Urban Design (WSUD) would deliver the outcomes as set out in Forbes Rigby Pty Ltd (2006). The conclusions in Section 4 of this report are dependant upon the targets as stated in the WSUD report being met.

# 3. The Environment

Several aquatic ecosystems occur downstream from the proposed Stockland development site and these are:

- The upper Moona Moona Creek catchment;
- Wetlands;
- Saltmarsh and mangrove communities; and
- Jervis Bay.

These are complex and interconnected systems and each has the potential to be impacted by future development. The following sections provide a background to the key components of each of these ecological systems in terms of processes and components.

## 3.1 The Upper Catchment

The three drainage lines that drain from the Stockland development site are largely undefined watercourses. The Western creek flows into Wetland 325 whilst the Central and Eastern creeks flow into Wetland 324.

The vegetation along the Western and Central creeks is predominately *Eucalyptus longifolia* Open-woodland (Vegetation Community No. 11 of the SIS (ERM 2005) and is characterised by riparian vegetation in the shrub and ground layers. *E. longifolia* is the dominant canopy species and *M. lineariifolia* is the dominant shrub species. Dominant ground layer species include *Lomandra longifolia*, *Hydrocotyle laxiflora*, *Centella asiatica*, *Juncus continuus*, *Dampiera stricta* and *Lepyrodia scariosa*. There have been levels of disturbance through clearing along the transmission line easement on the southern end of the creeks resulting in some introduced species becoming established. However, the overall weed cover in the community was estimated to be 1 %. This Community corresponded to Community 3.3 *Eucalyptus longifolia* – *Melaleuca* forest – woodland of Mills (1993), which occurs along drainage lines and other low-lying areas. Mills (1993) identified it as a significant botanical community because it has limited occurrences, is often associated with wetlands and provides important fauna habitat.

The eastern portion of the Stockland development site is characterised by grassland and sedgeland communities and a number of vegetation communities were mapped along the Eastern creek (ERM 2005) which flows into Wetland 324. *Anisopogon avenaceus* Grassland occurred around the west and graded into *Xanthorrhoea resinifera* Sedgeland to the east and heathland along Eastern creek to the west. This community (Vegetation Community No. 15 of the SIS (ERM 2005)) has experienced some disturbance in the past through the formation of vehicle and walking tracks though few weeds were present. Further to the north-east this community grades into *Eucalyptus robusta* Woodland (Vegetation Community No. 7 of the SIS (ERM 2005)). This narrow community is dominated by *E. robusta* and other trees included *E. sclerophylla* and *Syncarpia glomulifera*. The understorey layer is relatively dense and

dominant species include *Melaleuca linariifolia* and *Acacia longifolia*, sedges and riparian species along the creek. This vegetation community is also relatively weed free and the total weed cover was estimated to be around 1 %. This community corresponded to Community 3.2 *Eucalyptus robusta* forest – woodland of Mills (1993), which is a botanically significant vegetation community in the Jervis Bay region because it has limited occurrences and can contain wetland habitats. It is considered to be Sydney Coastal Estuary Swamp Forest Complex, an endangered ecological community listed under the NSW *Threatened Species Conservation Act 1995*.

## 3.2 Wetlands

### 3.2.1 Description of Wetlands 325 and 324

The differences in the vegetation community assemblages upstream are further reflected in numerous differences in the two wetlands detailed in Table 1.

Wetland 325 has characteristics of a *Marine and Coastal Zone Wetland* in its lower north-easterly reaches, including subtidal aquatic beds and intertidal marshes, and of an *Inland Wetland* in its upper reach of both shrub swamps and freshwater swamp forest. This wetland contains mangroves and saltmarsh, with tidal *Casuarina* grading into wet heath and swamp communities of *Juncus, Melaleuca* and *Phragmites* (Shortland Wetland Centre Ltd 1994).

Conversely, Wetland 324 has been characterised as an *Inland Wetland* dominated by shrub swamps of wet heath with *Melaleuca*, *Hakea*, *Phragmites* and *Juncus* (Shortland Wetland Centre Ltd 1994).

**Table 1 General description of Wetland 325 and 324**

| **SEPP 14 No. 325** | |
|---|---|
| Coordinates | 35$^{o}$03'S Latitude, 150$^{o}$39'E Longitude |
| Location | Located on low-lying land surrounding Moona Moona Creek, Jervis Bay, immediately south-west of Huskisson. |
| Type of Wetland | *Marine & Coastal Zone Wetland:*<br>Subtidal aquatic beds – kelp beds, seagrasses, tropical marine meadows.<br>Intertidal marshes - saltmarshes, salt meadows, raised saltmarshes, tidal brackish and freshwater marshes.<br>Intertidal forested wetlands – mangrove swamps, nipa swamps, tidal freshwater swamp forests.<br>*Inland Wetland:*<br>Shrub swamps – shrub dominated freshwater marsh, shrub carr, alder thicket on inorganic soils.<br>Freshwater swamp forest – seasonally flooded forest, wooded swamps on inorganic soils. |

| **SEPP 14 No. 325** | |
|---|---|
| Elevation | < 10 m metres above sea level (asl) |
| Site Description | Contains mangroves and saltmarsh, with tidal *Casuarina* grading into wet heath and swamp communities (*Juncus, Melaleuca* and *Phragmites*). |
| Landuse | Adjacent landuse is primarily confined to the Wastewater Treatment Works. Trails occur within the vicinity of the majority of its margins. |
| Significance | A number of species which are either rare or absent further north have been recorded in the Jervis Bay wetlands including the saltmarshes of Moona Moona Creek. Species include *Wilsonia backhousei, Gahnia filum* and *Stipa stipoides*. |
| **SEPP 14 No. 324** | |
| Coordinates | 35°04'S Latitude, 150°40'E Longitude |
| Location | 0.3 km from the ocean at Collingwood Beach, Jervis Bay. |
| Type of Wetland | *Inland Wetland*:<br>Shrub swamps – shrub dominated freshwater marsh, shrub carr, alder thicket on inorganic soils. |
| Elevation | < 10 m asl |
| Site Description | Wet heath with *Melaleuca*, *Hakea*, *Phragmites* and *Juncus*. |
| Landuse | Collingwood urban development borders this wetland. A road linking Collingwood Beach with the STP crosses the wetland. Tracks occur around much of the wetland margins. |
| Significance | No details recorded. |
| **Source:** This study, Shortland Wetland Centre Ltd (1994), Travers Morgan (1988) | |

### 3.2.2 Baseline surveys

***Landscape characteristics***

Landscape characteristics varied within and between wetlands and these are detailed in Table 2. The soil texture at the eastern side of Wetland 324 varied from friable to spongy humus which was consistently damp and dark in colour across the entire 100 m transect. In contrast, the soil characteristics along the western side varied across the 100 m from friable to chalky clay and eventually sandy. Soil colour also varied from dark to beige to grey brown and in places was similar to the soil type associated with the Jervis Bay Leek Orchid (*Prasophyllum affine*) populations on the development site. No bare earthen patches were recorded across the sampling sites of this wetland.

Wetland 325 had variable slope conditions from entirely flat in the south-east to flat and gently sloping with a slight channel occurring at around 80 m from the edge. This was reflected in changes in the drainage of the area which varied from dry to moist. Soils varied from more friable drier humus to waterlogged humus towards the centre of the wetland. In sections up to 2 % of the sampled area was bare earth.

***Species composition***

The dominant species at each sampling site within each wetland are detailed in Table 5. Those species recorded at a cover abundance of over 6 % are shown. Wetland 324 (Figure 4) was dominated by *Melaleuca* spp., *Leptocarpus* spp. and *Baumea* spp. whilst the more variable and drier drainage conditions of Wetland 325 (Figure 5) have resulted in a stronger emphasis on *Conosperma* and *Hakea* species. In general, Wetland 325 was dominated by fewer species than Wetland 324.

The quadrats sampled at the edge of Wetland 324 were numerically the most diverse with 33 and 26 species recorded in each, whilst the eastern edge quadrats along Wetland 325 both recorded 13 and 15 species, respectively (Table 3). Overall species richness for the eastern side of Wetland 324 was 53 compared to 33 for the western side whilst for Wetland 325 species richness was the same 28 on both the eastern and western sections. However, when variability with the samples is taken into consideration Shannon-Wiener Diversity Indices (Table 4) indicate that species diversity was lowest along the eastern boundary of Wetland 324 at 1.185, with an index of 2.018 on the western side of this wetland. A similar index was recorded in the west of Wetland 325 at 2.089 whilst the eastern side of this wetland was 1.954.

An increase in species numbers along the eastern boundary of Wetland 324 can be attributed to the presence of weed species which had colonised the edge of this wetland which borders the Collingwood Beach development. The edge impacts associated with this development include dumping of garden refuse, modification of land levels, introduction of weed species and the use of fertilisers and these impacts are shown in Figure 6 and Figure 7. There were significantly more weeds along the eastern boundary of Wetland 324 compared to the western boundary ($X^2 = 11$, DF = 1, P = 0.001). Only one weed species was recorded within Wetland 325 and that was along the eastern side. These data indicate that both wetlands are currently intact

unmodified ecosystems with little weed invasion.  Away from the edges of the wetlands no obvious human disturbance was recorded.

The wetlands would currently provide important fauna habitat for a number of terrestrial and aquatic species.  Although currently dry, during times of inundation these wetlands would be important for dispersal of fauna and flora propagules and wetland birds would be expected to forage in these areas.  These provide an important link between the upper catchment and downstream saltmarsh areas.

**Table 2 Characteristics of Wetland 245 and 245**

| Feature | Wetland 324 | | Wetland 325 | |
|---|---|---|---|---|
| | **Eastern Side** | **Western Side** | **Eastern Side** | **Western Side** |
| Soil texture | Friable to spongy humus | Friable/chalky clay/sandy | Humus | Humus/sandy |
| Soil colour | Dark | Dark/beige/greybrown | Dark | Dark/Beige |
| Soil depth | > 1 m | > 1 m | > 1 m | > 1 m |
| Drainage | Damp | Damp/Moist | Moist / Waterlogged | Dry/moist |
| Physiography | Flat | Flat | Flat | Flat/Gentle Slope |
| Bare earth (%) | 0 | 0 | 0-2 | 0-2 |

**Table 3 Total number of plant species and the percentage of weeds within each wetland**

| Parameter | Eastern Side | | | | | | Western Side | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Transect 1 | | | Transect 2 | | | Transect 3 | | | Transect 4 | | |
| **Wetland 324** | | | | | | | | | | | | |
| **Distance from edge (m)** | **0** | **40** | **80** | **0** | **40** | **80** | **0** | **40** | **80** | **0** | **40** | **80** |
| Species Richness | 33 | 15 | 8 | 26 | 15 | 8 | 17 | 19 | 18 | 14 | 9 | 6 |
| Weed species (%) | 27.27 | 13.33 | 12.50 | 3.85 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Wetland 325** | | | | | | | | | | | | |
| **Distance from edge (m)** | **0** | **40** | **80** | **0** | **40** | **80** | **0** | **40** | **80** | **0** | **40** | **80** |
| Species Richness | 13 | 16 | 17 | 15 | 13 | 18 | 14 | 12 | 14 | 13 | 16 | 13 |
| Weed species (%) | 0 | 6.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Note: 20 m x 20 m quadrats at 0, 40 and 80 m.**

**Figure 3 Species richness and species diversity**

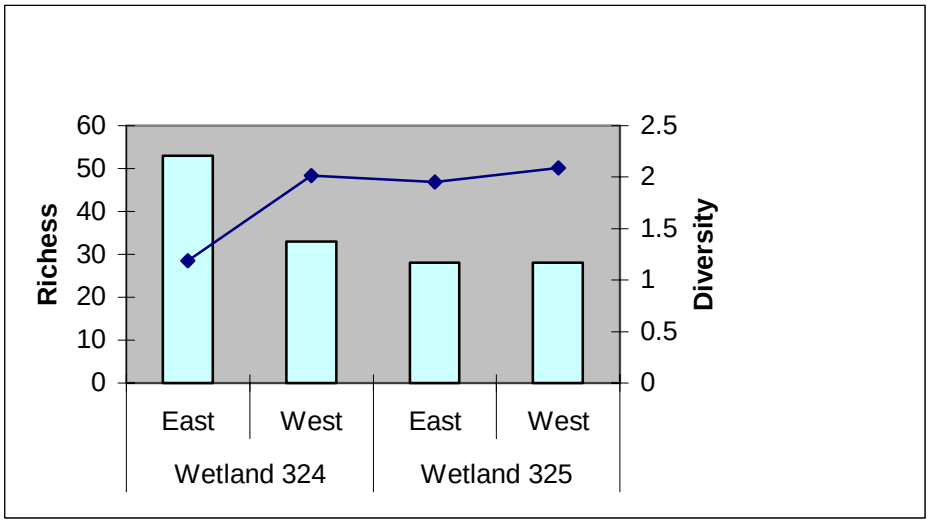

**Table 4 Shannon-Weaver Index of species diversity for each wetland**

| Shannon-Weaver Index | Wetland 324 | | Wetland 325 | |
|---|---|---|---|---|
| | East | West | East | West |
| **Indice** | 1.185 | 2.018 | 1.954 | 2.089 |

**Table 5 Dominant flora species at each of the sampling sites within Wetlands 325 and 324**

| Parameter | Distance from Edge (m) | Dominant Species |
|---|---|---|
| **Wetland 324** | | |
| Eastern side | 0 | *Baumea articulata, Lepidosperma limocola, Acacia elongata, Sprengelia incarnata, Leptocarpus tenax, Exocarpus cupressiformis, Banksia ericifolia, Xanthorrhoea media, Oxylobium arborescens* |
| | 40 | *Melaleuca ericifolia, Baumea articulata, Lepidosperma limocola, Baekea linifolia, Leptocarpus tenax, Sprengelia incarnata, Callistemon linearis, Xanthorrhoea media, Eucalyptus robusta, Hakea sericea, Juncus kraussii, Eleocharis(*?), *Pimelea linearis, Banksia ericifolia* |
| | 80 | *Eleocharis*(?), *Leptocarpus tenax, Villarsia exaltata, Sphagnum novo-zelandicum, Baekea linifolia* |
| Western side | 0 | *Leptocarpus tenax, Viminaria juncea, Melaleuca squarrosa, Melaleuca ericifolia, Leptospermum juniperinum, Baumea juncea, Epacris microphylla, Xanthorrhoea media, Baekea linifolia, Hakea sericea* |
| | 40 | *Xanthorrhoea media, Melaleuca squarrosa, Leptocarpus tenax, Stackhousia* sp.*, Melaleuca ericifolia, Baumea juncea, Phragmites australis, Baumea juncea, Leptospermum juniperinum, Baumea articulata, Hakea sericea* |
| | 80 | *Baumea juncea, Melaleuca squarrosa, Xanthorrhoea media, Melaleuca ericifolia, Leptocarpus tenax, Leptospermum juniperinum, Burchardia umbellata, Goodenia* sp. |

| Parameter | Distance from Edge (m) | Dominant Species |
|---|---|---|
| **Wetland 325** | | |
| Eastern side | 0 | *Leptocarpus tenax, Villarsia exaltata, Lepryodia muelleri, Thysanotus juncifolius, Goodenia* sp.*, Xanthorrhoea media, Burchardia umbellata* |
| | 40 | *Xanthorrhoea media, Pteridium esculentum, Leptocarpus tenax, Eurychorda complanata, Melaleuca squarrosa, Viminaria juncea, Villarsia exaltata, Goodenia sp*. |
| | 80 | *Melaleuca ericifolia, Baumea juncea, Xanthorrhoea media, Eurychorda complanata, Leptocarpus tenax, Melaleuca squarrosa, Viminaria juncea, Villarsia exaltata, Baekea linifolia, Goodenia* sp. |
| Western side | 0 | *Leptocarpus tenax, Xanthorrhoea media, Petrophile pulchella, Baekea linifolia, Melaleuca squarrosa, Viminaria juncea, Eurychorda complanata, Villarsia exaltata, Stackhousia* sp. |
| | 40 | *Eurychorda complanata, Melaleuca squarrosa, Leptocarpus tenax, Baekea linifolia, Xanthorrhoea media, Conosperma ericinum, Epacris microphylla* |
| | 80 | *Conosperma ericinum, Melaleuca squarrosa, Leptocarpus tenax, Xanthorrhoea media, Petrophile pulchella, Baekea linifolia, Hakea sericea* |

**Note: Only species with a cover abundance of 6 % or greater shown.**

**Figure 4  Wetland 324, Jervis Bay NSW**

**Figure 5  Wetland 325, Jervis Bay NSW**

**Figure 6 Wetland 324 boundary with Collingwood Beach**

**Figure 7 Dumping on the eastern boundary of Wetland 324**

## 3.3 Saltmarsh and Mangrove

Mangroves and saltmarsh are recognised as providing important habitat for a diverse range of fauna including crabs, molluscs, insects and spiders, birds and fish during and between tidal inundation (NSW Scientific Committee 2004). Saltmarshes are globally threatened through processes associated with agriculture and urbanisation and the majority of these threats are also common to Australian saltmarsh communities. These communities are particularly sensitive to changes in ground level and modified flows as well as trampling. In recognition of the ongoing threat to saltmarsh communities, Coastal Saltmarsh has been listed as an endangered ecological community under Part 3 of Schedule 1 of the *Threatened Species Conservation Act 1995* (TSC Act) as saltmarsh in the NSW north Coast, Sydney Basin and South East Corner bioregions is likely to become extinct in nature in NSW unless the circumstances and factors threatening its survival cease (NSW Scientific Committee 2004). Threatening processes include:

- Infilling;
- Modified tidal flows;
- Weed invasion;
- Damage by domestic and feral animals;
- Human disturbance;
- Altered fire regimes; and
- Climate change (Adam 2002).

The Moona Moona Creek wetlands are considered to be important on a regional and local scale due to their relatively high species diversity (Adam & Hutchings 1987, Clarke 1993) especially in light of the decline in saltmarsh within south-eastern Australia (Saintilan & Williams 1999, 2000) and the Jervis Bay region in particular (Saintilan & Wilton 2000). The Moona Moona Creek saltmarsh has also been designated as a “Sanctuary Zone” under the Jervis Bay Marine Park Zoning Plan (Marine Parks Authority 2002).

Australian-wide trends over the past 50 years have seen the expansion of mangroves into saltmarsh areas and on occasion mangroves have also advanced seawards (Commonwealth of Australia 1994). Expansion of mangroves is often associated with infilling and sedimentation. Aerial photograph interpretation indicated that in general these changes are reflected in the areas of mangrove vegetation in the Jervis Bay area with an increase in mangrove vegetation recorded from 1944 to 1989 at Cararma Creek, Callala Creek and Currambene Creek. Conversely, no changes in the area of mangrove vegetation were recorded at Moona Moona Creek or Flat Rock Creek over this time (Commonwealth of Australia 1994), although finer scale changes to the distribution of vegetation communities may have occurred within these two areas (Commonwealth of Australia 1994).

The Moona Moona Creek saltmarsh and mangrove communities are dominated by the sedge, *Juncus krausii* and the mangrove, *Aegiceras corniculatum*. These are characteristic of a system which is currently adapted to moderately freshwater conditions as *J. krausii* is an indicator of strong groundwater flows whilst *A. corniculatum* is a mangrove commonly associated with river systems (N. Saintilan, pers. comm.).

## 3.4 Jervis Bay

Jervis Bay is a kidney shaped marine embayment with a maximum depth of 30 m and a surface area of 102 $km^2$ (Commonwealth of Australia 1994). The majority of the shoreline is bordered by dune formations although the bay opens onto the continental shelf via coastal sandstone cliffs. Oceanographic currents are predominantly temperate but with seasonal tropical influences. It is a relatively pristine marine environment, which is considered to be attributable to:

- A relatively small catchment (approximately 400 $m^2$) which limits freshwater run off into the bay except during heavy rainfall events; and
- Limited urbanisation and industrialisation within the catchment.

Jervis Bay supports a diverse range of marine environments including:

- Sandy beaches;

The shallow waters of sandy beaches provide important habitat for fauna with 108 species of fish and invertebrates being recorded in these waters. The sandy beach environments have also been shown to provide important habitat for rare species, baitfish and juveniles of a number of species (Commonwealth of Australia 1994).

- Rocky reefs (< 10 m in depth);

The intertidal and subtidal epifauna of rocky shores are diverse and unique which is thought to be related to Jervis Bay being a transition zone between warm and cold temperate biogeographic zones (West 1987).

- Extensive seagrass meadows;

The seagrass meadows of Jervis Bay are comprised of around six species which is one of the highest known species diversity of any meadows in Australia. They are dominated by *Posidonia australis* and *Zostera* spp. although other species are present, including *Halophila ovalis* and *Heterozostera tasmanica*. Seagrass meadows are crucial to the development of many species of fish and provide habitat for a range of infauna (Commonwealth of Australia 1994).

- Open sandy areas within the bay; and

These areas provide habitat for a range of fish species some of which have commercial importance.

- Scattered biogenic structures, polychaete mounds and clumps of bivalves.

These are found spread across the open sandy areas within the bay and provide additional habitat through increases in substrate complexity.

The uniqueness and relatively pristine nature of Jervis Bay was recognised as being of exceptional value and consequently it was declared a Marine Park under the *Marine Parks Act 1997* (MP Act) and placed under the management of the NSW Marine Parks Authority (NSW Marine Parks Authority 2002). The objectives of the MP Act are:

- The conservation of marine biological diversity and marine habitats through declaration and provision for the management of a comprehensive system of marine parks; and
- The maintenance of ecological process in marine parks.

This does not necessarily preclude ecologically sustainable fishing or recreational use but activities are guided by zoning of activities in appropriate areas in response to the spatial spread of ecological values across the park. For Jervis Bay Marine Park these zones are:

- Sanctuary Zones which make up 20 % of the park and include areas of estuaries, sandy beaches, intertidal rocky shores, seagrass meadows, soft sediments, subtidal reefs, mudflats and several other small areas in various locations. Moona Moona Creek is the closest Sanctuary Zone to the Stockland site. Wetland 325 and 324 discharge into Moona Moona Creek.
- Habitat Protection Zones provide for stringent environmental protection and consequently prohibit high impact activities, such as trawling, from occurring within this zone. All estuaries not zoned as a Sanctuary Zone are included under this zoning. A range of other habitats is also included and the total area covered by this zoning is approximately 72 %. The point of discharge of Moona Moona Creek into Jervis Bay is zoned as Habitat Protection.
- General Use Zones provide for a wider range of activities including commercial and recreational. Two areas are zoned as General Use and both of these are outside the Jervis Bay embayment. One is located at Crookhaven Bight to the north and the other within Wreck Bay to the south. These areas account for around 8 % of the entire marine park area.
- Special Purpose Zones account for approximately 0.2 % of the marine park. This zone accounts for areas which require special management including habitat around the Huskisson Wharves and an area immediately adjacent to HMAS Creswell. None of these areas are in areas adjacent to Moona Moona Creek.

An area designated as Commonwealth Waters is located between HMAS Creswell and Bowen Island.

# 4. Potential Changes and Impacts

The Stockland proposal includes retention of the three drainage lines which flow through the site in a northerly direction and which discharge into Wetland 324 and 325. Retained riparian zones have been designed to allow retention of important fauna habitat, movement corridors and an endangered ecological community.

The proposed development has the potential to result in changes to the hydrology through alteration to the natural drainage and flow patterns and changes to water quality and water levels through the piping of the Eastern creek, construction of stormwater retention ponds and the introduction of hard surfaces. Several ephemeral ponds will be constructed in the asset protection zones (APZs) as will swales to aid infiltration before water is released into the drainage areas.

Predictions of impacts rely on an understanding of the nature, extent, components and functioning of the proposed development combined with the processes and components of the surrounding ecological systems and the causal links between the development and likely impacts on the ecological system (Commonwealth of Australia 1994). These process are well understood although each situation and ecosystem is unique and changes at microscales cannot always be predicted and changes at larger scales may be irreversible once noticed.

The key threats for wetlands world-wide are well known and centre around anthropogenic affects which effect water flows and water quality with the diversion of water resources and floodplain development considered to be the most deleterious and pervasive. In particular, threats to wetlands in coastal NSW are derived from the drainage and alteration of floodplains through agricultural development and urbanisation (Adams 2000, Kingsford *et al.* 2003). Coastal aquatic ecosystems within NSW face significant pressures from growth in populations and settlements (NSW EPA 2003).

Potential impacts to the upper catchment, wetlands, saltmarsh / mangrove and marine ecosystem of Jervis Bay National Park are common to all areas and are undoubtedly interrelated. The potential indirect impacts associated with changes to the subject site's hydrology include:

- Changes in the flow regimes are predicted with an annual increase in volumes to each of the wetlands of:
  - Wetland No. 324: 13 ML; and
  - Wetland No. 325: 88 ML.
- An increase (or decrease) in flows may alter vegetation patterns along the three creeks and wetlands shifting them to a wetter system. An increase in hydrological flows which delivered increased freshwater to the wetland and saltmarsh may promote the colonisation of non-wetland species and provide mangroves with a competitive advantage over saltmarsh species;

- Ephemeral ponding associated with swales constructed within the APZs may result in the death of at least some of the trees within these areas;
- Increased nutrient loads may encourage colonisation of the area by weeds and result in a loss of fauna from the wetlands, including wetland birds; and
- Sedimentation rates and nutrient loads have the potential to increase, especially during construction and / or major rain events as sediments get washed through the system and deposited within the wetlands, saltmarsh and Jervis Bay. This could result in the shift of vegetation over time and in the contraction of the wetlands. Increased levels of sedimentation could also result in the colonisation of mangrove propagules within the saltmarsh community (N. Saintilan, pers. comm.).

This study demonstrated that the system currently is relatively intact which is most likely due to limited development in the upper catchment resulting in:

- Few weed species within the vegetation communities of the riparian areas;
- Intact and generally weed free wetlands despite encroaching development;
- No obvious changes to saltmarsh / mangrove distributions over the past 50 years; and
- Relatively pristine marine environment of Jervis Bay.

Contrary to expectations the spread of weeds into Wetland 324 from the adjacent Collingwood Beach development was limited and mostly confined to the edges. The limited spread of weeds through the wetland could be partially attributable to the fact that the majority of the inflow water would come from the largely undeveloped catchment upstream at Stockland's proposed development site. Nonetheless, the spread of weed propagules would be expected once the edges had been altered but this appears to be limited in this case suggesting that these currently low phosphorous environments are inhospitable to exotic species.

Based on the results of the baseline monitoring survey of Wetland 324 and 325, one of the most obvious risks to the drainage lines throughout the site and downstream wetlands could potentially be human disturbance. Along the south-eastern edge of Wetland 324 adjacent to Collingwood Beach impacts associated with urbanisation included introduction of weed species and dumping of rubbish and other inappropriate landuse activities such as storage of trailers and boats.

Moona Moona saltmarsh currently has few obvious impacts associated with current levels of development as indicated by stable saltmarsh / mangrove boundaries over many years, although some trampling along informal tracks has occurred (N. Saintilan, pers. comm.). However, the saltmarsh community is potentially at risk through urbanisation of the catchment allowing mangrove communities a competitive advantage over saltmarsh (Saintilan 2005) through:

- An increase in hydrological flows which would freshen the saltmarsh plain, promoting the colonisation of the saltmarsh by mangrove; and
- An increase in sedimentation rate, facilitating the survival of mangrove propagules in the saltmarsh plain.

The relatively pristine nature of Jervis Bay is reliant on the small catchment area limiting runoff and ensuring quality of that runoff. Potential impacts to the marine ecosystem of Jervis Bay National Park include disruption of flow regimes and water quality, resulting from an increase of pollutants in the form of changes to physico-chemistry resulting ultimately in changes to species composition.

Changes to water quality through pollution have measurable impacts on marine environments particularly those in estuaries and along coastal zones close to human population centres (Ponder *et al*. 2002). Sources of pollution can generally be grouped into two types:

- Point source pollution resulting from direct discharge into the marine environment and these can include sewage outfalls, industrial discharge or accidental spills; and
- Diffuse sources of pollution can result from a wide range of land based human activities and carried as catchment runoff to the marine environment via watershed streams and ground water, or through atmospheric sources such as wind and rain (Ponder *et al*. 2002). These can include sediments as a result of land clearing, agricultural runoff including pesticides and fertilisers, development and / or construction works, urban stormwater discharge (NSW Fisheries 1998).

Pollution can directly impact marine ecosystems by reducing species fecundity, increasing physiological stress and causing mortality immediately or over a longer time frame through such factors as bioaccumulation. Indirect effects may result from changes to community composition and function through selection for pollution-tolerant species or may have broader effects on the health or survival of predatory species (Ponder *et al.* 2002). These major categories of marine pollution and their effects are detailed in Table 6:

**Table 6 Pollution types and affects**

| Pollution Type | Affects |
|---|---|
| Toxic substances | Organochlorine, PCBS and heavy metals may cause direct poisoning and a range of secondary or cumulative impacts. |
| Excessive nutrients | Eutrophication and changes in communities, algal blooms and increased Biological Oxygen Demand. |
| Sediments | Siltation and sedimentation resulting in smothering, substrate changes, reduction in light and loss of vegetation. |
| Oil and petroleum | Spills may result in smothering of benthic organisms and toxic effects. |

Currently in Jervis Bay, the primary sources of suspended solids and nutrients originate from:

- Oceanographic movement of water experienced during upwelling events and storms;
- Stormwater runoff experienced through rainfall that enters the system through creeks or groundwater; and
- Sewage (Commonwealth of Australia 1994).

The concentration of nutrients and suspended solids is likely to arise from diffuse sources and be delivered to Jervis Bay through catchment run-off. Catchment run-off is primarily linked to landuse activities within the catchment. The effects of increased nutrient loads via groundwater are less well understood but it is considered that there is potential for the effects to be significant (Commonwealth of Australia 1994).

Impacts on marine ecosystems from urbanisation are well known and many cases of nutrient over-enrichment of estuarine and coastal waters have resulted in algal blooms and eutrophication ranging from the Gulf of Mexico 'Dead Zone' of up to 20,000 km resulting from excess nutrient runoff from the Mississippi basin to frequent algal blooms from nutrient enrichment within Lake Illawarra. The effects of nutrient enrichment can be reversed and lower phytoplankton concentrations, greater water clarity and more extensive seagrass meadows were recorded in four estuaries of South-west Florida in 2002, compared to 1982 after nitrogen loads entering the estuaries were reduced by around 50 % (Tomasko *et al*. 2005). However, species distribution and composition will not necessarily return to post-impact assemblages as those species returning to an areas will be depend on a number of variables including current sediment chemistry and recruitment levels.

Broader impacts across the locality may also be experienced by fauna which are sensitive to changes within large home range areas. This may include the White-bellied Sea-eagle *(Haliaeetus leucogaster)* which is known to nest in the locality. This species is particularly sensitive to alterations in habitat and have been known to abandon home range and nesting sites in response to increased urbanisation (F. Clements, pers. comm.). However, it should be noted that the current levels of urbanisation have not disrupted its home range to such an extent that it has resulted in abandonment of this area.

# 5. Mitigation and recommendations

Mitigation measures will be implemented to reduce impacts on the relatively pristine and intact downstream ecosystems.

## 5.1 Water Sensitive Urban Design

An important design criterion for the development of the Stockland proposal was the incorporation of a number of Water Sensitive Urban Design (WSUD) features (Forbes Rigby Pty Ltd 2006) which will focus on:

- Stormwater management measures to minimise impacts of litter, sediments and nutrients on water quality;
- Water supply management to reduce town water usage;
- Wastewater management to optimise opportunities for recycling; and
- Groundwater management.

WSUD measures are detailed in Forbes Rigby Pty Ltd (2006). However, they will include the installation of general pollutant traps, which will remove coarse pollutants such as litter. Bioswales will also be used in the role of physical filtration and capture of fine sediments and exfiltration to groundwater. Small particle sizes will be removed by the bio-swale including fine sands. The subsurface filter component of the swales will be designed to treat trickle flows up to a few litres per second and will also aid in recharge of the groundwater system during dry periods.

Artificial wetlands will be constructed with deepwater zones and macrophyte zones. Deepwater zones will remove those particle size ranges and hydraulic loadings that are not captured and assimilated at earlier stages. Fine sediments will be stored in the bottom of the wetland and absorbed nutrients made available for plant uptake. Macrophyte zones provide for enhanced sedimentation through provision of direct filtration by plant stems and reduced resuspension of bottom sediments. Macrophytes actively take up nutrients and convert them into a less bio-available form.

Modelling by Forbes Rigby Pty Ltd (2006) has indicated *that the proposed wetlands and bioswales are capable of reducing the mean pollutant loads to the same (or reduced) levels expected to occur under existing (mostly forested) conditions. The proposed wetland and bioswales system will therefore ensure the low pollutant loads currently entering the wetlands downstream of the site are not increase beyond exiting (low) levels*.

Modelling of the average annuals flows for each of the wetlands by Forbes Rigby Pty Ltd (2006) indicates that increased flows to each of the wetlands are expected and the volumes are:

- Wetland No. 324: 13 ML; and
- Wetland No. 325: 88 ML.

Such an increase in volume is within natural year to year variability in inflow volumes for these wetlands and is less than modelled increases in annual flow resulting from existing development in Vincentia (Forbes Rigby Pty Ltd 2006). However, there is the potential that such changes may still shift the downstream ecosystems to wetter ecosystems.

## 5.2 Riparian zones

Retention and design of the riparian zones on the development site have also been aimed at providing important habitat features for a number of species including the Yellow-bellied Glider (*Petaurus australis*), microchiropteran bats, the Giant Dragonfly (*Petalura gigantea*) and nest sites of the Glossy Black-cockatoo (*Calyptorhynchus lathami*) as well as providing movement corridors through the site to assist in the retention of connectivity within the locality. These areas will also retain the endangered ecological community, Sydney Coastal Estuary Swamp Forest Complex.

## 5.3 Buffers

Stockland's proposal does not directly adjoin the wetlands and a physical buffer occurs between the development footprint and the wetlands. This buffer has been increased along the Central creek to accommodate Glossy Black-cockatoo nest sites and foraging habitats.

## 5.4 Monitoring Program

The data from this survey could be used to develop a Vegetation Management Plan for the site and wetlands and this should be designed around a Reactive Monitoring Program. The program should have the following attributes:

- Integration of biophysical monitoring program within a management response framework;
- It should apply development and habitat trigger levels to predict and mitigate environmental impacts prior to their occurrence; and
- Trigger levels and management responses should be formally adopted within approvals and permits to ensure compliance.

The benefit of a Reactive Monitoring Program is that it predicts and moderates impacts by monitoring and controlled important construction processes to meet habitat tolerances and validates its effectiveness by monitoring key habitats and incorporating model validation studies.

Dr Neil Saintilan has also begun monitoring of the saltmarsh communities in Moona Moona Creek and this will form part of a larger monitoring program for saltmarsh within the Jervis Bay catchment.

# 6. Conclusion

On a broad scale, the pristine nature of Jervis Bay reflects the relative small-scale nature of development within the wider catchment area as currently there appears to be few large scale impacts on this ecosystem. However, there are examples of impacts on a smaller scale mostly around the areas of concentrated urbanisation. These are reflected in changes to mangrove / saltmarsh distribution over time and direct impacts such as trampling and the dumping of rubbish.

Wetlands No. 324 and 325, and downstream saltmarsh / mangrove areas, appear to be healthy ecosystems with few apparent impacts as a result of current levels of urbanisation within the catchment. These findings suggest that these systems have some degree of resilience to the current moderate levels of urbanisation upstream from the subject site and Collingwood Beach development. Weed species have not spread into the wetland adjacent to the Collingwood Beach development and there are currently few measurable impacts on the Moona Moona Creek saltmarsh / mangrove complex.

This could reasonably be expected to continue if the current hydrological processes including groundwater, surface flow regimes and water quality are maintained at present levels. Modelling by Forbes Rigby Pty Ltd (2006) has predicted that there will be an increase in annual inflow volumes of 13 ML and 88 ML for Wetlands 324 and 325, respectively. Although these volumes are within the range of natural year to year variability there is the potential for the downstream ecosystems to become wetter and changes to species composition and distribution to alter. However, modelling results show that the increase in annual inflow into the wetlands will be less than that historically experienced through urbanisation of the existing Collingwood Beach development. The assessment associated with the Water Sensitive Urban Design features incorporated into the proposal have indicated that groundwater and water quality will be maintained at current conditions. Additionally, around 48 ha of the subject site will also be retained for conservation of critical areas including riparian and adjacent woodland and heathland creating a buffer to the streams and downstream wetlands.

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Appendix A

# Wetland Flora Species Lists

| Family | Scientific Name | Common Name | Wetland No. 324 | | | | | | | | | | | | Wetland No. 325 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | East | | | East | | | North | | | North | | | East | | | East | | | North | | | North | | |
| | | | Quadrat Number | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1A | 1B | 1C | 2A | 2B | 2C | 3A | 3B | 3C | 4A | 4B | 4C | 5A | 5B | 5C | 6A | 6B | 6C | 7A | 7B | 7C | 8A | 8B | 8C |
| **Angiosperms** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Apiaceae | *Centella asiatica* | Indian Pennywort | | | | | | | | | | | | | | | | | | | | | | | X | |
| | *Hydrocotyle bonariensis** | | X | X | | | | | | | | | | | | | | | | | | | | | | |
| | *Hydrocotyle* sp. | | X | | | | | | | | | | | | | | | | | | | | | | | |
| Asparagaceae | *Protoasparagus aethiopicus** | Asparagus Fern | X | | | | | | | | | | | | | | | | | | | | | | | |
| Asteraceae | *Aster novi-belgii** | Michaelmas Daisy | X | | | | | | | | | | | | | | | | | | | | | | | |
| | *Chrysanthemoides monilifera* subsp*. rotundata** | Bitou Bush | X | | | | | | | | | | | | | | | | | | | | | | | |
| Baueraceae | *Bauera rubioides* | River Rose, Dog Rose | | | | X | X | | | | | | | | | | | | | | | | | | | |
| Blandfordiaceae | *Blandfordia nobilis* | Christmas Bells | | | | | | | | | | | | | | | | | | | | | | | X | |

| Family | Scientific Name | Common Name | Wetland No. 324 | | | | | | | | | | | | Wetland No. 325 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | East | | | East | | | North | | | North | | | East | | | East | | | North | | | North | | |
| | | | Quadrat Number | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1A | 1B | 1C | 2A | 2B | 2C | 3A | 3B | 3C | 4A | 4B | 4C | 5A | 5B | 5C | 6A | 6B | 6C | 7A | 7B | 7C | 8A | 8B | 8C |
| Casuarinaceae | *Allocasuarina* sp. | | X | | | | | | | | | | | | | | | | | | | | | | | |
| Colchicaceae | *Burchardia umbellata* | Milkmaids | | | | | | | X | X | X | | | | X | | | X | X | X | | | | | X | |
| Cyperaceae | *Baumea articulata* | Jointed Twig-rush | | X | | X | | | | | | | X | | | | | | | | | | | | | |
| | *Baumea juncea* | | | | | X | X | X | | X | X | X | X | X | | | | | | | | | | | | |
| | *Eleocharis*(?) | | | X | X | | | | | | | | | | | | | | | | | | | | | |
| | *Lepidosperma limicola* | | | | | X | X | | | | | | | | | | | | | | | | | | | |
| Dennstaedtiaceae | *Pteridium esculentum* | Bracken | | | | | | | | | | | | | | X | | | | | | | | | | |
| Dilleniaceae | *Hibbertia* sp. | | X | X | | | | | | | | | | | | | | | | | | | | | | |
| Droseraceae | *Drosera peltata* | Sundew | X | | | | | | X | X | | | | | | | | | | | | | | | | X |
| Epacridaceae | *Epacris microphylla* | | | | X | X | | | X | X | X | X | X | | | X | X | X | X | X | X | X | X | X | | X |
| | *Epacris obtusiflora* | Blunt-leaf Heath | | | | | | | | | | | | | | | X | X | X | X | | | | | | |

| Family | Scientific Name | Common Name | Wetland No. 324 | | | | | | | | | | | | Wetland No. 325 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | East | | | East | | | North | | | North | | | East | | | East | | | North | | | North | | |
| | | | Quadrat Number | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1A | 1B | 1C | 2A | 2B | 2C | 3A | 3B | 3C | 4A | 4B | 4C | 5A | 5B | 5C | 6A | 6B | 6C | 7A | 7B | 7C | 8A | 8B | 8C |
| | *Sprengelia incarnata* | Pink Swamp Heath | X | | | X | X | | | | X | | | | | | | | | | | | | | | |
| Faboideae | *Oxylobium arborescens* | Tall Shaggy Pea | | | | X | | | | | | | | | | | | | | | | | | | | |
| | *Viminaria juncea* | Native Broom | | | | X | | X | X | X | X | | | | X | X | X | X | X | X | X | X | X | | | |
| Goodeniaceae | *Goodenia paniculata* | Branched Goodenia | X | | | | | | | | | | | | | | | | | | | | | | | |
| | *Goodenia* sp. | | | | | | | | X | | X | X | X | | X | X | X | X | X | X | X | X | X | | | |
| Haemodoraceae | *Haemodorum corymbosum* | | | | | | | | | X | | | | | | | | X | X | X | X | X | X | | X | X |
| Juncaceae | *Juncus kraussii* | Sea Rush | X | X | | | | | | | | | | | | | | | | | | | | | | |
| Lentibulariaceae | *Utricularia uniflora* | | | | X | | | | | | | | | | | | | | | X | | | X | | X | |
| Lilaceae | *Dianella* sp. | Flax Lily | | | | | | | | | | | | | | | | X | | | | | | X | X | X |
| Lindsaeaceae | *Lindsaea linearis* | Screw Fern | | | | X | X | | | | | | | | | | | | | | | | | | | |

| Family | Scientific Name | Common Name | Wetland No. 324 | | | | | | | | | | | | Wetland No. 325 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | East | | | East | | | North | | | North | | | East | | | East | | | North | | | North | | |
| | | | Quadrat Number | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1A | 1B | 1C | 2A | 2B | 2C | 3A | 3B | 3C | 4A | 4B | 4C | 5A | 5B | 5C | 6A | 6B | 6C | 7A | 7B | 7C | 8A | 8B | 8C |
| Lobelliaceae | *Lobelia alata* | Angled Lobelia | X | X | | | | | | X | | | | | | | | | | | | | | | | |
| Loganiaceae | *Mitrasacme polymorpha* | | | | | | | | | | | | | | | | | | | | | | | X | X | |
| Lomandraceae | *Lomandra obliqua* | | | | | | | | | | | | | | | | | | | | | | | X | | |
| Menyanthaceae | *Villarsia exaltata* | Yellow Marsh Flower | X | X | X | X | X | | | | | X | | | X | X | X | X | | X | X | | | | | |
| | *Villarsia reniformis* | | | | | | | | | | | X | X | X | | | X | | | | | | | | | |
| Mimosoideae | *Acacia elongata* | Swamp Wattle | X | | | X | | X | | | | X | | | X | X | | | | | | | | | | |
| Myrtaceae | *Baeckea diosmifolia* | Fringed Baeckea | X | | | | | | | | | | | | | | | | | | | | | | | |
| | *Baeckea linifolia* | Weeping Baeckea | | | X | X | X | X | X | X | X | X | | | X | X | X | | | X | X | X | X | X | X | X |
| | *Callistemon linearis* | Narrow-leaved | | | | X | X | X | | | | | | | | | | | | | | | | | | |

| Family | Scientific Name | Common Name | Wetland No. 324 | | | | | | | | | | | | Wetland No. 325 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | East | | | East | | | North | | | North | | | East | | | East | | | North | | | North | | |
| | | | Quadrat Number | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1A | 1B | 1C | 2A | 2B | 2C | 3A | 3B | 3C | 4A | 4B | 4C | 5A | 5B | 5C | 6A | 6B | 6C | 7A | 7B | 7C | 8A | 8B | 8C |
| | | Bottlebrush | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Darwinia leptantha* | | | | | | X | X | X | | | | | | | | | | | | | | | | | |
| | *Eucalyptus robusta* | Swamp Mahogany | X | X | | X | | | | | | X | | | X | X | X | | | | | | | | | |
| | *Leptospermum juniperinum* | Prickly Tea-tree | X | | | | | | X | X | X | X | X | X | | | | | | | | | | | | |
| | *Leptospermum polygalifolium* | Tantoon | X | | | | | | | | | | | | | | | | | | | | | | | |
| | *Melaleuca ericifolia* | Swamp Paperbark | | X | | | | | | | | X | X | X | | | | | | | | | | | | |
| | *Melaleuca squarrosa* | Scented Paperbark | | | | | X | | X | X | X | | | | X | X | X | X | X | X | X | X | X | X | X | X |
| Orchidaceae | *Cryptostylis subulata* | Large Tongue Orchid | | | | | | | | | | | | | | X | X | | | | | | | | | |
| | *Thelymitra sp.* | | | | | | | | | X | | | | | | | | | | | | | | | | |
| Plantaginaceae | *Plantago lanceolata** | Lamb's Tongue | X | | | | | | | | | | | | | | | | | | | | | | | |

| Family | Scientific Name | Common Name | Wetland No. 324 | | | | | | | | | | | | Wetland No. 325 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | East | | | East | | | North | | | North | | | East | | | East | | | North | | | North | | |
| | | | Quadrat Number | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1A | 1B | 1C | 2A | 2B | 2C | 3A | 3B | 3C | 4A | 4B | 4C | 5A | 5B | 5C | 6A | 6B | 6C | 7A | 7B | 7C | 8A | 8B | 8C |
| Poaceae | *Austrodanthonia monticola* | | | | | | | | | | X | | | | | | | | | | | | | | | |
| | *Briza maxima** | Quaking Grass | X | | | | | | | | | | | | | | | | | | | | | | | |
| | *Briza minor** | Shivery Grass | X | | | | | | | | | | | | | | | | | | | | | | | |
| | *Entolasia marginata* | Bordered Panic | | | | | | | X | | | | | | | | | | | | | | | | | |
| | *Entolasia stricta* | Wiry Panic | X | | | | | | | | | | | | | | | | | | | | | | | |
| | *Panicum simile* | Two Colour Panic | | | | X | | | X | | X | | | | | | | | | | | | X | | | |
| | *Pennisetum clandestinum** | Kikuyu | X | | | | | | | | | | | | | | | | | | | | | | | |
| | *Phalaris aquatica** | Phalaris | X | X | X | X | | | | | | | | | | X | | | | | | | | | | |
| | *Phragmites australis* | Common Reed | | | | | | | | | | X | X | X | | X | X | | X | X | X | X | X | | | |
| Polygalaceae | *Comesperma* | Pyramid | X | | | X | X | | | X | X | | | | X | X | X | X | X | X | X | X | X | X | X | X |

| Family | Scientific Name | Common Name | Wetland No. 324 | | | | | | | | | | | | Wetland No. 325 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | East | | | East | | | North | | | North | | | East | | | East | | | North | | | North | | |
| | | | Quadrat Number | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1A | 1B | 1C | 2A | 2B | 2C | 3A | 3B | 3C | 4A | 4B | 4C | 5A | 5B | 5C | 6A | 6B | 6C | 7A | 7B | 7C | 8A | 8B | 8C |
| | *ericinum* | Flower | | | | | | | | | | | | | | | | | | | | | | | | |
| Proteaceae | *Banksia ericifolia* | Heath-leaved Banksia | X | X | | X | X | | | | | | | | | | | | | | | | | | | |
| | *Banksia marginata* | Silver Banksia | | | | | | | | | | | | | | | | | | | | | | X | X | X |
| | *Banksia spinulosa* | Hairpin Banksia | | | | | | | | | | | | | | | | | | | | X | | | | |
| | *Hakea sericea* | Needlebush | X | X | | X | | | X | X | X | | | | | | X | X | | X | X | | X | X | X | X |
| | *Lambertia formosa* | Mountain Devil | | | | X | X | | | | | | | | | | | | | | | | | | | |
| | *Persoonia leavis* | Broad-leaved Geebung | | | | | | | | | | | | | | | | | | | | | | | X | |
| | *Petrophile pulchella* | Conesticks | | | | | | | | | | | | | | | | | | | | | | X | X | X |
| Restionaceae | *Empodisma minus* | | | | | X | | | X | X | X | | | | | | | | | | | | | | | |
| | *Eurychorda* | | | | | | | | | | | | | | | X | X | X | | X | X | X | X | | | |

| Family | Scientific Name | Common Name | Wetland No. 324 | | | | | | | | | | | | Wetland No. 325 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | East | | | East | | | North | | | North | | | East | | | East | | | North | | | North | | |
| | | | Quadrat Number | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1A | 1B | 1C | 2A | 2B | 2C | 3A | 3B | 3C | 4A | 4B | 4C | 5A | 5B | 5C | 6A | 6B | 6C | 7A | 7B | 7C | 8A | 8B | 8C |
| | *complanata* | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Leptocarpus tenax* | | X | X | X | X | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| | *Lepyrodia muelleri* | | | | | | | | | | | | | | X | | | | | | | | | | | |
| | *Lepyrodia scariosa* | | | | | | | | | | | | | | | | | | | | | | | X | | |
| Rubiaceae | *Opercularia varia* | Variable Stinkweed | X | | | | | | X | X | X | X | | | | | X | | X | X | | | | | | |
| Santalaceae | *Exocarpus cupressiformis* | Cherry Ballart | X | | X | | X | | | | | | | | | | | | | | | | | | | |
| Stackhousiaceae | *Stackhousia nuda* | | | | | | | | | | | | | | | | | | X | | | | | | | |
| | *Stackhousia* sp. | | X | | | X | X | | X | X | | | | | | | | X | | X | X | | | | | X |
| Thymelaeaceae | *Pimelea linifolia* | Slender Rice Flower | X | X | | | | | | | X | X | | | | | | | | | | | | | | |
| Xanthorrhoeaceae | *Xanthorrhoea media* | Grass Tree | X | X | | X | X | X | X | X | X | | | | X | X | X | X | X | X | X | X | X | X | X | X |

| Family | Scientific Name | Common Name | Wetland No. 324 | | | | | | | | | | | | Wetland No. 325 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | East | | | East | | | North | | | North | | | East | | | East | | | North | | | North | | |
| | | | Quadrat Number | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1A | 1B | 1C | 2A | 2B | 2C | 3A | 3B | 3C | 4A | 4B | 4C | 5A | 5B | 5C | 6A | 6B | 6C | 7A | 7B | 7C | 8A | 8B | 8C |
| Xyridaceae | *Xyris operculata* | | | | | X | | | | | | | | | | | | | | | | | | | | |
| **Bryophypta** | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | *Sphagnum novo-zelandicum* | Moss | | | X | | | | | | | | | | | | | | | | | | | | | |
| **Note**: * denotes introduced weed species | | | | | | | | | | | | | | | | | | | | | | | | | | |

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**Document Status**

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|---|---|---|---|---|---|---|
| | | Name | Signature | Name | Signature | Date |
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