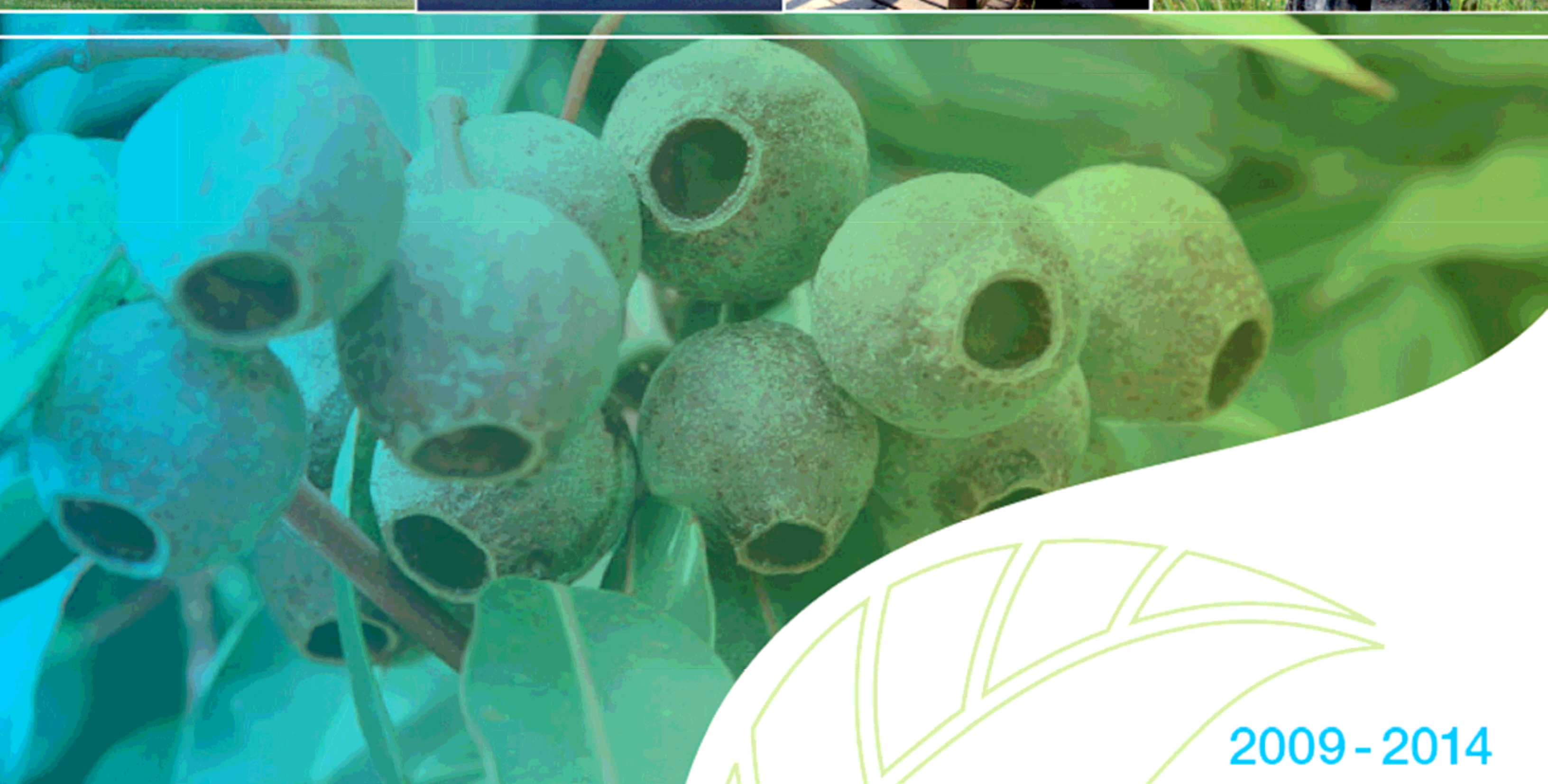
City of Wanneroo

City of Joondalup

Part 1
Technical Report

Yellagonga Integrated Catchment
Management Plan 2009 – 2014



2009 - 2014

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Abbreviations

ANZECC – Australia and New Zealand Environment and Conservation Council

ARMCANZ – Agriculture and Resource Management Council of Australia and New Zealand

BTEX – Benzene, Toluene, Ethylbenzene and Xylene

CoJ – City of Joondalup

CoW – City of Wanneroo

CCW – Conservation Category Wetland

DoW – Department of Water

DPI – Department of Infrastructure and Planning

DEC – Department of Environment and Conservation

EWR's – Ecological Water Requirement's

FoY – Friends of Yellagonga

GPT – Gross Pollutant Trap

NMCG – North Metro Catchment Group

TPH – Total Petroleum Hydrocarbon

TSS – Total Suspended Solids

TP – Total Phosphorus

TN – Total Nitrogen

WAPC – Western Australian Planning Commission

WCP – Water Conservation Plan

WSUD – Water Sensitive Urban Design

Acknowledgements

Many groups and individuals have contributed valuable ideas, information and effort in the Yellagonga Integrated Catchment Management planning process and the Cities of Joondalup and Wanneroo would like to thank the following and gratefully acknowledge their contributions:

Project Management Group (PMG)
Community Reference Group (CRG)
Technical Working Group (TWG)
Friends of Yellagonga (FoY)
The former Yellagonga Catchment Group (YCG)
Department of Environment and Conservation (DEC)
DEC Yellagonga Regional Park Community Advisory Committee (DEC YRP CAC)

Special thanks goes to Gary Tate for his wonderful photo's of the biodiversity found in Yellagonga Regional Park - many of which are presented in this report. Also to John Chester, for his photo's highlighting issues of water quality. Many thanks to Ian W.A. Davis, for kindly allowing us access to his ongoing and highly valuable water bird survey data for Lakes Goollelal and Joondalup. Thankyou also goes to scientists from the West Australian Museum who very kindly identified some of the fauna presented in this report, and also scientists from the Department of Agriculture for weed identification.

Executive Summary

The Site

Yellagonga Regional Park is one of eight regional parks within the Perth Metropolitan area and lies on the Swan Coastal Plain located approximately 20km north of Perth. Yellagonga Regional Park consists of a wetland chain including, from north to south, Lake Joondalup, Beenyup Swamp, Walluburnup Swamp and Lake Goollelal (Yellagonga Regional Park Management Plan, 2003-2013).

The Park's catchment includes a diverse range of land uses all of which can impact on the Park. The Cities of Joondalup and Wanneroo, the Department of Environment and Conservation and various community groups, recognise that land use practices in the surrounding catchment from both past and present activities can have detrimental impacts on the wetlands of the Yellagonga Regional Park. Impacts include water quality and quantity entering the wetlands and threats to the ecological integrity and biodiversity of the Park.

Scope and Purpose of the Plan

In order to maintain and enhance the amenity, recreational, educational, scientific, and conservation values of Yellagonga Regional Park, for present and future generations, the Yellagonga Integrated Catchment Management Plan (Yellagonga ICM Plan) has been developed to provide a comprehensive and integrated approach to managing the Park. The Plan has been developed following important consultation with and guidance from a Community Reference Group and Technical Working Group.

Part 1 of the YICM Plan document provides a community and technical report on the research and information collected during the two-year planning process. It provides a current state analysis assessment of both the Park and catchment, and to this end, provides an historical record for future generations. Part 2 provides an implementation plan and the projects to be implemented in the catchment to mitigate the key threatening processes and issues identified affecting Yellagonga Regional Park.

The Yellagonga Integrated Catchment Management Plan represents a commitment by State and local governments, community and stakeholder groups to ensure the long-term health of Yellagonga Regional Park. This project was jointly funded by the adjoining cities of Joondalup and Wanneroo to provide for an holistic, strategic approach to managing natural resources within the Yellagonga catchment. By understanding and identifying the key processes and activities occurring within the catchment that are, or have the potential to, impact detrimentally on the Park, and to develop projects across the catchment to mitigate key threatening processes.

Key Findings

Key Focus Areas

Literature review identified a range of threats to the long-term viability of the Yellagonga Regional Park, including those from the wider catchment, and within the Park itself. Impacts from urbanism and past land use within the catchment were identified as the key threats that underpinned a number of other threatening processes, and require immediate consideration.

Community consultation identified the key focus areas for the YICM Plan as being:

1. Contaminants
2. Inappropriate / Inadequate Infrastructure
3. Urbanisation (Development and Planning)
4. Climate Change and Hydrology
5. Weeds
6. Impacts of Introduced Animals and Pets
7. Lack of Community Education and Awareness
8. Incidences of Inappropriate Fire Regimes
9. Incidences of Vandalism and Rubbish Dumping
10. Habitat Destruction and Fragmentation
11. Lack of understanding of Fauna Populations
12. Disease

Projects

To achieve significant gains across the catchment, and control the impacts of key external threats to the Yellagonga Regional Park, key projects were identified for implementation in the first five years of integrated catchment management for the Park. Projects were designed to encompass the full range of key focus areas to address priority community concerns for the Park.

Key catchment projects include retrofitting of the Wangara Sump, significant community education, stormwater management plans to guide improved urban water management, and strategic planning and policy development to ensure future urban development in the Yellagonga Catchment reflects and enhances the Park environment.

1.0 Introduction

It has been estimated that more than 70 percent of wetlands on the Swan Coastal Plain have been destroyed in the last 100 years as a result of urban activities and primary production (Halse, 1988). For wetlands that remain, there is a great need and urgency to manage and protect these wetlands, for present and future generations, and for the flora and fauna that are a vital part of these ecosystems. Yellagonga Regional Park (henceforth referred to as “the Park”) is one of eight regional parks within the Perth Metropolitan area and lies on the Swan Coastal Plain located approximately 20km north of Perth. The Park consists of a wetland chain including, from north to south, Lake Joondalup, Beenyup Swamp, Walluburnup Swamp and Lake Goollelal (Yellagonga Regional Park Management Plan, 2003-2013).

The wetland chain within the Park (lakes and swamps), have been identified as Conservation Category Wetlands (CCW) (Hill *et al.,* 1996). This management category identifies these wetlands as high priority and most valuable wetlands that support a high level of ecological integrity (Waters and Rivers Commission, 2001). The wetlands are protected under the States *Environmental Protection (Swan Coastal Plains Lakes) Policy 1992* and the Park is recognised under the Western Australian Planning Commission’s (WAPC) Bush Forever program (Bush Forever Site 299).

The Park is predominantly managed by the Department of Environment and Conservation (DEC), and the Cities of Joondalup and Wanneroo (the boundary of which passes through these wetlands). Land tenure is also vested in the Conservation Commission of Western Australia and the Western Australian Planning Commission, however, the overall integrated management of the Park, is currently administered by the DEC (Figure 2). There is a small portion of land that remains privately owned within the Park with individual landholders responsible for the management of their own property (Yellagonga Regional Park Management Plan, 2003-2013). In addition, there are many community groups, including Aboriginal groups, who have input into the management of the Park.

Figure 1. The Park lies within the Perth Metropolitan area on the Swan Coastal Plain, and is located approximately 20km north of Perth (DEC, Yellagonga Regional Park Management Plan 2003-2010).

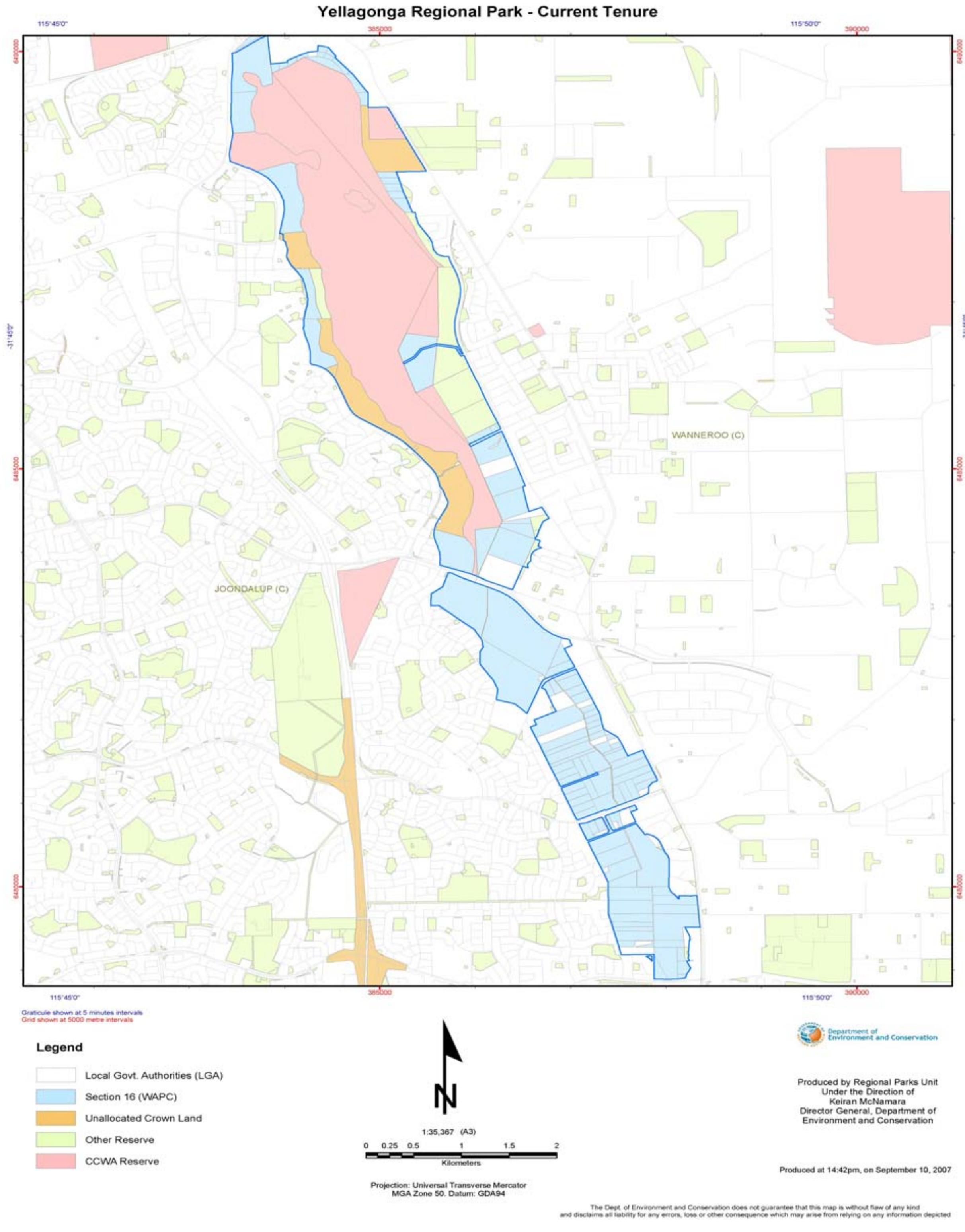

Figure 2. Land tenure in Yellagonga Regional Park.

The City of Wanneroo is a rapidly growing urban area, with the population in the northwest corridor expected to reach more than 429,000 by 2031 (WAPC, Appendix 5, 2001-2031). Urbanisation results in a highly modified natural landscape; with the catchment of Yellagonga Regional Park being no exception. The catchment has a diverse range of land uses comprised of residential developments, market gardens, aged care, grassland and playgrounds, orchards and poultry farms, horse agistment, pine tree lots and various commercial developments (car yards, service stations, shopping centres etc), all of which can impact on the Park.

The Cities of Joondalup and Wanneroo, the Department of Environment and Conservation and various community groups, recognise that past and present land use practices in the Yellagonga catchment can have detrimental impacts on water quality and quantity entering the wetlands of the Park, and threaten the ecological integrity and biodiversity of the Park. In order to maintain and enhance amenity, recreational, scientific, educational and conservation values of the Park for present and future generations, an Integrated Catchment Management Plan has been developed to provide a comprehensive and integrated approach to managing the Park.

2.0 The Yellagonga Integrated Catchment Management Plan

2.1 Background

The Department of Environment and Conservation (DEC) and the Cities of Joondalup (CoJ) and Wanneroo (CoW) share the management of the Park's wetlands. The overall health of these wetlands though, is dependent on the nature and state of the surrounding catchment. Due to previous and changing land use with rapid urbanisation environmental problems are being experienced in the Park's wetlands and are impacting on local residents, causing algal blooms and midge swarms.

An urban catchment has diverse values associated with it - economic, natural, recreational, and cultural - with natural systems within the catchment having to absorb a number of uses associated with these values. Any land use will impact to some extent on the quality and quantity of water entering the Park's wetlands, as well as impacting on floristic and faunal communities within the Park. Integrated Catchment Management (ICM) is about balancing use of the land, water and biological resources within a catchment, in a sustainable manner, by encouraging co-operation and co-ordination at all levels of government, in collaboration with the whole community on management of these resources (Bunny and Mouritz, 1995).

In recognition of the need to approach wetland health through an integrated management process, the two Cities have supported the community's drive for 'a whole of catchment approach'. In 2001, the community-based Yellagonga Catchment Group was formed to facilitate an integrated catchment management process for the Yellagonga Wetlands. The two Cities jointly funded a Catchment Co-ordinator for Yellagonga who worked to support the Community Group. In 2004-2005, the two Cities established a partnership agreement to develop the Yellagonga Integrated Catchment Management Plan (YICM Plan).

2.2 Aims and Objectives

The aim of the YICM Plan was to provide an holistic and long-term strategic plan to improve catchment health to protect the diverse values of the Park. Understanding and identifying the key processes and activities occurring within the catchment that are, or have the potential to, impact detrimentally on the Park has been the basis of developing the YICM Plan and the priority projects for implementation.

The objectives of the integrated catchment management plan were to:

1. Establish an Integrated Catchment Management structure for the catchment.
2. Provide a 'snap-shot' of the current state of Yellagonga Regional Park.
3. Engage community and stakeholder groups to promote a sense of stewardship with participation in the conservation and improvement of the Park.
4. Develop programs aimed at protecting and enhancing ecological values of the Park and maintaining functional integrity of the natural systems.
5. Protect and restore biodiversity.
6. Improve water quality entering the Park's wetlands.
7. Reduce pollution entering the Park from land use activities.
8. Ensure land use activities avoid environmental degradation without compromising the ability for economic activity.
9. Enable ICM to be incorporated into strategic and local planning.
10. Produce a Strategic Report and Integrated Catchment Management Implementation Plan for the Yellagonga catchment area.

2.3 Structure of the Plan

The YICM Plan has been presented in two discrete sections to facilitate its use by different audiences.

Part 1 of the YICM Plan presents an introduction to the integrated catchment management planning process, and provides a detailed literature review on the threats and condition of the Yellagonga Regional Park and its catchment.

Part 2 of the YICM Plan provides an implementation plan to address the key issues arising from literature review, developed in consultation with the community.

2.4 Project Based Implementation

Recognising that the YICM Plan represents the first of a number of revised plans to achieve integrated catchment management for the Yellagonga Regional Park, the implementation plan has been designed to achieve significant gains in the first five years.

To address the priority issues in the first five years, key projects have been identified and prioritised for implementation. Projects have been designed to encompass the full range of key focus areas identified by the community and implement the larger scale action required to address the more significant threats to the Park from within the Catchment.

The YICM Implementation Plan highlights the key issues and focus areas, and identifies the key projects for implementation to address them. Both existing and new projects to address threats to the Yellagonga Regional Park are included and detailed within the YICM Implementation Plan.

Future reviews of the YICM Plan will assess the achievements of projects, and identify additional projects and lesser priority areas of action for implementation.

3.0 The Yellagonga Regional Park Catchment Area

3.1 Location and Topography

The Park catchment lies on the Swan Coastal Plain and is located approximately 20 km north of central Perth. The surface water catchment area considered to impact on the Park is estimated to cover an area of approximately 4000 hectares (Ove Arup and Partners). The catchment is linked to the Park by surface flows via drainage infrastructure and groundwater flows. The catchment encompasses land on either side of the Park located in the Cities of Joondalup and Wanneroo and includes medium to high-density residential and commercial development interspersed with green areas. Lakes Joondalup and Goollelal, and the swamps Beenyup and Walluburnup are the receiving aquatic environments for water from this catchment via surface and groundwater flows.

Wetlands of the Park lie in the inter-dunal depression of a sloping dune system. The topography is steepest to the west rising to an estimated elevation of 50 metres with a relatively gentle slope running eastwards, with the eastern and southern aspects of the Park being relatively flat (Upton and Kinnear, 1997; Yellagonga Regional Park Management Plan, 2003-2013) (Figure 3).

Figure 3. Topographical and groundwater contours for Lake Joondalup.

3.2 Climate

Climate of the Swan Coastal Plain is described as being Mediterranean characterised by long hot dry summers and a shorter period of wet winter months. The rainfall average from 1905-2007 is around 807mm (rainfall data from the Bureau of Meteorology Perth Regional Office). However, rainfall has declined markedly since 1976, recording an average of 733mm to 2007, which reflects a 9 percent reduction from the long-term average. From 2001 to 2007, average rainfall was recorded at 683 mm, reflecting an even greater reduction of 15 percent below the long-term average.

From 1950 to 1975, the Perth climate was classified as 'wet', however is now considered 'dry' and, from 1998 to 2007, the southwest has experienced fewer wet months than experienced in the last 100 years (from McFarlane's presentation, 2008). From 1944 to 2008, the highest rainfall event occurred in June 1945 (165 mm), whilst recent years exhibit records for lowest raingfall recordings (December 2007, January 2008, February 1998, March 1973 and April 1982 all recording 0 mm of rainfall) (Data collected from the Bureau of Meteorology Perth weather station) (Appendix 1).

Temperatures appear to be experiencing greater extremes in recent years. The two hottest days recorded since 1944 fell on 31st January 1991 and 23rd February 1991 recording 46.0 °C and 46.7 °C respectively. Other recent high temperatures were recorded on 11th November 2003 and 26th December 2007 at 40.8 °C and 44.5 °C . The lowest recorded temperature was experienced on 17th June 2006 at -1.3 °C (taken from the Bureau of Meteorology Perth weather station)

The mean daily evaporation (mm) was highest in the month of January, at 10.1 mm and lowest in July, at 2.1 mm for the period 1981 – 2008.

During the summer months, the prevailing wind affecting Perth is a strong, gusty, hot easterly. However, as the interior landmass heats up more quickly than the ocean during the summer, a strong and significant sea breeze blows back across the coast in the afternoons – known locally as the "Fremantle Doctor" (westerly wind).

3.3 Geology and Soils

Soils and geology of the Perth metropolitan north-west corridor have been described by McArthur and Bartle (1975-76). They describe the Park and catchment as lying over Quarternary deposits known as the Spearwood Dune System, which presents as a low hilly and undulating landscape. The wetlands and surrounding catchment lies predominantly over Spearwood Sand with some areas of Karrakatta limestone and Karrakatta sand. The Spearwood Sands consist of some limestone outcrops with shallow brown soils and the Karrakatta limestone is characterised by bare limestone or shallow siliceous or calcareous sand over limestone. The Karrakatta sand is yellow and limestone usually lies beneath this layer.

Substrate soils within the Park and catchment have been identified as high risk acid sulphate soils, although these areas are yet to ground-truthed.

3.4 Landuse

Historically, Aboriginal people utilised wetlands and surrounding area of the Park as a food bowl providing a well-balanced diet of protein and carbohydrates with one campsite in the Park reputedly dated at 38,000 years old indicating exceptionally long-term and sustainable use of the area (see section 6.0 on Socio-economic characteristics of the Yellagonga Catchment) (Meagher, 1974; see McGuire, 1996). Market gardening has been practised since the 1840's, not long after European settlement of the Wanneroo area, whereupon the region became renowned for the primary industry.

Today, the Yellagonga Catchment is highly modified with diverse land uses. The present main land uses are residential (~ 60 percent), undeveloped and public open space (~ 15 percent), light industry (~ 7 percent), commercial (~ 8 percent) and a smaller proportion today (compared to earlier times) still dedicated to horticultural / primary productivity activities (~ 10 percent) (Figure 4). Primary productivity, particularly in east Wanneroo, still supplies a significant proportion of fresh produce to the Perth market. However, increased land values, productivity and market forces combined with declining groundwater supplies and water allocation budgets, threatens the long-term viability of the horticultural industry in east Wanneroo (WAPC, 2005).

Horticultural industries usually require regular use of fertilisers, herbicides, pesticides and fungicides. Some of these compounds may be highly mobile within the environment moving via surface or groundwater-water infiltration. With the high horticultural land use that has occurred in the past as well, there may be legacy impacts associated with such substances. Compounds such as organochlorines may have been used in the past, and although their use was phased out completely in 1992 (ACT Government Health Information, 1996), they are highly resistant to degradation. Issues may also arise with some of these contaminants remaining *in-situ* and changes to land use zoning from rural to residential, which may present with contaminated soil issues.

A broad range of business activities (light industry / commercial) also exist within the Yellagonga catchment area, including car yards and automotive related industry, veterinary hospitals and fruit and vegetable markets, shopping complexes, plumbing, electrical and medical centres, plant nurseries and many others. These land uses, if not managed, can introduce contaminants such as hydrocarbons, heavy metals, pesticide residues or pharmaceuticals into the Park's wetlands from surface run-off and infiltration into ground water. Roads are concomitant with residential and commercial developments and act as conduits for pollutants from surface run-off into urban wetlands, including gross matter from littering.

Other land uses in the catchment include pastured land (for horse agistment), which are considered to contribute some nutrients into the Park's wetlands. Given the low fertility of the soils, local residents contribute nutrient loadings into the Park's wetlands by way of run-off from garden and lawn fertilisers. Septic systems may also contribute a nutrient loading to groundwater which is dependant upon soil type, vegetation cover, depth to groundwater, system design, maintenance and amount of use (Congdon, 1979). There are also likely to be small quantities of pesticides, herbicides and detergents used by local residents that make their way into the Park's wetlands.

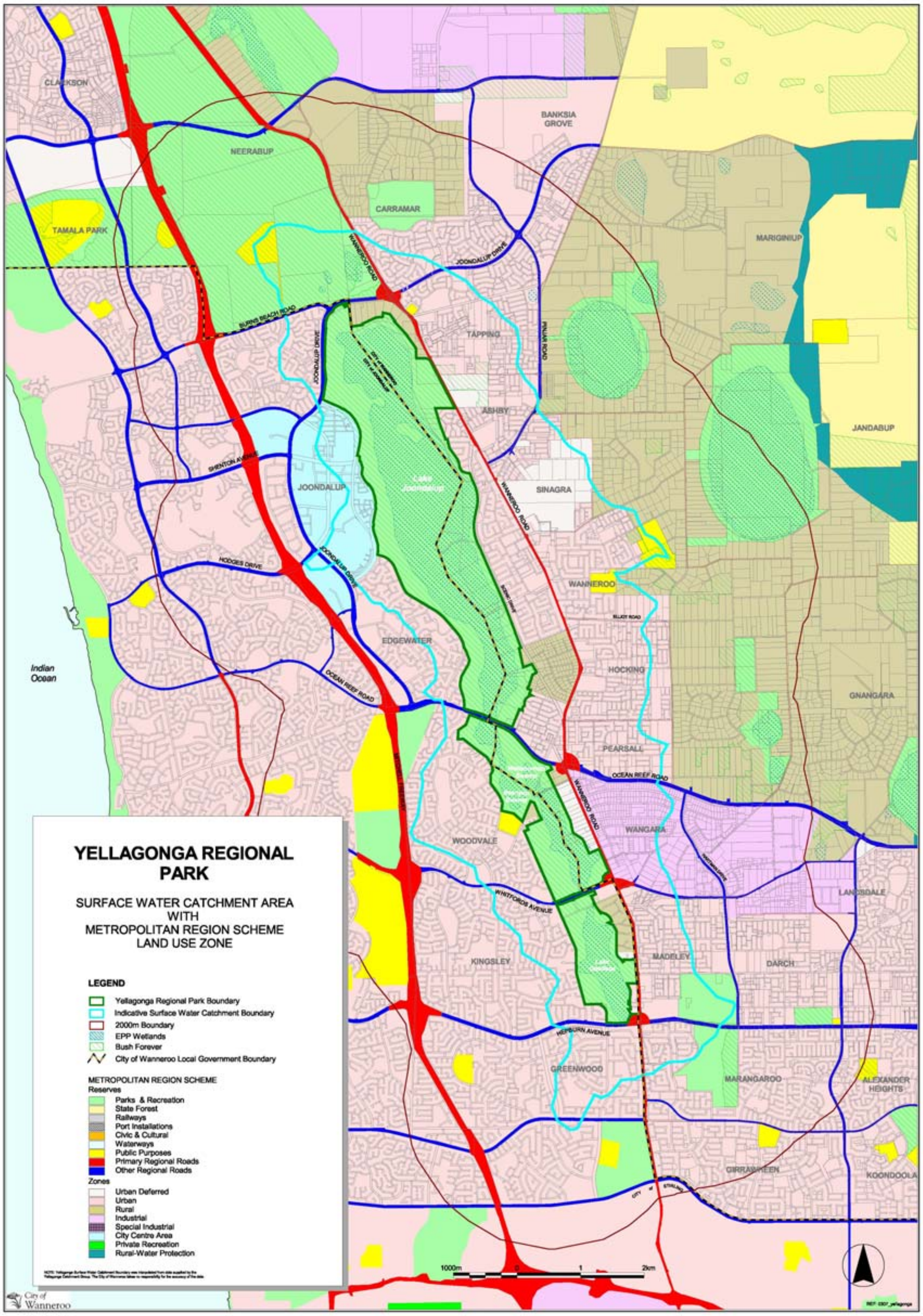

Figure 4. Metropolitan Region Scheme landuse map for the Yellagonga catchment.

4.0 Hydrology

4.1 Groundwater

4.1.1 Groundwater flow and levels

A clear or defined boundary is yet to be established for the groundwater catchment that impacts on the Park's wetlands. However, given that groundwater flows from northeast to southwest across the Swan Coastal Plain towards the Indian Ocean (Perth Groundwater Atlas, 2004), inputs into the groundwater from land uses many kilometres to the east, could eventually see impacts on the Park's wetlands. While a groundwater catchment boundary has not been developed, strategies can still be developed to address potential land use impacts on groundwater - particularly given the high groundwater recharge rates found on the Gnangara Mound. The highest recharge rates occur over the Gnangara Mound, and range from 15-20 percent reaching as high as 40 percent of rainfall as total net recharge (Department of Water, 2008a), which highlights the rapidity that any contaminants from landuse over the Gnangara Mound may leach to groundwater.

Steep groundwater gradients occur to the east and west of the lake system and are steepest on the west side of the wetland system, becoming shallow heading west towards the ocean (Congdon, 1979) (see Figure 3). Congdon (1979) estimated that Lake Joondalup would have an hydraulic residence time in excess of several months. Meaning that the groundwater is moving at a rate through the wetland systems, such that the same body of water is there for several months before it completely flows through. Cumbers (2004) estimated a groundwater flow rate of between 0.05 m/day and 13.33 m/day. Accurate flow rates are difficult to calculate as they depend on transmissivity of the surrounding geology and the saturated aquifer thickness. This rate is probably similar for Lake Goollelal, although there may be local differences according to the above physical parameters. Given the relatively slow rate of flow, residence time has implications for nutrient concentrations held within the lake systems. Congdon (1979) estimated that 30 to 40 percent of phosphorus input would be retained at estimated groundwater flow rates.

Since the mid 1970's, the annual rainfall in the southwest of Western Australia has diminished by around 9 percent compared to the long-term annual average, (or a 20 percent decline in winter rainfall (Perth Groundwater Atlas, 2004)) which has led to a reduction in groundwater recharge (Hope and Foster, 2005). Water levels of the superficial aquifer have dropped throughout the metropolitan area, with some parts on the Gnangara Mound declining by up to four metres (on the crest of the mound) since 1969 (Commander and Hauck, 2005). Diminished recharge to groundwater levels have been attributed to a decline in rainfall. Groundwater resources are under considerable pressure to meet demands of a rapidly expanding population, abstraction by various commercial activities (such as market gardens, private bore water users and tree plantations), and requirements by the natural environment (Commander and Hauck, 2005). The combination of a drying climate and over abstraction of groundwater are processes that will ultimately compromise the ecological integrity of groundwater-dependant ecosystems across the whole of the Swan Coastal Plain.

As part of long-term management of the Gnangara groundwater system, the Department of Water has recently reviewed the Ministerial Conditions on the Groundwater Resources of the Gnangara Mound (DoW Draft, 2008b). The review is expected to result in management actions to protect important groundwater dependant ecosystems in conjunction with meeting demands of water abstraction from the Gnangara Mound. Lakes Goollelal and Joondalup are recommended to be retained as Ministerial criteria sites (DoW draft, 2008b).

Table 1. Ministerial Criteria summer water levels currently used for Lakes Joondalup and Goollelal (DoW Draft, 2008b; Froend *et al.,* 2004, p. 77-79).

Summer water levels	Lake Joondalup	Lake Goollelal
Summer preferred minimum	16.2 m AHD	26.2 m AHD
Summer absolute minimum	15.8 m AHD	26.0 m AHD

To determine Ecological Water Requirements (EWR's) for an ecosystem, it is necessary to identify and understand the water regime needed to maintain important components and functioning of that ecosystem, which includes a qualitative and quantitative assessment. This entails an understanding of where the water is required and what time of day / season, how much water is needed and for how long the water should remain. Management of water levels for waterbirds and other fauna was given a high priority rating in the Yellagonga Regional Park Management Plan 2003-2013. Froend *et al.,* (2004) have recently revised the EWR's for Lakes Goollelal and Joondalup as part of a larger study of ecological water requirements on the Gnangara and Jandakot Mounds. These are listed below for the flora, fauna and sediments of these lakes (Table 2).

Table 2. Revised water requirements for the flora, fauna and sediment at Lakes Joondalup and Goollelal to maintain ecological integrity of the wetlands (adapted from Froend *et al.,* 2004, p. 77-79).

Vegetation	Water birds	Macroinvertebrates	Vertebrates	Sediment processes
Water requirements were based on the minimum water requirement that would encompass all vegetation in autumn. This is given at 15.88 m AHD for Lake Joondalup and 25.38 m AHD for Lake Goollelal.	Water requirements were based on the need for permanent water with some seasonal fluctuation to provide variety in feeding habitat types. This was given as 17.0 m AHD for Lake Joondalup and 27.1 m AHD for Lake Goollelal for at least 2 months in a 12 month cycle in at least 4 out of 6 years.	Water requirements include permanent water in the wetland with similar water levels and regime described for the waterbirds. Includes, inundation of the littoral zone and fringing vegetation each spring to maintain habitat diversity.	Water requirements are for permanent or near-permanent water (current Ministerial Critiera EWR's adequate)	Sediments must remain saturated during the summer with groundwater levels that do not drop 0.5 m below the ground surface. A summer / autumn minimum of 16.5 m AHD at Lake Joondalup was given, while Lake Goollelal does not dry at any stage of the year and sufficient water levels remain here to ensure continuous saturation of sediments.

Froend *et al.,* 2004 have also established susceptibility, risk of impact and level of response to draw-down on the vegetation at Lakes Joondalup and Goollelal. They note that depth to groundwater is seen as an important indicator of a site's sensitivity to changes in groundwater levels, in particular, the shallower the depth, the more sensitive the site. For example, a site with groundwater levels at 0-3m is more vulnerable to change than a site with groundwater levels at 6-10^{+}m. While the magnitude and current rate of drawdown at Lakes Joondalup and Goollelal are considered to have a low risk of impact to the wetland vegetation, when depth to groundwater, history of water level changes and conservation values are accounted for (i.e. susceptibility of vegetation at each site), a moderate level of response to drawdown is predicted for Lake Goollelal but a significant level of response is predicted for Lake Joondalup (DoW Draft, 2008b).

4.1.2 Groundwater use

The Cities of Joondalup and Wanneroo use groundwater to maintain public open space. As a society, we have become accustomed to green public open spaces. However, in today's drying climate, 'brown' public open space will become more familiar and watering will only continue on high-use parks and sports fields.

Licensing for abstraction of groundwater is bore-specific and the volume abstracted is restricted. New restrictions and license conditions by the Department of Water require an up-grade of irrigation equipment to ensure accuracy of water being measured and to ensure that groundwater is being abstracted efficiently without wastage. All metropolitan Local Governments in WA are now required to have a Water Conservation Plan (WCP) completed and lodged with the DoW. The WCP's encourage use of new concepts such as *Hydro-zoning*. These concepts are based on water needs and use of an area.

Zones are established according to similarities in water requirements. For example, plants are grouped together that have similar water, soil and microclimate requirements, while other zones may be sports ovals or road verges which have different water requirements and watering will be determined by public use (DoW). Public education plays a large part in the success of the Water Conservation Plans and, at present, Koondoola Park in the City of Wanneroo and Heathridge Park in City of Joondalup, which have been retro-fitted, are demonstration sites for hydro-zoning. The City of Joondalup, has also initiated a second pilot project at Emerald Park in Edgewater to demonstrate the use of hydro-zoning.

4.2 Surface Water

4.2.1 Wetlands

Wetlands on the Swan Coastal Plain are generally surface expressions of an unconfined aquifer with water levels reflecting the rising and falling groundwater levels (Allen, 1976). In the past, some wetland areas existed as damplands (seasonally water-logged soils), but, as water tables rose in response to land use changes or higher rainfall, they became lakes (e.g. Blue Gum Lake (Street, 1992)). Now the reverse trend appears to be occurring (Commander and Hauck, 2005). For the larger deeper lakes; they now remain as shallower lakes for shorter periods than previously and are drying earlier, displaying altered hydroperiods.

In the past, Lakes Joondalup and Goollelal have fluctuated and followed natural cycles of drying and filling, displaying patterns of long-term seasonal fluctuations according to climatic conditions (Hamann, 1992). However in more recent times, Hamann (1992) sugegsts the wetlands are not exact surface expressions of the Gnangara groundwater system due to seasonal fluctuations in wetland depth that does not match seasonal changes in the groundwater table. The research suggests that since urbanisation post 1975, an increasing volume of surface water has entered the wetlands via impervious and cleared surfaces, resulting in deeper lake systems.

Lake Goollellal appears to have been more affected by urban water runoff than Lake Joondalup (Lake Joondalup has had deeper water levels in the past compared to current depths recorded by Hamann). Comparing water levels from the years of 1975 to 1992, Hamann (1992) found Lake Joondalup varied from a recorded minimum of approximately 16.3 mAHD to a recorded maximum of approximately 18.0 mAHD (a difference of 1.7 m), while Lake Goollelal varied between the years of 1975 to 1992, from a recorded minimum of approximately 26.2 mAHD to a maximum of 27.7 mAHD (a difference of 1.5 m).

While Hamann (1992) noted a trend of increasing water levels between the years of 1975 to 1992, the trend does not appear to be reflected in current water levels. Lake Joondalup now dries to small shallow pools with water levels recorded in summer 2006 and spring 2007 by Sommer and Horwitz (2007) of 16.170 to 16.858 mAHD (a difference of 0.688 m). Lake Goollelal still remains as a permanent body of water but with a water level difference now of 0.620 m recorded in summer 2006 and spring 2007 with water levels fluctuating from 26.655 to 27.275m AHD (Table. 3). While this may, in part, be seen as reverting to a state pre European influences, the continued effects of a drying climate and declining groundwater will, in the long term, impact detrimentally on the viability of these wetlands.

Table 3. Summary of water levels in Lakes Joondalup and Goollelal taken from Hamann (1992) and Sommer and Horwitz (2007).

		Min (m AHD)	Max (m AHD)	Water level difference		Min (m AHD)	Max (m AHD)	Water level difference
Lake Joondalup	1975-1992	16.3	18.0	1.7	**Lake Goollelal**	26.2	27.7	1.5
	2006-2007	16.170	16.858	0.688		26.655	27.275	0.620

Surface flow through the Park's wetlands moves from south to north, but, as this habitat is now bisected by roads, dividing it into three fragments, culverts and tunnels have been constructed to enable the surface water flow to mimic the natural hydrological regime. Water drains from Lake Goollelal into Walluburnup Swamp via a culvert under Hocking Road and Whitfords Avenue and flows north into Beenyup Swamp. Ocean Reef Road bisects Lake Joondalup into north and south sections. Flow between the two sections only occurs during the winter months via a culvert. There is no surface outflow from this wetland chain but outflow occurs via groundwater in an east to west direction (Ove Arup and Partners, 1994).

4.2.2 Drainage

In a natural system, rainfall would infiltrate directly to groundwater with limited overland flow to wetlands. However, urbanisation has resulted in constructed roads and other impervious surfaces, with traditional piped drainage networks and altered topography causing a significant alteration to the natural hydrological regime. For the Park's wetlands, urbanisation has resulted in increased surface water run-off through drainage networks, bringing with it polluted water (Ove Arup and Partners, 1994; Kobryn, 2001).

While Hamann (1992) provides historical and baseline data on water level changes in the Park's wetlands prior to and post European settlement, suggesting that the urban catchment was contributing to increased water levels from 1975 to 1992, in the current climate of diminished rainfall and a reduction in recharge to groundwater impervious surface contributions can be viewed as vital arterial flows for many wetlands. Congdon (1985) estimated that in 1980, 0.9 GL of water entered Lake Joondalup via surface flows, but with the continued urbanisation of the catchment and the many impervious surfaces, Cumbers (2004) estimated that surface flows entering the lake were now 5.3 GL from the Southern Drain and 0.2 GL from storm water drains.

Despite the increased water input via surface flows, Cumbers (2004) estimated increased evaporation compared to Congdon, with a loss in the groundwater contribution to the water budget in Lake Joondalup. This trend is reflected in recent sampling at Lake Joondalup north by Sommer and Horwitz (2007) who recorded peak spring water levels at their lowest in 37 years, with levels below the summer preferred minimum. Similarly, in Lake Goollelal, while summer / spring water levels did not drop below the management criteria (26.2 mAHD preferred summer minimum and an absolute summer minimum of 26 mAHD), the spring peak water level was the lowest recorded since 1989.

4.2.3 Stormwater Drains

There are 34 drainage outfalls into the Park, including piped outfalls, swales, sumps, and constructed wetlands (Figure 5). The CoW manages 22 drains, and the CoJ manages 14. (See Appendix 3 which identifies the outfall type). Main Roads Western Australia also manage drains and sumps along Wanneroo Road. Several of these drains feed directly into City of Wanneroo drains, which eventually lead to the Park's wetlands. Specific information regarding Main Roads drains is not well documented and, while there are plans by Main Roads to document the nature of catchments feeding into sumps in the Yellagonga Catchment, there is no timeframe for this to occur.

Stormwater drains are known to contribute significant nutrient loads into wetlands. Kobryn (2001) recorded significant pollutant loads in stormwater entering Herdsman Lake from a catchment with similar landuse but half the impervious surface area of the Yellagonga catchment. Highest concentrations of total suspended sediments, nutrients and heavy metals were from areas with the highest proportion of roads, industry and commercial development, as well as coming from low-to-high density residential developments.

More recent investigations by Cumbers (2004) and Khwanboonbumpen (2006) suggest that nutrient loads into the Park's wetlands via storm water may not be as significant as identified point sources of nutrients, however, over time, cumulative effects of nutrient inputs via stormwater is still an issue to be addressed. Separation of drainage upstream to prevent stormwater reaching the Park's wetlands for those subcatchments identified with high polluting land uses has been suggested as a potential management technique. Examples include the Wangara Industrial area, Ariti Avenue, and Church Street subcatchments (P. Van de Wyngaard pers. com., 2008: Community Reference Group).

4.2.4 Drainage Upgrades in the Yellagonga Catchment

In 1994 the previous City of Wanneroo (which has since separated into the current CoW and CoJ) commissioned Ove Arup and Partners to:

- Undertake a study of all stormwater drainage facilities impacting on Lake Joondalup and Lake Goollelal;
- Identify stormwater catchments that discharge into the Park; and
- Recommend prioritised drainage upgrade of all outfalls (City of Wanneroo, 2004).

Ove Arup and Partners (1994) recommended the removal of existing outfalls discharging directly into the Yellagonga wetlands as a priority and that no further direct outfalls be constructed in the Park. They recommended drainage upgrades be prioritised according to subcatchment size, however, from the planning process for the Yellagonga ICM, it is recommended that upgrades be appropriate to those subcatchments with the most polluting or potentially polluting land uses (Figures 7-9).

When CoW and CoJ partitioned in 1998, responsibility of drainage facilities was then managed by which ever City the drain was located in.

In 2000, PPK Environment and Infrastructure P/L prepared the *Yellagonga Regional Park – Water Sensitive Urban Design Technical Report* for the Cities of Joondalup and Wanneroo (guided by '*A Manual for Managing Urban Stormwater Quality in Western Australia' (1998)*(Water and Rivers Commission) and *Planning and Management Guidelines for Water Sensitive Urban Residential Design (1994)*(DPUD now DPI). This included a concept design for Outfall 12.

In the City of Wanneroo, Outfall 12 (Ariti Avenue drain, refer figure 5) was upgraded in 2001/2002 (designed by PPK Environment and Infrastructure) to incorporate best management practices. Baseline stormwater quality monitoring of Outfall 12 was undertaken pre-upgrade. Post-upgrade monitoring was undertaken by JDA Consultant Hydrologists and suggested:

- A reduction in total suspended solids (TSS) (95%) and total phosphorus (TP) (80%).
- No observed reduction in total nitrogen (TN).
- Stormwater in the catchment contributed more pollutants to Lake Joondalup than groundwater flow (indicated by lower groundwater nutrient load estimates through Outfall 12 than the pre and post upgrade storm load estimates).

Monitoring results indicated the water quality discharging from the Outfall 12 catchment appeared improved as a result of the upgrades. However, it did not identify which upgrade measures resulted in observed improvements. The report recommended monitoring the performance of individual measures prior to further drainage upgrades and that monitoring occur over a longer period with ongoing maintenance of Outfall 12.

The *Yellagonga Regional Park Final Drainage Investigation Report 2004* (BSD Consultants P/L for the CoW) is the most recent drainage study. Concept design upgrades were developed for existing stormwater outfalls. However, the report acknowledged there had been a change in stormwater drainage best practice away from storage and detention structures in preference for infiltration and 'at source' controls during the preparation of the report. Limitations of the concept designs were identified explaining that the concept designs were based on 'in-system' treatment approaches in response to the CoW project brief (BSD 2004).

Other than revegetation and landscaping improvements at the end of outfalls to offer bio-filtration (e.g. Ottawa Way and Church St), further upgrading of Lake Joondalup outfalls have been delayed pending an investigation into a whole of catchment approach to stormwater management, including the development of the Yellagonga ICM (City of Wanneroo 2004).

The City of Joondalup upgraded six outfalls between 2007-2008, which discharge directly into Lake Goollelal – #18 (Duffy Terrace), #19 (Goollelal Drive), #20 (Goollelal Drive), #22 (Hepburn Avenue), #4 (Lakeway Drive) and #25 (Whitfords Avenue) (see Appendix.3). Upgrades were guided by the *Stormwater Management Manual for Western Australia (Department of Water 2004-2007)*. Outfall #21 (Bindaree Terrace) was upgraded in 2003/4 and was a pilot program for Water Sensitive Urban Design (WSUD). The remaining stormwater catchment points are sumps and do not discharge directly into the Park's wetlands.

No upgrades have occurred at outfall #17 (Castlegate Way) as it does not discharge directly into the wetlands and was included in the upgrade that occurred for sump 30. Outfall #22 is a piped outfall with both outfall #20 and #22 having a gross pollutant trap (GPT) installed with a 'bubble-up' unit in August 2008. No upgrade has occurred for sumps 23 (Kingsway Road) and 30 (Castlegate Way). There was previously a sump 33 however this has been amalgamated with sump 32 (Hepburn Avenue).

Sumps 15,16,17, 30 and 31 have upgrades proposed for these sites with bio-filtration being achieved by vegetation programs.

Pre and post upgrade monitoring did not occur for the Outfall 21 upgrade, however pre upgrade water quality monitoring has occurred for the recent upgrades with planned post upgrade monitoring by Bioscience Pty Ltd.

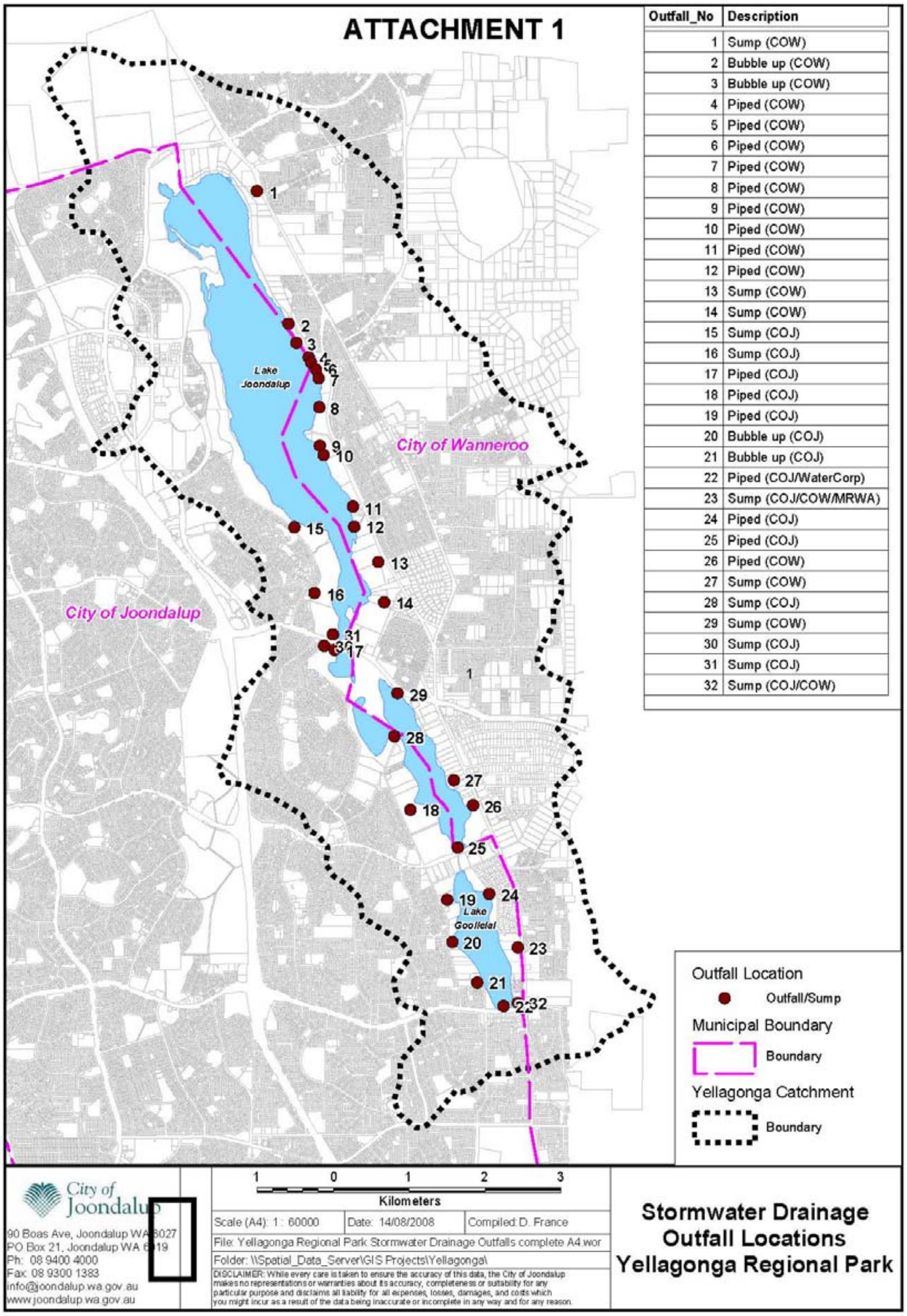

Figure 5. Location of drains around Yellagonga wetlands.

4.2.4 Surface Water Catchment and Sub-catchment Boundaries

An indicative surface water catchment boundary has been produced by Peter Van de Wyngaard and identifies subcatchments based on drainage networks in the surrounding catchment (see Figure 6 and 9). While this map is yet to be completed and verified, it is a very useful tool in identification and prioritisation of sub-drainage catchments for stormwater upgrades and installation of water sensitive urban design technologies. The Department of Water has recently undertaken Digital Terrain Modelling of the catchment boundary based on land contours which is currently under review and not available yet. The hydrographic catchment (DoW) is depicted in Figure 6 and has three surface water catchments identified with a northern boundary extending well beyond the one established for sub-drainage catchments.

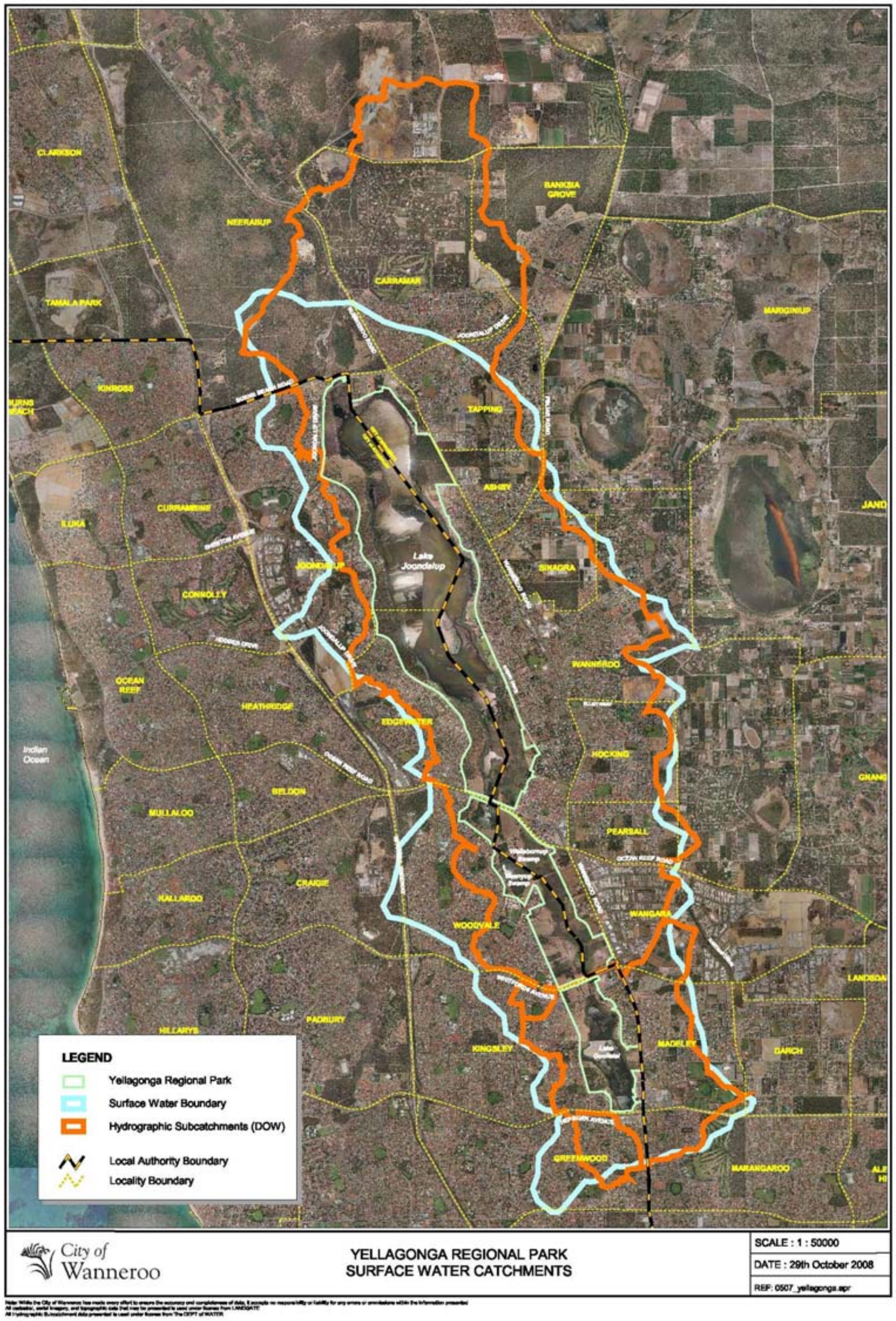

Figure 6. Surface water catchment boundary and the three hydrographic subcatchments for the Yellagonga Regional Park (DoW).

5.0 Water Quality

5.1 Pollutants

Contaminants such as heavy metals, surfactants, hydrocarbons, nutrients, suspended solids, litter and pesticides are now common substances in urban wetlands (e.g. Davis *et al.,* 1993; Bunny and Mouritz, 1995, Whiteley, 2004). Pollutants and contaminants enter the Park's wetlands via stormwater run-off, groundwater flow and, to a lesser extent, rainfall.

Key water quality issues arising from pollutants that can impact on the Park's wetlands include:

- Nutrient enrichment resulting in eutrophication, algal blooms and midge outbreaks – this is an ongoing problem today for the Park's wetlands.
- Pollutants from toxicants (heavy metals, petroleum products, pesticides and herbicides, industrial and household chemicals) can cause compromised immune systems for wetland fauna, mutations, hormone disruption, reproductive interference, poisoning, injury, and death.
- Pollutants bound to sediments can be re-released in water leading to mobility of these contaminants throughout food chains with unknown effects of bio-accumulation on wetland fauna. For example heavy metals are mobilised under acidic conditions (see ASS section).
- Sedimentation and suspended solids reduce light penetration leading to restricted plant growth and smothering of flora and fauna.
- Litter is unsightly and can reduce light reaching some plants, with unknown effects of dyes and chemicals from printed materials, and possible choking / ingestion hazards for some wetland fauna such as freshwater turtles and avian fauna.

Little is known about the impact of pathogens, for example from dog faeces, garden manure, sewer overflows / septics, and any potential impact may warrant further investigations.

5.2 Sources of Pollutants

The legacy issues of past land uses are considered to have an ongoing adverse impact on the Park's wetlands; these include market and commercial gardens, poultry industries and septic tanks.

A reputed old landfill site was thought to exist at the end of Neville Drive and has been anecdotally implicated as a source of nutrient contamination into Lake Joondalup in the past. However, aerial photography and further investigations suggest the reputed landfill consists of clean fill introduced over a section of parkland to control a problematic weed species (P. Thompson and P. Wesley, pers. com., 2008). The source of nutrient contamination is more likely derived from previous and existing poultry industry and horticulture to the east of the wetlands (Figure 7 and 8).

A catchment boundary that incorporates the influence of groundwater currently does not exist and while this would be a useful tool to focus mitigating strategies to counteract contaminants from entering the Park's wetlands via groundwater, its development would require extensive modelling and bore water data analysis. In response to nuisance swarms of midges, the Cities of Wanneroo and Joondalup, as well as the Department of Environment and Conservation are funding research which includes:

1) Identification of the source of nutrients into Beenyup Swamp and

2) Monthly monitoring of groundwater over a 12-month period in groundwater bores located around the Park. Information from this type of study will derive data on nutrient levels in groundwater entering the wetlands, the direction from where nutrients are arriving and temporal variations in concentrations.

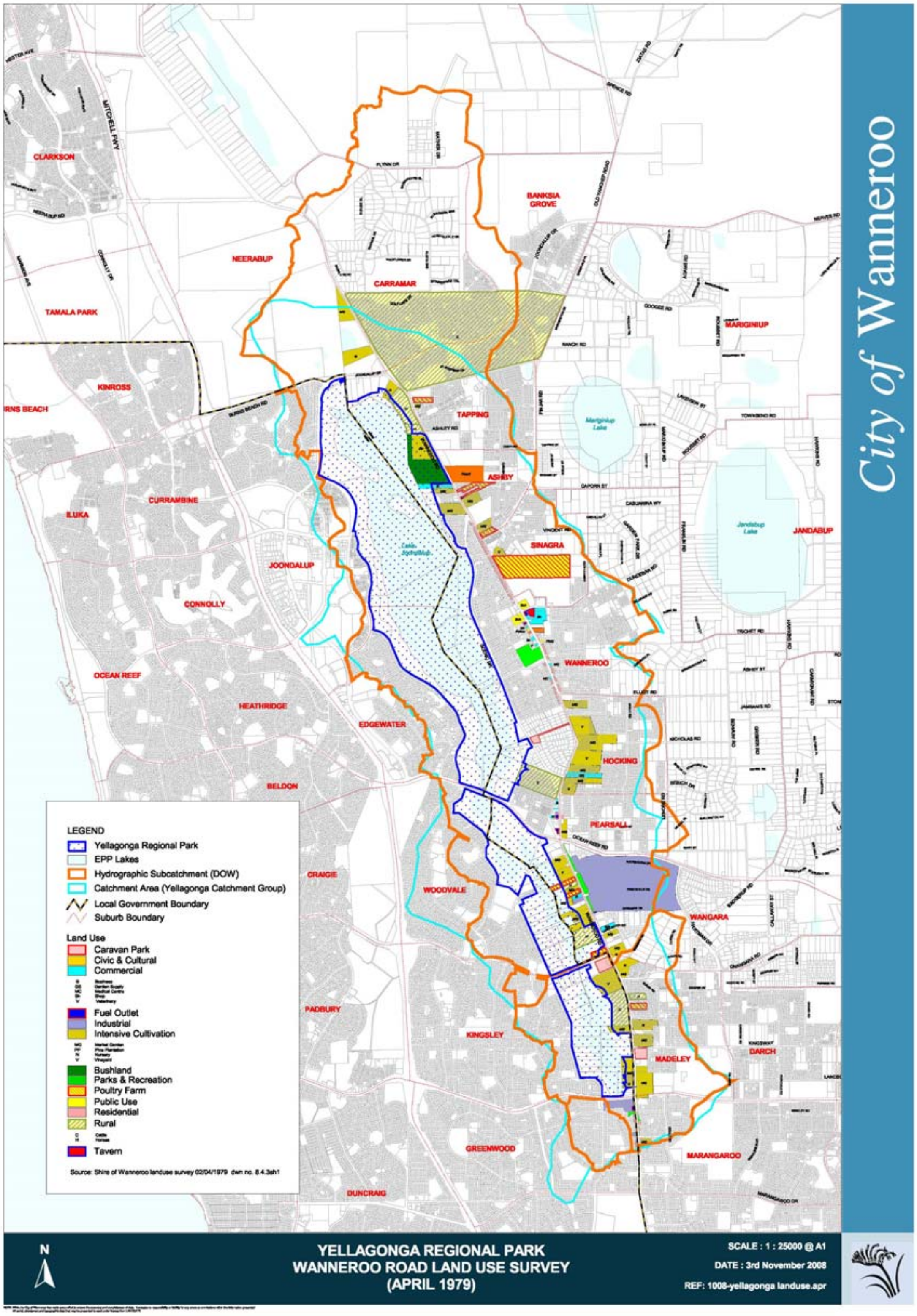

Figure 7. Past land uses to the east of Yellagonga Regional Park in 1979.

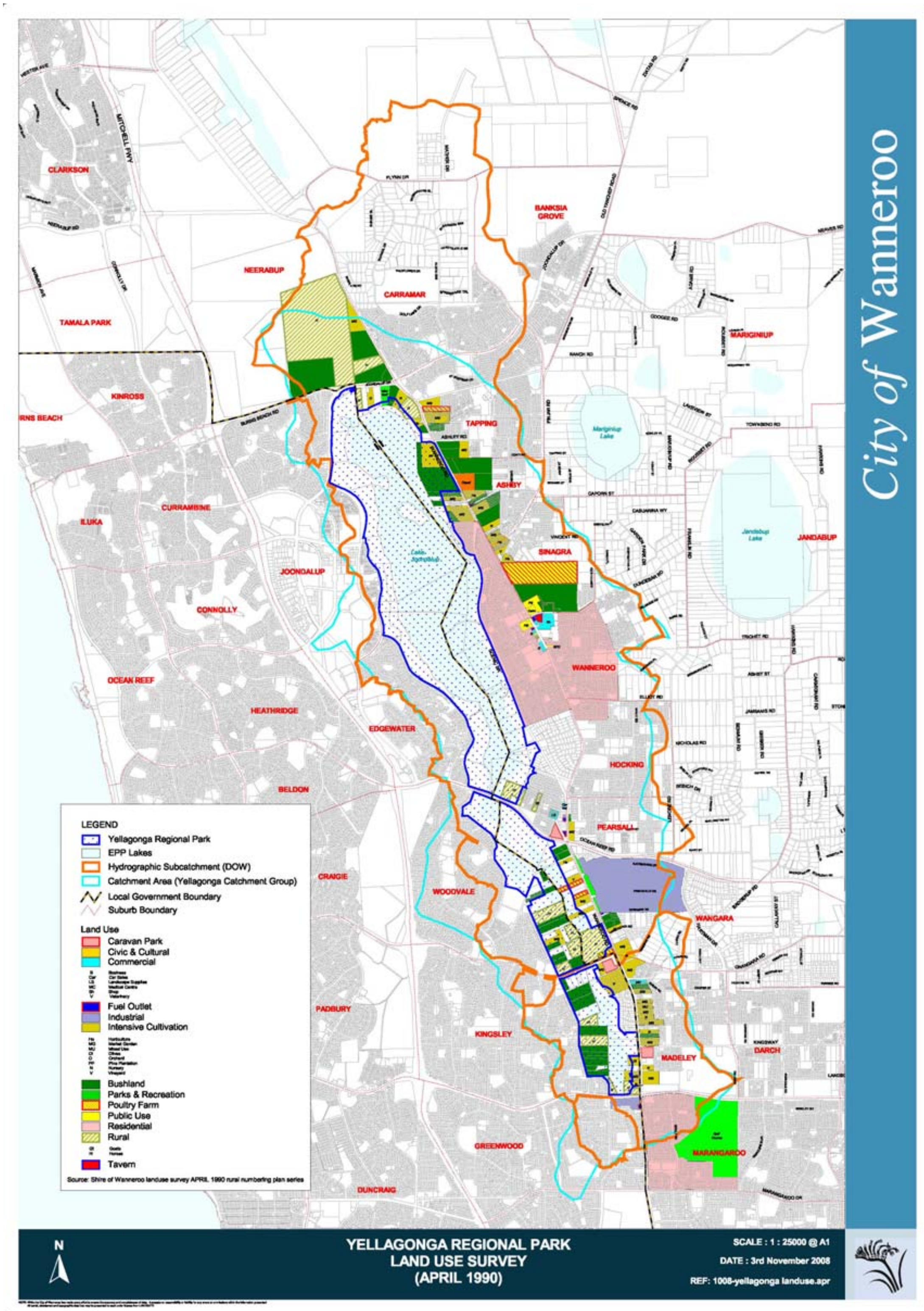

Figure 8. Past land uses to the east of Yellagonga Regional Park in 1990.

Current land uses with potential adverse impacts on the water quality of the Park's wetlands includes the Wangara industrial area where untreated stormwater drains into a compensating basin on the boundary of Walluburnup Swamp (NMCG and DOW, 2006). Other present land uses include market gardens, septic tanks, diverse commercial uses, residential areas and the high use major and minor roads, which surround the Park. Some drainage subcatchments accommodate significantly more potentially polluting land uses than others as indicated in Figure 9. Pollutants potentially arising from these land uses can also enter the Yellagonga wetlands via groundwater movement.

Members of the Community Reference Group and Technical Working Group met to discuss upgrade prioritisation of the City of Wanneroo drains. Prioritisation was based on drainage sub-catchment size and landuse, proximity to wetland, and road density (Appendix 3).

High Priority drains identified were:

1. #27 Wangara Sump was identified overall, as the highest priority
2. #8 Dallas Cr drain
3. #9 Church St drain and
4. #11 Mundaree.

Medium priority drains identified were:

1. #29 Ocean Reef Rd
2. #32 Hepburn Ave
3. #12 Ariti Ave

All remaining drains were considered low priority.

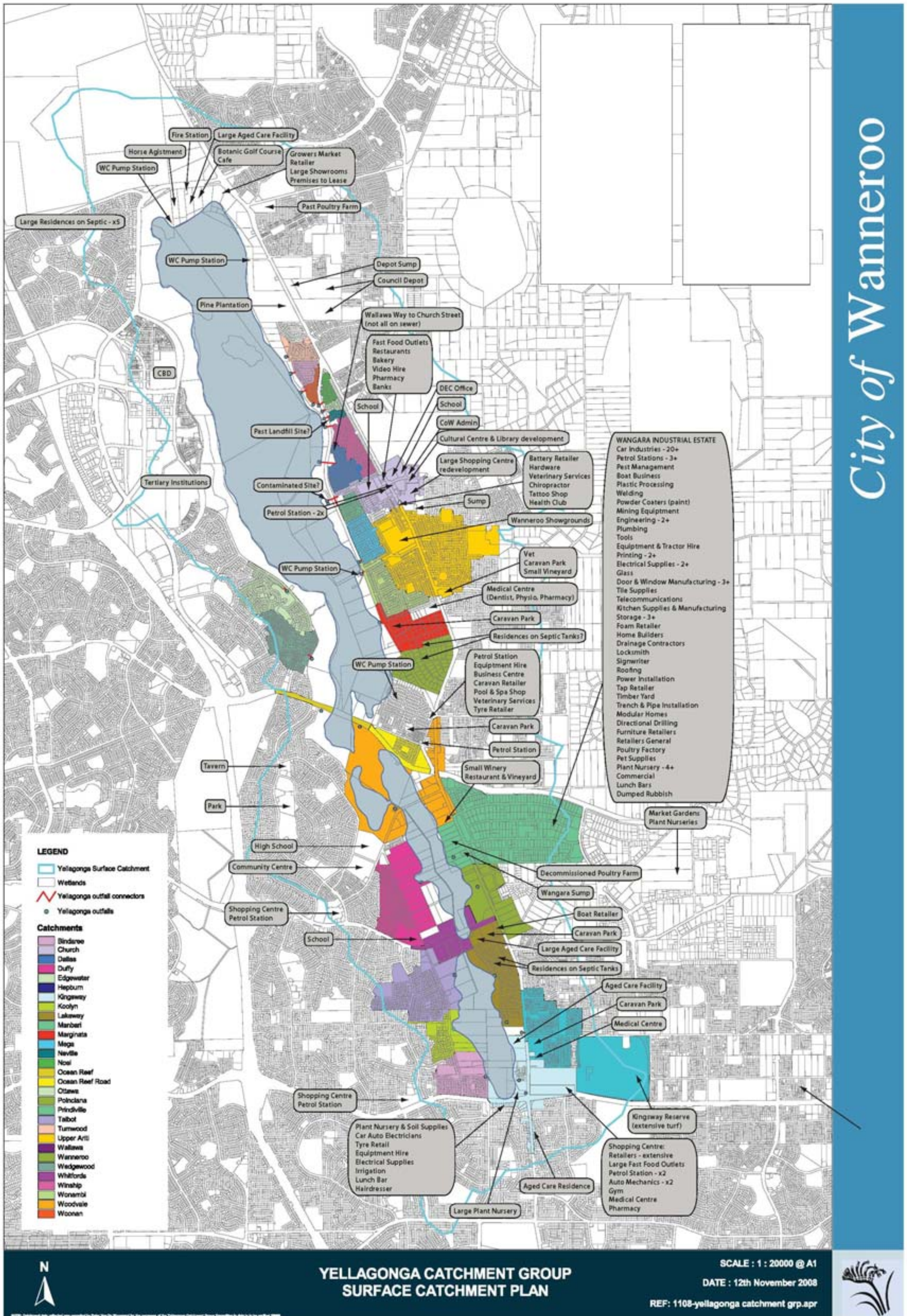

Figure 9. Sub-drainage catchments in the Yellagonga catchment with land use today (map produced by P. Van de Wyngaard with land use balloons by A. Craig). Note that the drainage sub-catchments are yet to be verified.

5.3 Monitoring

Research and monitoring programs of surface and groundwater quality have been undertaken in the Park and in the surrounding catchment by the following:

- Congdon, 1979; Kinnear et al.,1997.
- Department of Water groundwater monitoring bores (since 1973).
- North Metro Catchment Group 2005 - 2007 (Wangara Sump Wanneroo).
- Yellagonga Catchment Group / Ribbons of Blue (Outfalls 9 and 10; Bores located at Poinciana, Neville and Wallawa Drive, Ariti Avenue and Ashley Road).
- ECU Mark Lund (currently being undertaken using the former YCG bores above).
- ECU, CoW, CoJ water quality monitoring for midge research.
- Cumbers 2004
- Sommers and Horwitz 1995 – 2006 (study included Lakes Goollelal and Joondalup); Kwanboombumpen 2006 (Outfall 11 Lake Joondalup).

Findings on water quality analyses are summarised below under key contaminants / factors. Throughout these analyses, the ANZECC and ARMCANZ (2000) Guidelines have been used to provide a point of reference. The guidelines provide a means to assess water quality of a water resource, and guide actions of water managers. The guidelines can help assess the appropriateness of the water quality for the function of the water resource, for example, recreational or for aquatic ecosystems. The guidelines may also be used to trigger a further monitoring / management response and used to help refine appropriate values for local conditions.

5.3.1 Nutrients

Nitrogen input into a lake system occurs via rainfall, biological fixation of atmospheric nitrogen, surface drainage, groundwater and water bird arrival. Loss of nitrogen is through the biological process of denitrification, groundwater flow and water bird departure. Phosphorus inputs come from rainfall, surface drainage, groundwater flow and water bird arrival. Loss of phosphorus is by groundwater flow and water bird departure (Congdon, 1979).

Lake Joondalup was previously identified as being mildly eutrophic as far back as 1976 (Congdon and McComb, 1976) with nutrient concentrations still rising today (Cumbers, 2004). Recent water quality monitoring undertaken in Lake Goollelal in June 2008 (Bioscience Progress Report, June 2008), recorded elevated concentrations for NH^{+}_{4}–nitrogen, total nitrogen (TN) and filterable reactive phosphorus (FRP) above the ANZECC / ARMCANZ (2000) trigger guidelines. Particularly high nutrient levels were recorded coming from outfall #22, higher than concentrations found in outfalls #24 and #25, and well above the ANZECC / ARMCANZ (2000) guidelines prior to upgrades of these outfalls.

Identifying the sources of nutrient enrichment has been an ongoing process by the two Cities to provide direction for best management. Ove Arup and Partners (1994) developed drainage improvement strategies by estimating nutrient levels entering Lake Joondalup via stormwater drains. They identified that:

- The total phosphorus in the Park's lakes exceeded the criteria for hyper-eutrophy and, in terms of nitrogen levels, it was considered eutrophic.

- The main transporter of phosphorus (considered a major contributor to nutrient enrichment) was considered to be particulate matter which is readily discharged via stormwater to Lake Joondalup through outfalls (Ove Arup and Partners, 1994).

Kwanboonbumpen (2006) identified fertilisers and nitrogen deposits via vehicle emissions as the main source of nutrients in stormwater entering Lake Joondalup. However, similar to Cumbers (2004), direct stormwater inputs were not considered to be the main contributor of nutrients to Lake Joondalup. When comparing nutrient and water budget studies (Cumbers, 2004; Congdon, 1979, 1986), differences in quantities of phosphorus and nitrogen entering Lake Joondalup from stormwater, rainfall and via the Ocean Reef road culvert from Beenyup Swamp, indicated substantially more nutrients entering via the Ocean Reef Road culvert (Figure 10). Cumbers (2004) monitored outfalls 2,3,5,6,9,11 and 12 while Congdon (1979) monitored a range of sites that included sites nearby to sumps as well as throughout the centre of Lake Joondalup. Only four sites were selected through the remaining wetlands - one in Beenyup Swamp and three in Lake Goollelal.

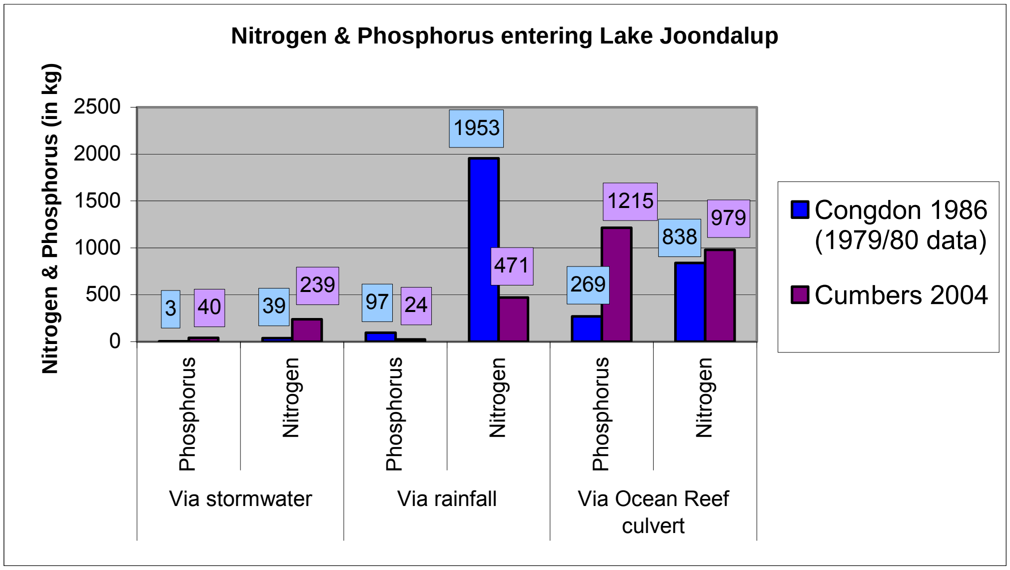

Figure 10. Comparison of nutrient concentrations entering Lake Joondalup (source Lund 2008a).

High concentrations of nutrients entering Lake Joondalup from surface flow via Beenyup Swamp (Congdon,1979; 1986; Garnett and Kinnear, 1997; Cumbers, 2004; Lund, 2007), provide substantial and sustained nutrient inputs resulting in algal blooms in central Lake Joondalup throughout the year. Lower nutrient levels were found in Lake Goollelal compared to Walluburnup and Beenyup Swamps, and as surface flows are from south to north, Lake Goollelal is not considered the main contributor of nutrients to these swamps which ultimately flows into Lake Joondalup.

Nutrients are considered to have originated from adjacent areas to the east of Walluburnup and Beenyup Swamps from past land uses of market gardens, grazing, poultry farms, a caravan park and viticulture (Garnett and Kinnear, 1997; Congdon, 1986). Given results of nutrient monitoring of the Wangara Sump, nutrients originating from the sump may also be implicated in the high levels recorded in Beenyup Swamp (see Figures 7- 9) (North Metro Conservation Group and DoW, 2006; North Metro Conservation Group, 2007).

Lund (2007) undertook a project on sediment and water sampling in south of Lake Joondalup to:

- Examine nutrient and key sections of the water flow from Lake Goollelal to Lake Joondalup and
- Make investigations into whether the sources of southerly nutrient input from Beenyup Swamp into Lake Joondalup are point sources or diffuse.

Lund (2007) also concluded that Beenyup Swamp is the source of much of the phosphorus and nitrogen entering the south of Lake Joondalup – probably occurring via sediment release and groundwater as well as surface water. Recent investigations by Goldsmith *et al.,* (2008) have confirmed high phosphorus and nitrogen concentrations in Beenyup sediments, particularly in the open water zone. By contrast, water sampling found highest total nitrogen and total phosphorus concentrations in the southern and western margins of the swamp, with the lowest concentration in the open water region. Gunner *et al.,* (2008) found that release of phosphorus by sediments under three different forcing conditions (anoxia, bioturbation and sediment drying) were not primary factors in phosphorus concentrations recorded in the surface waters of Lake Goollelal. Gunner *et al.,* (2008) concluded that high phosphorus concentrations in Beenyup Swamp are likely to be from groundwater inputs.

There is some uncertainty of the water flow movements through these swamps. It is suggested that a perched water table may exist under the swamps containing much of the nutrients that they receive (Lund, pers.com, 2008b). Another suggestion offered is that a circular flow pattern may occur here where the surface water circles back on itself (Horwitz, pers. com, 2008). Given water flow uncertainties, Horwitz (pers. com, 2008) proposes that a hydro-geological study of the lakes and swamps be undertaken to provide a better understanding of water and pollution movement throughout these swamps.

In recent years, Lake Goollelal has also experienced problems associated with nutrient enrichment, potentially resulting from increasing urbanisation and concomitant increases in urban pollutant loads. Nutrient loading due to septic tanks in the catchment may also contribute, with many of the dwellings to the east of Lake Goollelal (Kingsley) still unconnected to deep sewerage. Other contributing factors include reduced groundwater levels and the drying of lakes, which increases water temperature and may enhance nutrient availability (Lund, 2008a).

The drying and re-wetting of organic-rich wetland sediments is an important factor in nutrient availability. Sommer (2006) identified two distinct organic sediment types in Lake Goollelal - suspended detrital floc (aquatic algal origin) and peat (vascular plant origin). She found that when floc was dried, it resulted in a significant increase in phosphorus being released in an easily mobilised form, which then has the potential to result in eutrophication upon refilling. Sommers (2006) work suggests that any increases in drying regimes in the lake may result in an increase in nutrient availability with further exacerbation of midge problems. This highlights the need for responsible management of lake water levels and reducing external nutrient inputs. Increased eutrophication was a likely factor in the midge outbreak in December 2007 and the current level of algal growth (Figure 11).

Figure 11. Algal growth occurring in Lake Goollelal which has been seen in recent years (Photo by John Chester).

Groundwater monitoring by Cumbers (2004) and the Yellagonga Catchment Group (Unpublished report, 2002-2003) in the years 2001 (from Jul - Nov) and 2003 (Jun - Nov) occurred along the eastern shore line of Lake Joondalup. The investigations identified high nutrient contamination entering Lake Joondalup, and were considered to originate from surrounding current and historical land use practices. Inputs were thought to come from fertiliser run-off from intensive agricultural practices, as well as originating from a reputed old landfill site (Whincup, 2000). As previously mentioned, the existence of this landfill cannot be verified, and it is likely nutrients are originating from the poultry industries to the east of the Yellagonga wetlands (see Figures 7 - 9).

The site recording the highest nutrient loading (Total Nitrogen-TN and Total Phosphorus-TP) was found at borehole LJ3 located at the end of Neville Drive. These findings are consistent with groundwater monitoring undertaken by DoW in 1994 (WIN borehole # 5002) (Appendix 2). Fluctuations in the concentrations of nutrients in the groundwater were recorded between months and between bores with Ariti Avenue in October 2001 revealing the highest peak overall in phosphate concentrations (0.78 mg/L). For the bores located at Poinciana Drive, Wallawa Street and Ashley Road, the highest peak in phosphates were recorded in June 2003. Further groundwater monitoring would identify the source and extent of nutrient contamination in groundwater arriving from eastern land use activities.

Excessive fertiliser applications combined with a shallow groundwater depth, may have resulted in nutrients leaching rapidly to groundwater, in particular NH_4 and NO_3 (ammonium and nitrate respectively). Although attenuation occurs with depth and distance from the market garden areas (Salama *et al.,* 2001a), small inputs received from these areas over many years, may be another contributing source of nutrients into Yellagonga wetlands that should be addressed.

Some households to the east of the Park are still connected to septic systems, and have been implicated as a potential source of nutrients entering the Park's wetlands. A septic tank requires regular maintenance and servicing, and has a serviceable life of 20 – 30 years. Failure rates in Australia have been estimated to be as high as 60 percent in some councils (Herbert and Workman, 2004).

In 1994, the Water Corporation initiated the $800M Infill Sewerage Program, which is a long-term program (expected completion date of around 2014-15) to provide access to deep sewerage in those areas throughout the Perth Metropolitan where existing septic and leach drains have been considered inappropriate (for example, soil type or lot size). At present, prioritisation of infill does not include the Wanneroo / Joondalup area (Water Corporation). While much of the catchment is thought to be connected to deep sewerage, the Yellagonga Community Advisory Committee have recently requested the Water Corporation prioritise deep sewerage to remaining households within the Yellagonga catchment that are not connected – in particular the Kingslake Estate to the east of Lake Goollelal.

Owners are given five years to connect to new sewer lines. While a property owner may connect to deep sewerage, there is no legal requirement to decommission their old septic systems except under the *Health (Treatment of Sewage and Disposal of Effluent and liquid waste) Regulations 1974*. Regulations specify if the property is sold (or other change of use such as redevelopment or becoming a commercial property), then 60 days after the 'material change' the owner of the premises must decommission the old septic system.

The slow conversion to deep sewerage or decommissioning of old septic systems, presents potential for nutrient contribution from old or poorly maintained septic systems, adding to the over-all nutrient load into the Park's wetlands. While a large store of nutrients is thought to exist from old and poorly maintained septic systems in residential areas (Whincup, 2000), physical characteristics of the area, such as soil type, vegetation cover, groundwater depth as well as system design and maintenance, will determine the movement of phosphorus (Congdon, 1979). Spearwood sands found in the Yellagonga catchment do not have an unlimited capacity to retain phosphorus, although breakthrough times calculated for phosphorus reaching groundwater may take many years in some instances, and is dependant upon phosphorus accumulation and recharge rates (Ecologia, 1998). However, this potential additional source of nutrients should be considered in reducing pollutant loads entering the Park's wetlands.

Additional nutrient sources have been identified in the 2005–2007 Wangara sump monitoring programs. The Wangara sump is a compensating basin that receives untreated storm water from much of the Wangara industrial area (North Metro Conservation Group and DoW, 2006) (Figure 12). The monitoring program included water quality monitoring (monthly – bimonthly) at the inlet and outlet of the sump (Figure 11). Total nitrogen concentrations were consistently elevated (particularly at the inlet) and up to double ANZECC / ARMCANZ (2000) guideline concentrations (North Metro Conservation Group, 2007). Total phosphorus concentrations were consistently elevated at the inlet and outlet with the inlet recording over 120 times ANZECC / ARMCANZ (2000) trigger guideline concentrations. In addition, the sump has overflowed directly into Walluburnup Swamp in times of high rainfall (Figure 12a). The ability to do so, raises questions on the suitability of the sump to address issues of stormwater for which it was intended.

Figure 12. Aerial photo of the Wangara sump, which receives untreated stormwater from the Wangara industrial area.

Figure 12a. In times of high flow rates after heavy rainfall, the untreated water from the Wangara Industrial area overflows directly into Walluburnup Swamp (Photos by John Chester taken in May, 2004).

An additional source of nutrient loadings often implicated in poor water quality in wetlands, is bird faeces. Congdon (1979) did not consider that bird faeces made significant contributions to nutrients into the lake systems, particularly when compared to inputs from other sources and the nutrient store within the sediments. However today, large numbers of water birds have been reported on the Yellagonga Lakes (Bekle, 1997; Davis, unpublished data) since Congdon (1979) undertook his study. Cumbers (2004) calculated substantial nutrient inputs into Lake Joondalup from water birds, exceeding inputs from rainfall and stormwater drains. However, Congdon (1979) noted the nutrient conversion that would occur where birds convert organic forms of nutrients into inorganic forms, and remove nutrients as increased body mass when they leave the wetland system to continue their migratory journeys.

5.3.2 Toxicants

Toxicants can be poisonous to wetland ecology at certain concentrations and include:

- Heavy metals
- Petroleum products
- Industrial by-products
- Pesticides and herbicides and
- Household chemicals

(Bunny and Mouritz, 1995)

Contaminants and toxicants recorded in the surface water and sediments of the Wangara sump (entering and exiting the sump) over the full 12 months of 2006 (NMCG and DOW, 2006), included heavy metals, petroleum and industrial by-products. As the Wangara sump drains into Walluburnup Swamp and, given the highly porous nature of soils on the Swan Coastal Plain, contaminants can enter the wetlands by either surface flow or groundwater flow. Data suggests that the sump may be effective at removing some contaminants, possibly due to complexing or adsorption with sediments and / or uptake of heavy metals by vegetation (see Van der Welle *et al.,* 2007). However, the ability to attenuate contaminants by vegetation or sediments is limited and the ability to do so will decrease over time as adsorption sites are used up or vegetation dies off. In addition, a change in physico-chemical conditions, such as acidification, can promote the re-release of these contaminants. Groundwater sampling reveals there is also loss of contaminants via this route.

Adverse impact of toxicants on fauna and flora include:

- immune depletion,
- mutations,
- interference with life cycle and reproduction,
- bio-accumulation,
- acute and chronic poisoning and
- death

For example, oil clogs feathers and fish gills, and detergents can cause deterioration of the protective barriers on a frog's skin (Bunny and Mouritz, 1995). At present, the effects of such compounds with respect to bioaccumulation, or acute / chronic effects on the aquatic or avian fauna in the Park are not known. However, contradictory to adverse impacts, one positive side-effect of such contaminants was proposed in a recent Australian study which compared urban and non-urban frog populations. Lane and Burgin (2008) found greater abundance and diversity in urban frog populations. They propose that the salts, detergents and other chemicals found in urban wastewaters may inhibit diseases such as chytridiomycosis, the fungus linked to the dramatic decline in many frog populations worldwide. By virtue of this inhibitory effect, it may confer some protection to frogs. However, long-term effects of contaminants on frog populations still requires further investigation.

5.3.3 Heavy Metals

Sources of heavy metals include road run-off, commercial and industrial sites, and leaching from land fill sites. Roads act as conduits for many contaminants and are considered to be the main pathway by which urban wetlands are exposed to autocatalyst-derived Platinum Group Elements such as palladium, platinum and rhodium catalysts which are used in catalytic converters (Whiteley, 2004).

The 2008 sediment monitoring of the Wangara Sump (360 Environmental, 2008) identified high concentrations of copper, zinc, lead and, to a lesser extent chromium in 15 of 50 sediment samples, all of which exceeded the Ecological Investigation Level (EIL) but were within the Human Health Investigation Level appropriate for an industrial / commercial site. Only zinc in surface water was found to exceed the DoE (2003) Guidelines for Freshwater. Groundwater monitoring recorded exceedances of the guidelines for aluminium east of the sump and chromium and arsenic at the western end of the sump, indicating loss of metals to groundwater below the sump.

Lund (2007) identified a trend of metal contamination in sediments at the 'Join' between Walluburnup and Beenyup Swamps of arsenic, copper, iron, manganese, lead and zinc with concentrations declining further into Beenyup Swamp. Zinc concentrations were particularly high, recording 142.0 µg/L (by comparison, Lake Goollelal recorded 2.0 µg/L and northern Beenyup recorded 4.6 µg/L). Lund (2007) concluded that the source of the contaminants was close to the 'Join' and most of the metals were being concentrated there. Lund (2007) also identified exceedances of the ANZECC / ARMCANZ (2000) guidelines (at the level of protection where 95% of species are protected in surface waters) in Beenyup Swamp of aluminium (recorded highest at 90.0 µg/L with ANZECC / ARMCANZ (2000) trigger guideline at 55 µg/L), copper (recorded highest at 40.0 µg/L with ANZECC / ARMCANZ (2000) trigger guideline at 1.4 µg/L) and zinc (recorded highest at 21 µg/L with ANZECC / ARMCANZ (2000) trigger guideline at 8.0 µg/L). Given that Walluburnup and Beenyup Swamps lie to the west of the Wangara sump and that some uncertainty surrounds water flow movements in these swamps, it is possible that migration of these substances is occurring from the Wangara Sump and previous land uses.

Heavy metals, such as Arsenic, have been found to cause detrimental reproductive effects in freshwater crustaceans (Yamaguchi *et al.,* 2008). Copper concentrations in freshwater snails were strongly correlated to copper concentrations found in sediments, indicating uptake by these organisms and possible bio-accumulation with detrimental effects through the food chain, in particular avian fauna (Frakes, et al., 2008). In Yellagonga wetlands, freshwater turtles are top order predators beneath the waterline and possible bio-accumulation in these animals and avian fauna, has not yet been investigated.

The Wangara sump sediment is classified for a Class1 landfill. This landfill classification is given to unlined sites accepting inert substances. If the material contains contaminants such as found in the Wangara sediments, then they must be below the relevant ecological investigation levels (Western Australia, Department of Environment *Landfill Waste Classification and Waste Definitions 1996 (As amended)*). The Wangara sump is due to be excavated around March / April 2009. However, given the contamination found in the sediments of Beenyup and Walluburnup Swamps, indicating migration of toxicants, monitoring results suggest upgrades to the Wangara sump are a high priority to address the issue of contaminants entering and migrating from this site.

Some information exists referring to previous monitoring at the Church Street outfall, however this data cannot be verified at present. Water quality and sediment sampling should re-occur at this site to ascertain its current status.

5.3.4 Petroleum Products

The 2006 Wangara Sump water quality monitoring program (NMCG, 2007), identified elevated concentrations of Total Petroleum Hydrocarbons (TPH) (which includes petrol, diesel and motor oils), BTEX compounds (Benzene, toluene, ethylbenzene and xylene), and surfactants (detergents) occurring on several occasions throughout the 11 month period (February – December 2006) although no clear pattern existed. July recorded the highest concentrations of TPH's and surfactants. Monitoring in 2008 (360 Environmental) found concentrations of TPH's and BTEX compounds below the level of laboratory detection in groundwater and surface water with low levels of surfactants detected in surface water of the sump. Given the fluctuations identified as occurring throughout the 2006 study (NMCG, 2007), long-term monitoring may reveal differences in contaminants being detected in this sump.

As there are likely to be numerous land uses that can release petroleum products, analysis of petroleum products across a broader area of the catchment would better indicate levels of hydrocarbon inputs to the wetlands.

5.3.5 Pesticides and Herbicides

With the substantial extent of current and past market gardening, it is possible that quantities of herbicides and pesticides have entered the Park's Wetlands. Leaching of agrochemicals are seen as a threat to the groundwater resources of the Gnangara

Mound. Modelling of agrochemicals and their filtration through the soils of the Spearwood and Karakatta Sands found eight commonly used pesticides had potential to leach through to groundwater (Salama *et al.,* 2001b). Field-testing has demonstrated that none of the pesticides were found in the groundwater at depths ranging from 30 centimetres up to 2.0 metres, when applied at the recommended rates. However, applications of pesticides outside recommended concentrations and excessive irrigation regimes, can lead to pesticide contamination in groundwater. To ensure recommendations for chemical use is adhered to, watering regimes are guided by pan evaporation, and increasing organic content in the soil (Salama *et al.,* 2001b). Factors affecting attenuation of pesticides include the physico-chemical characteristics of the receiving environment and the pesticide. For example:

1. Organic content of the soils, which has the greater effect on pesticide attenuation compared to physical characteristics of the soil such as percentage composition of sand or gravel, and particle size; and

2. Decay rates of the compounds (half-life)

(Salama *et al.,* 2001b).

Some compounds used in the catchment and tested for by Salama *et al* (2001b) include: *Chlorpyrifos* and *Atrazine. Chlorpyrifos* is a commonly used insecticide in Australia and has been used as a crop spray and for treating termites and can be fatal to small animals, birds and fish (ACT Government Health Information, 1996). Impacts have been found on small crustaceans in wetlands (Water fleas (Cladocera) and Copepods) from repeated applications of *Chlorpyrifos* (López-Mancisidor *et al.,* 2008). *Atrazine,* a widely used pesticide, with small amounts readily leaching to groundwater (Salama *et al.,* 2001) has been found to cause hermaphroditism in frogs at low concentrations, with unknown long-term effects for persistence of populations (Withgott, 2002).

In the Park, *Abate* (Temephos) is an organophosphate used for the control of midge larvae since 1978. Its use is likely to continue in the short-term, however the effect on non-target fauna or the widespread effects throughout the aquatic food web is not known. A range of herbicides are also used within the Park for weed control. These include, *Glyphosate* and *Chipco Spearhead* and *metsulfuron* for broad-leaved weeds in turf and *Targa* for the control of annual and perennial grasses.

5.3.6 Household chemicals

Household chemicals generally refer to detergents, bleaches, pool chemicals, paints and solvents that are at risk of being washed down stormwater drains. At present, there is a lack of research linking household chemicals to water quality monitoring data of the Park's wetlands.

The CoJ / FoY Green Frog Drain stencilling project has highlighted the need to prevent household chemicals entering stormwater drains and address the issue in educational materials that accompanies this campaign.

5.3.7 Pathogens

A pathogen is a disease-producing organism and includes viruses, bacteria, protozoa, fungi and parasites. Although some pathogens occur naturally in soil or water, sources of introduced pathogens to the Park's wetlands may include dog / wild cat faeces, garden manure, sewer overflows and degraded sanitary infrastructure / septic systems and *Phytophthora* dieback (Bunny and Mouritz, 1995). There is limited research in the Park on the nature of pathogens and the impacts on the flora and fauna present.

5.3.8 Suspended Solids

Suspended solids include particles of soil, sand, and silt, as well as decaying organic material, algae and micro-organisms. Given the extent of clearing, agricultural activities and urban development in the surrounding area, the Park's wetlands would likely receive elevated sediment loads from these sources.

Suspended solids in the lakes increase turbidity, reduce light penetration leading to restricted plant growth, and settling solids can smother flora and fauna.

5.3.9 Gross Litter

Gross litter can be a hazard to aquatic fauna, for example, injury from plastic bags, broken glass and metals or from ingestion of these products. Gross litter can also contribute to water flow blockages and may release further nutrients (for example from leaf litter) or toxicants, which can affect water quality. However, litter has been observed being used by some wetland fauna for example, incorporated into birds nests, or soft drink tins used as gilgie (*Cherax quinquecarinatus*) habitat (pers obs).

Leaf litter from deciduous trees may also be a problem for wetlands, as some can degrade more rapidly than the leaf litter from native trees.

High inputs of deciduous leaf matter could result in an oxygen deficit in the water unable to support aquatic organisms. In addition, Australian wetlands are adapted to an organic pulse during the summer months (not autumn) as this is the time of year when Eucalypts drop their leaves and senescence occurs in some fringing vegetation (Bunn, 1986).

5.4 Water Quality Conclusions

Land uses that can have adverse impacts on the Park have been identified through subcatchment mapping and prioritised for action to reduce wetland contamination. Past land uses have been identified as continued sources of contaminants in the wetland system, for example, pollutants bound and released in sediments and contaminated groundwater flow from previous and existing poultry / horticultural industries to the east of the wetlands.

The wetlands of the Park have been receiving excessive nutrient input for decades from point and non-point sources including potential groundwater plumes (from past or existing land uses) and stormwater inputs, including the Wangara Sump.

Continued research to address nutrient enrichment and avoidance of midge pesticide use, continues through the Midge Management Strategy. This research includes groundwater quality monitoring, which suggests pollutants in groundwater may be a greater source of pollutants than contributions from stormwater, particularly in Lake Joondalup (Yellagonga Catchment Group 2002-2003; Lund, 2008a).

Water quality research has indicated that stormwater drainage contributes substantially less nutrients into Lake Joondalup than that entering via Beenyup Swamp (e.g. Lund and McCullough 2008; Cumbers, 2004; Congdon 1986). However, upgraded stormwater drainage is still recognised as important for the Park's wetlands particularly given the following:

- There is a lack of monitoring data on toxicants and impacts on the wetland ecology.
- Some existing drainage infrastructure is not consistent with more current best practice for water sensitive urban design.
- The direct discharge of stormwater through outfalls is considered to be a major source of particulate matter as there is no opportunity for the stormwater to be treated. The main transporter of phosphorus (another major contributor to nutrient enrichment) is suggested to be particulate matter (Ove Arup, 1994).
- Threats to the wetlands from the drying climate may lead to reduced surface water expression from groundwater as well as from direct precipitation with subsequent terrestrialisation of the sediments.
- Surface water inputs from the surrounding urbanised environment may become more important for lake levels, however the wetland ecology would require uncontaminated water entering the Lake.

Pre and post drainage upgrade monitoring will assess effectiveness of such programs.

6.0 Biodiversity

As part of writing an integrated catchment management plan and the inter-linking between the Park and its catchment, it was considered appropriate that the biodiversity section include catchment biodiversity characteristics as well as a current 'state of the Park.'

6.1 Vegetation

Much of the surrounding catchment has been cleared for urbanisation and market gardens, with vegetation existing mainly as parkland and residential gardens. Small fragments of native vegetation remain further east of the Park consisting of Banksia, Jarrah, Marri woodlands (*Banksia sp - Eucalyptus marginata - Corymbia calophylla*), interspersed between market gardens. These remnants are under pressure from illegal use such as 4x4 driving, general recreational uses, and the effects of edge. DEC have listed two sites with threatened flora, one site with declared flora and one site with rare priority flora within the surface water catchment. One site containing a threatened ecological community also exists, although this appears to be just outside the surface water catchment (but within the groundwater catchment).

Seeds from these areas could presumedly reach the Park via wind or bird faeces, however, these events would not make a significant contribution to re-seeding native vegetation in the Park. Exotic seeding into the Park is a concern, and is largely derived from surrounding residential gardens.

Within the Park, a recent survey of vegetation communities by Regeneration Technology (2002) identified nine wetland communities (consisting of sedgelands, woodlands, open and closed forests) and five dryland communities (consisting of open and closed forest as well as woodlands). Much of the remnant vegetation has been altered with only a small area now considered to be in pristine condition in the northern-most section of the Park found in the *Melaleuca rhaphiophylla / Eucalyptus rudis* closed forest community. Weeds are a key threat in the Park with 91 species identified. The ecological priority rating of many of the exotic grasses is high and a serious threat to the ecology of the Park; the most dominant and widespread weed species being Veldt grass (*Erharta calycina*) (Regeneration Technology, 2002).

6.1.1 Wetland Vegetation - Emergent

Originally, rushes existed around much of the shorelines of all wetlands in Yellagonga, ranging from a few metres to extensive stands around the southern aspect of Lake Joondalup and Walluburnup Swamp (Bamford and Bamford, 1990).

Today, three types of emergent vegetation exist within the park – *Baumea articulata, Schoenoplectus validus* and the introduced giant reed *Typha orientalis* which is a key threat to native rush communities – particularly in Lake Joondalup and Walluburnup Swamp (Yellagonga Regional Park Management Plan, 2003-2013; Regeneration Technology, 2002). Contraction of *B. articulata* around Lake Goollelal, and a general decline in condition of this species at Lake Joondalup with terrestrialisation noted to have occurred in recent years – particularly at Lake Joondalup South (DoW Draft, 2008; Sommer and Horwitz, 2007).

6.1.2 Wetland Vegetation – Fringing Vegetation

Previously, fringing vegetation consisted of the Paperbark (*Melaleuca raphiophylla*), Flooded gum (*Eucalyptus rudis*) and some Swamp banksia (*Banksia littoralis*), with *Acacia saligna* and *Acacia cyclops* further upland. Distribution of fringing vegetation was found to exist in a restricted band around the lakes with the least disturbed and most extensive stands located at Beenyup Swamp (Bamford and Bamford,1990; Yellagonga Regional Park Management Plan, 2003-2013).

Today, much of the fringing vegetation is fragmented with some decline in *Eucalyptus rudis* and *Melaleuca rhaphiophylla* observed at Lake Goollelal as well as Lake Joondalup (DoW Draft, 2008) (Figure 13). Weed invasion is also evident in the understorey, such as the highly invasive introduced grasses Kikuyu (*Pennisetum clandestinum*), Buffalo (*Stenotaphrum secundatum*) and Couch (*Cynodon dactylon*) (Yellagonga Regional Park Management Plan, 2003-2013)

Figure 13. A tall stand of fringing vegetation found in Yellagonga Regional Park (Photo by GaryTate).

6.1.3 Dryland Vegetation

Originally, upland vegetation in the Park consisted of Tuart (*Eucalytus gomphocephala*) forest along much of the western boundary of the system (Bamford and Bamford, 1990). Today, much of the forest has been cleared. Tuart-Jarrah-Marri (*Eucalytus gomphocephala - Eucalyptus marginata - Corymbia calophylla*) open forest exists as a patchy distribution in the west with some open forest to the north east of Lake Joondalup, with scattered Tuarts to the east of Walluburnup and Beenyup Swamps and northeast of Lake Goollelel. Banksia, Jarrah and Marri exists in an open forest along much of the southeastern shore of Lake Joondalup with large areas cleared for recreational landscape along the eastern shores of Walluburnup and Beenyup Swamps, and Lake Goollelal (Regeneration Technology, 2002) (Figure 14).

Figure 14. Upland vegetation found in Yellagonga Regional Park. Much of the forested areas in Yellagonga Regional Park have now been cleared (Photo's by Gary Tate).

6.1.4 Fungi

Recent surveys have now included the fungi in the Park and have identified a wide diversity of mycorrhizal and decomposer fungi. A possible 43 fungi species were found (species yet to be verified for some) and was considered to only represent a small proportion of the fungi likely to exist within the Park (Bougher *et al.,* 2006). Further surveys are expected, in order to describe the full compliment of fungi in the Park (Figure 15).

Fungi survey's have not been conducted in the catchment and representation outside the Park is not known.

Figure 15. Two of the many fungi species found in Yellagonga Regional Park (Photo's by Gary Tate).

6.2 Fauna

As a consequence of land clearing for urbanisation and fragmentation of habitat, fauna in the Yellagonga catchment have been impacted, with many species now in decline or have disappeared. Within the surface water catchment boundary, at least seven sites with threatened fauna have been identified and many others further east of the boundary have been listed by the DEC. Two sites have been identified with threatened fauna within the Park. Further degradation and destruction of habitat, including the lack of ecological linkages, threatens the viability of many remaining fauna groups in the catchment and within the Park. Little recruitment, if any, would be expected to occur from the catchment into, or out of, the Park.

Many animals are sighted in the Park, however, a register of fauna in the Park does not currently exist. Promoting the survey and study of fauna in the Park, including the invertebrates, is a medium priority strategy in the Yellagonga Regional Park Management Plan 2003-1013. The management plan has also given a high priority rating for the preparation and implementation of a fauna management program, however these strategies have not yet been actioned.

To effectively manage fauna remaining in the Park, an understanding of their population status and life history is needed to focus revegetation and rehabilitation programs. Ongoing surveys on vertebrate and invertebrate fauna can ascertain population dynamics and age structures, whether breeding is occurring, and assess the ability of the habitat to sustain them (Figure 16). Fauna surveys should also include nesting clusters to identify them for protection during seasonal emergence (for example, altered mowing regimes which was given a high priority rating in the Yellagonga Regional Park Management Plan 2003-2013). Surveys should include introduced fauna with location of dens/warrens for control.

As this will be a significant and on-going project in terms of resources and time, partnerships should be developed with universities and community groups.

The most recent terrestrial fauna survey, was conducted 18 years ago by Bamford and Bamford (1990). No terrestrial invertebrate surveys appear to have been undertaken. Kinnear and Garnett (1997a) undertook an important and detailed baseline survey of the aquatic invertebrates of Yellagonga wetlands, and aquatic invertebrate surveys are regularly undertaken as part of the Gnangara Mound Wetland Macro-invertebrate Monitoring Program (Sommer and Horwitz, 2007).

Avian fauna are the most conspicuous fauna in the Park; in particular the water birds, and have been the subject of several abundance and diversity surveys conducted in the past (RAOU Jaensch *et al.,* 1988; Jaensch and Vervest, 1988; Bekle, 1997) with an on-going survey currently being undertaken by Davis (unpublished data 2005-2008). A recent survey for the semi-aquatic Rakali, or Water-rat (*Hydromys chrysogaster*) was conducted at Lakes Joondalup and Goollelal in 2008, as part of the Gnangara Sustainability Strategy research. Greatest abundance of this animal was found at Lake Goollelal.

Figure 16. A wide diversity of terrestrial invertebrates have been sighted in Yellagonga Regional Park, however no scientific surveys have been undertaken to record these animals. Above, is a Hairy-backed Pie-dish beetle (*Helea perforatus*) commonly seen in the summer months and is a ground-dwelling invertebrate that is active at night (Identification and description by Terry Houston from the West Australian Museum, 2008) (Photo by Gary Tate).

6.2.1 Reptiles and Amphibians

Three snake species have been sighted in the park - the Tiger snake (*Notechis scutatus*) (Bamford and Bamford, 1990; G.Tate, pers. com., 2008), the Carpet python (*Morelia spilota*) (Yellagonga Regional Park Management Plan, 2003-2013) and Dugites (*Pseudonaja affinis*) (G. Tate, pers. com., 2008).

Five lizard species have also been identified in the park (Bamford and Bamford, 1990); the Australian Scincid lizard (*Ctenotus fallens*), Striped skink (*Ctenotus leseurii*), Yellow-bellied skink (*Hemiergis peroni*) *and Lerista praepedita*, as well as the Bobtail lizard (*Tiliqua rugosa*). Due to limited surveys, the current status of snakes and lizards in the Park is not known.

The Oblong turtle (*Chelodina oblonga*) still exists within the lake systems. While a relatively large population is predicted to exist here, no population studies have been undertaken in the Park's wetland chain to establish size structure, recruitment of younger turtles into the population or the overall health of the animals. In temperate wetlands, freshwater turtles are top end predators and their overall health and presence is important in wetland ecology.

There is concern that many turtle hatchlings are not being recruited into the population given the extent of fox depredation of turtle nests reported by local residents. In some eastern states Murray River turtle (*Emydura macquarii*) populations, Thompson (1983) estimated 96% mortality at the egg stage with most depredation of turtle nests attributed to fox predation. While recruitment is important for continuation of species, hatchling turtles also represent an important seasonal food source for the many water birds that utilise the Park's wetlands.

In addition, hatchling turtles are important predators of invertebrates, particularly midge and mosquito larvae, helping in the control of these invertebrates, which reach nuisance densities (Figure 17).

Figure 17. Long-necked, freshwater turtle hatchling (*Chelodina oblonga*) making the long, and dangerous journey back to the wetland. This hatchling is crossing the footpath in the Park, exposing it to easy predation by birds, dogs and cats. Turtle hatchlings are predators of midge and mosquito larvae, helping to control these invertebrates, which can reach nuisance densities. There is concern that the extent of fox depredation of turtle nests may be impacting on recruitment into turtle populations (Photo by Gary Tate).

Six frog species previously occurred in the Yellagonga Park (Bamford and Bamford, 1990), including the Sandplain froglet (*Crinia insignifera*), Glauert's froglet (*Crinia glauertii*), Moaning frog (*Helioporous eyrei*), Western banjo frog (*Limnodynastes dorsalis*), Slender tree frog (*Litoria adelaidensis*), and the Western bell frog (*Litoria moorei).* The current presence, abundance and distribution of frog species in the Park is not known.

6.2.2 Fish

Four fish species have previously been observed in the Yellagonga lake systems – two native and two exotic species. These include the native Swan River Goby (*Pseudoglobius olorum*) (Bamford and Bamford,1990) and the Pygmy Perch (*Edelia vittata*) (WAWA, 1995). The exotic fish being *Gambusia affinis* (Bamford and Bamford,1990), and the European Carp (*Cyprinus carpio*) (Yellagonga Regional Park Management Plan, 2003-2013). A recent Gnangara Sustainability Strategy project has included a review of the status of fish in wetlands on the Gnangara Mound. It was recommended that, due to habitat loss and the effects of hydrological change, any wetland containing a population of native freshwater fish should be given high management priority (E-Bulletin of the Gnangara Sustainaiblity Strategy Jan 2009).

6.2.3 Avian Fauna

Water birds

The Park supports many resident and trans-equatorial migratory water bird species (Bekle, 1997). Bekle (1997) identified at least 37 waterbird species during 1991-1993 (from the families: Anatidae, Podicipedidae, Anhingidae, Phalacrocoracidae, Pelecanidae, Ardeidae, Plataleidae, Rallidae, Scolopacidae, Recurvirostridae, Charadriidae). While Bekle (1997) predicted the number of species was probably greater than this, Bamford and Bamford (1990) previously recorded 56 species occurring in this park with 51 species identified in Royal Australasian Ornithological Union (RAOU) surveys (Jaensch *et al.,*1988) in the early 1980's. Combined results of surveys suggest there may be a decline in water bird species utilising the Park's wetlands. Decline in total number of waterbirds utilising wetlands in south-western Australia was observed from 1986-1988 (Jaensch and Vervest, 1988). Bekle (1997) noted lower numbers of migratory species compared to previous surveys. It is not known if previous observations reflect current trends.

Lake Joondalup was noted to support nearly twice as many species as Lake Goollelal, with most species reported in north Lake Joondalup, which Bekle (1997) attributed to the diversity of habitats and food resources, and the greater surface water area of this lake. The preference by water birds for North Lake Joondalup is a trend observed previously by Bamford and Bamford (1990). Bekle (pers. com, 2008) also notes the relationship of water depth and use by birds.

There are also spatial and temporal variations in the use of the Yellagonga wetlands by water birds (Bekle, 1997; Davis, unpublished data 2005-2008). Bekle (1997) found species use of the wetlands peaked in February due to an influx of trans-equatorial migratory waders as well as the inland water birds, as inland wetlands dried up. Abundance of avian fauna was lowest in September, but rose steadily to peak in April with just over 5,000 birds being counted in this month. High numbers of waterbirds were also reported in the 1981-1985 study by Jaensch *et al*., (1988), with more than 6,500 waterbirds counted in one survey (in March 1984). The Eurasian coot (*Fulica atra*), Red-necked Avocet (*Recurvirostra novaehollandiae*) and the Black swan (*Cygnus atratus*) were the most numerically abundant of all species throughout the 1981-1985 survey

(Jaensch *et al.,* 1988), with Lake Joondalup considered to be one of three wetlands most important for the Eurasian coot (Jaensch and Vervest, 1988). This waterbird continues to be abundant in Yellagonga wetlands as Bekle (1997) found in the 1991-1993 study; the Eurasian coot in particular, and the Black swan were the most abundant species in his study, and, to a lesser extent, the Australian shelduck (*Tadorna tadornoides*) and the Pacific black duck (*Anas superciliosa*) (Figures 18 and 19).

Figure 18. Lake Joondalup is considered an important wetland for the Eurasian coot (*Fulica atra*) and is the most numerically abundant bird on the lake (Photo by Gary Tate).

Figure 19. Great white egrets (*Ardea alba*) perching on deadwood in Lake Goollelal (Photo by Gary Tate).

Recently, Davis (unpublished bird count data for 2004-2005) reported an estimated total water bird peak at Lake Joondalup of just under 50,000 birds. Davis's estimates are calculated using the sum total of bird counts from all surveyed sectors which are then multiplied by the total area surveyed (estimated 58.9%) divided by the total surface of lake available. As noted by Davis (unpublished data 2004-2005), bird counts previously undertaken by Bekle (1997) and Jaensch *et al*., (1988) appear to be maximum counts made in a single survey and are not estimates made for the entire lake surface area. Davis (unpublished data 2004-2005) also found the Eurasian coot continuing to be the most numerically abundant water bird on Lake Joondalup followed by the Pacific black duck and the Hardhead duck (*Aythya australis*) as well as the migratory wading species, the Black-winged Stilt (*Himantopus himantopus*), all of which are present in the tens of thousands, while remaining species are present in numbers often below one thousand (Figure 20).

Figure 20. The migratory wading species, the Black-winged stilt (*Himantopus himantopus*) feeding on aquatic invertebrates in the shallows of Yellagonga wetlands (Photo by Gary Tate).

Davis (unpublished data 2005-2008) also found an increase in numbers of birds using Lake Goollelal, including variations in temporal use since 2005. The highest abundances of birds in 2005 were found to occur from March to June, but in 2006 / 2007 highest abundances were found during November through to March and in 2007 / 2008, highest abundances were recorded earlier still - between October and January. However, declines are now being recorded, and in October to November 2008, only a small peak was recorded compared to the previous two years (abundances for 2007/8 : 2008/9 recorded at 1622 : 756 for same date) and has fallen rapidly to numbers similar to those recorded in 2005.

Greatest abundances were again recorded for the Eurasian coot, Pacific black duck, Black swan and the Hardhead. Only one Red-necked Avocet was reported by Bekle (1997) in the 1991-1993 study compared to 1200 reported by Jaensch *et al.,* (1988), however, recent observations by Davis (unpublished data 2005-2008) indicate that the species is still present in significant numbers (estimated 6428 birds) in Lake Joondalup but is absent from Lake Goollelal.

While use of a wetland by water birds is largely determined by water depth, and different water bird species have different depth requirements, corrections need to be made for abundance and water depth to enable interpretation of the above abundance data (see Bolduc and Afton, 2008). However, high numbers are not necessarily an indicator of health in an animal population. Given the amount of property development occurring in Perth and a drying climate, it may mean that other wetland habitats have been destroyed and abundances on Yellagonga wetlands may be part of the phenomenon known as 'crowding on the ark'. This phenomenon is described as a high influx of animals, usually highly mobile animals, into a fragment when the surrounding habitat has been destroyed (Noss and Csuti, 1997).

Terrestrial birds

Focus for avian surveys appears to be on water birds with the only known terrestrial bird survey undertaken by Bamford and Bamford (1990).

A diversity of upland habitats are recognised as being important for terrestrial avian fauna. Bamford and Bamford (1990) identified five habitats for the terrestrial avian fauna in The Park:

1.) rush-beds,
2.) fringing vegetation,
3.) forest and woodland (with native understorey),
4.) forest and woodland (with little native understorey) and
5.) parkland.

There were 47 species of terrestrial birds identified in the park by Bamford and Bamford (1990). Their study revealed some partitioning in resource use was evident in the terrestrial landscape, but predominant use by the terrestrial birds was in the forested / wooded areas. While most species required at least two or more habitat types, there was overlap in habitat use by different species. Six species utilised four habitat types: the Grey fantail (*Rhipidura fuliginosa*), Silvereye (*Zosterops lateralis*)**,** Brown honeyeater (*Lichmera indistincta)* and the Sacred Kingfisher (*Todiramphus sanctus*) utilised the fringing vegetation, forest and woodland with native understorey or little native understorey and the parkland. The remaining two species utilised four habitat types: the Welcome swallow (*Hirundo neoxena*) and the Tree martin (*Petrochelidon nigricans*), included the wooded habitats (with native understorey or very little understorey), open parkland along with the reed and rushbeds (Figure 21).

Figure 21. A singing Honeyeater (*Lichenostomus virescens*), perching on a bottlebrush branch in the open woodland areas of Yellagonga Regional Park. This bird was not identified in the original survey 18 years ago, highlighting the need for updated surveys (Identification by Ron Johnstone, West Australian Museum) (Photo by Gary Tate).

Despite overlap in habitat use recorded for most species, there were fourteen species which required only a single habitat type. Three of these required the forest and woodland with native understorey (Western Spinebill (*Acanthorhynchus superciliosus*), Splendid fairy-wren (*Malurus splendens*) and the Western Thornbill (*Acanthiza inornata*), while the remaining eleven species utilised the open parkland habitat (Australian kestrel (*Falco cenchroides*), Black-shouldered kite (*Elanus axillaris*), White-backed swallow (*Cheramoeca leucosternus*), Laughing turtle-dove (*Streptopelia senegalensis*), wild Pigeon (*Columba livia*), Banded lapwing (*Vanellus tricolor*), Rainbow bee-eater (*Merops ornatus*), White-winged Triller (*Lalage sueurii*), Richards's pipit (*Anthus novaeseelandiae*), Willie wagtail (*Rhipidura leucophrys*) and the Australian magpie (*Gymnorhina tibicen*)) (Bamford and Bamford, 1990) (Figure 22).

Figure 22. A male Splendid fairy-wren (*Malurus splendens*) in breeding plumage (above) and female (below) (Photo's by Gary Tate).

Partitioning and overlap in resource use highlights the need to ensure all habitat types are managed appropriately to ensure terrestrial avian fauna are able to meet life history needs. Recent research highlights the urgency to maintain habitats for terrestrial avian fauna given the extent of clearing for urbanisation occurring, with predictions of more than 80 per cent of Perth's bush birds facing extinction if land clearing continues at current rates (Thomas, 2008).

6.2.4 Aquatic Invertebrates

Kinnear and Garnett (1997a) identified 121 macro-invertebrate taxa excluding the segmented worms (Annelida), and therefore species richness is expected to be greater. The dominant groups were the ten-legged animals (from the order Decapoda such as shrimps and the small crustaceans) and true flies (from the order Diptera such as midges). Considerable variability was found in distributions of macro-invertebrates throughout the wetlands, both spatially and temporally, but the greatest diversity and abundances of macro-invertebrates were typically found at South Lake Joondalup and Beenyup Swamp.

North Lake Joondalup supports a relatively depauperate species diversity and abundance compared to South Lake Joondalup, despite the south to north flow through these wetlands and the piped connection between the two sections of the lake. Kinnear and Garnett (1997a) propose that this may be a natural condition for this part of Lake Joondalup. Phosphorus enrichment, seasonality of the wetland and emergent vegetation, along with sediment characteristics were seen as important determinants of species distribution and abundances. The Kinnear and Garnett (1997a) study suggest that the dragonflies and damselflies (order Odonata) were only present in low numbers, with highest number of species and abundances again found in South Lake Joondalup and Beenyup Swamp (Figure 23). The Odonata are an important group in wetland food chains as they prey upon other wetland invertebrates and, given the predominance of dipteran larvae, in particular midge (*Tanytarsus fuscithorax, Procladius villosimanus and Kiefferulus intertinctus* at South Lake Joondalup and Beenyup Swamp, and *Dicrotendipes conjunctus* in Lake Goollelal), the role of dragonflies and damselflies as predatory species for these dipterans can only be a minimal one.

Kinnear and Garnett (1997b) identified 12 microcrustacean species from the orders Cladocera, Copepoda and Ostracoda within the Yellagonga wetlands study, with greatest abundance of the Cladocerans – in particular the Waterflea (*Daphnia carinata*). Distribution of the microcrustacean communities appears to be influenced by phosphorus enrichment and seasonal temperature with increased abundances found at enriched sites - South Lake Joondalup and Beenyup Swamp, particularly in autumn and spring.

Richness of invertebrate fauna can be an indication of healthy functioning of a wetland system. As a system is degraded, it loses diversity of its invertebrate fauna and in turn, loses its functionality (Horwitz, pers. com., July 2008). The 2006 / 2007 Gnangara Mound Wetland Macroinvertebrate Monitoring program (Sommer and Horwitz, 2007) suggested macroinvertebrate family richness has declined at Lake Goollelal in spring compared to previous years, although family richness was similar between spring 2006 and summer 2007. However at Lake Joondalup (North and South), a decline in family richness well below average was evident in summer 2007 compared to previous summer sampling regimes. Conversely, spring sampling suggested macroinvertebrate family richness had increased since previous sampling years, which was higher overall.

Higher family richness in spring appears to be a general trend throughout all other Gnangara Mound wetlands sampled, except Melaleuca Park, although occasional reversal of this trend has occurred in some wetlands (Sommer and Horwitz, 2007). Sommer and Horwitz (2007) suggest that North Lake Joondalup is undergoing systematic changes related to declining water levels and increasing nutrient levels.

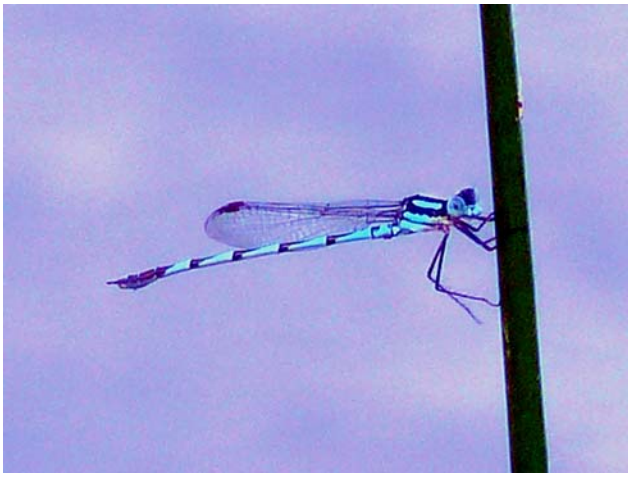

Figure 23. Low numbers of Damselflies and dragonflies (Odonata) were recorded in Yellagonga wetlands. Damselflies and dragonflies are important predators of midge (Photo by Gary Tate).

7.0 Threatening Processes

Many of the threatening processes for the Park have been identified in the Yellagonga Regional Park Management Plan 2003-2013. As many of these threats come from outside the Park, they have been discussed below in context of both the catchment and the Park. Some of these threats have been identified for action under the strategies section within the Yellagonga Management Plan 2003-2013. In addition, since the completion of the Yellagonga Regional Park Management Plan 2003-2013, additional threats have been identified and are discussed here.

7.1 Declining Water Levels

Variability is seen in wetland water levels along the Swan Coastal Plain as part of natural cycles of seasonal and annual water fluctuations. However, a drying climate and over abstraction of groundwater from the Gnangara Mound, have resulted in declining groundwater levels. Landuse to the east of the Park includes intensive horticultural industries and in addition, many private bores exist to the east of the Park. Research is currently being conducted on the environmental, economic and social needs of the groundwater supply under the Gnangara Sustainability Strategy.

Determining water requirements for the biota of a wetland is paramount to protect and manage wetland values, in particular, quantifying water requirements (Davis and Froend, 1998), and have been described by Froend *et al.,* (2004) for the wetlands of the Gnangara Mound. However, Davis and Froend, (1998) note that some vegetation communities do not have their water requirements known, for example the tree and shrub dominated wetland communities. Management of wetland water levels in the Park for waterbirds and other fauna habitat reflecting historical regimes, was given a high priority rating in the Yellagonga Regional Park Management Plan 2003-2013.

Natural variability is seen in wetland water levels along the Swan Coastal Plain, with fluctuations in water levels driving vegetation community structure and biomass, and is particularly obvious at the terrestrial / aquatic edge (Hudon, 2004). Declining water levels have been shown to alter vegetation compositions (diversity and structure) as well as their biomass. Both native and exotic vegetation that are well adapted to water level variability have been found to predominate, although there appears to be a greater propensity for invasions of monospecific exotic vegetation under declining water levels (Hudon, 2004) (Figure 24).

Figure 24. Drying of wetlands allows invasion of terrestrial vegetation. Lake Joondalup in summer 2007, with terrestrialisation of sediments evident (Photo by Gary Tate).

Water requirements for sedge and rush communities are largely dependent and adapted to permanently waterlogged soils (Chambers *et al*, 1995). Under conditions of low water levels, emergent plant assemblages have been shown to increase their below ground biomass and, although they were able to withstand desiccation for up to 12 months, longer periods of drying eventually lead to death of this vegetation resulting in marked changes in community composition (Hudon, 2004). Terrestrialisation of sediments is reported for at least five wetlands on the Gnangara Mound including Lake Joondalup South, with Lake Joondalup (north and south) being recognised as a high priority site for management (Sommer and Horwitz, 2007).

Fluctuations in wetland water levels, including interannual variation, have suggested changes in habitat use by avian fauna and impacts on reproductive success. In particular, obligate wetland breeding avian fauna (those species which can only exist under specific environmental conditions) may be more vulnerable than the facultative wetland breeding species (those species which are able to use a range of environmental conditions to survive) (Fletcher and Koford, 2004). Reduced densities of adult birds, and even complete reproductive failure, have been reported in some obligate species, attributed to the effects of food availability (bottom-up effects) and high nest predatory activities (top-down effects). Changes in water levels have been shown to impact on the composition, distribution and biomass of wetland vegetation (Hudon, 2004) which results in changes to the availability of suitable breeding habitat, and the quality of that habitat for avian fauna.

Complete drying in wetlands that may not have dried in the past or dried infrequently (for example Lake Joondalup, which has dried occasionally in the past (Hamann, 1992)) may result in more nuisance swarms of dipterans such as mosquitoes (e.g. Kaiser, 2003) or midges (Davis *et al.,* 2002). This may result from the lack of predators or competitors that are not adapted to dry periods. That is, they die out when the wetland dries and are therefore not present immediately when the wetland refills (see Kaiser, 2003). While this may be part of the problem, it is likely to be multifaceted. Davis *et al.,* (2002) predicted that the re-filling of Lake Joondalup following a season of drying to small remnant summer pools, as opposed to complete dryness or deeper water, resulted in warmer water conditions, with the warmer temperatures enhancing breeding conditions for midges.

7.2 Weeds

Weeds are undesirable plants and may include exotic plants or native Australian plants from the Eastern States (Keighery, 2002). Given the highly altered landscape of the Yellagonga catchment, invasion of weeds from the catchment into the Park is an on-going problem. In addition, given the extent of weed growth in the Park, propagation of weeds from within the Park itself, now also pose a threat to the ecological integrity of the Park. Weeds produce structural and compositional changes to the vegetation, degrade fauna habitat, and threaten persistence of fauna within the Park. Weeds also invade disturbed habitat, dominating post-fire succession and, in turn, promote susceptibility to fire re-occurrence.

Weeds may be known as environmental or declared weeds. Environmental weeds are those that spread throughout native bushland and are outside their normal geographic range (Figure 25). Declared weeds are those declared under the *Agriculture and Related Resources Protection Act 1976* and are serious weeds in agriculture (Keighery, 2002). Under powers conferred upon local government by the *Agriculture and Related Resources Protection Act 1976,* some local governments are developing local laws listing pest plant species within their district that need to be eradicated, which may include both declared and environmental weed species. Weeds are widespread throughout the Park and a *Weed Control and Revegetation Plan (2002*) has been developed.

Figure 25. Caltrop (*Tribulus terrestris*) is a weed commonly seen around Perth Metropolitan area after summer rain. They are a hazard to picnickers, cyclists and to those in wheelchairs - easily puncturing tyres. Seeds are dispersed by being caught in the tread of footwear and tyres of bikes (Identification and description by Sandy Lloyd, Department of Agriculture) (Photo by Gary Tate).

Although some weeds are utilised by native fauna, interactions are not well understood and more investigations are needed (Lawrie, 2002). For example, *Typha orientalis* is a highly invasive emergent species, often out-competing the local native species such as, *Baumea sp.* and *Schoenoplectus sp.* However, Typha provides good nesting, shelter and protection for birdlife at wetlands, and is used by aquatic invertebrates. Prior to the removal of weeds, Laurie (2002) proposes that an audit be undertaken in recognition of fauna use, to prevent detrimental impacts on faunal populations. Weed management should be considered as a long-term process rather than a single event.

Recent areas targeted for weed control include North Lake Joondalup, Luisini Winery, Kingsley foreshore, old Trandos property, Woodvale waters, Duffy Terrace, along Whitfords Ave and Wanneroo Road. Previously a large stand of Giant reed (*Arundo donax*) was removed behind the Wanneroo Recreation Centre with successful revegetation having occurred here.

Weeding and revegetation should continue to follow the Weed Control and Revegetation Priority Plans in the DEC's *Weed Control and Revegetation Plan (2002)* and link with the City of Joondalup's *Lake Goollelal Management and Implementation Plan (1998).* Weed control is an on-going activity and is undertaken by the Friends of Yellagonga, the two Cities and the DEC. Hand-removal and herbicides are the primary techniques used for weed control.

The Friends of Yellagonga have a nursery located at Landsdale Farm School and grow seedlings for use in revegetation works in Yellagonga and for other Friends groups throughout the metropolitan area. Seeds and cuttings are collected from each area to ensure endemism and provenance is maintained (FOY website 03/09/2008).

Community education programs should be developed on environmentally sound landscaping, for example, growing native vegetation in gardens can help address issues of growing highly invasive species near the Park. Weed management in the Park and the surrounding catchment requires a long-term commitment and a strategic approach and is intimately linked to revegetation programs.

7.3 Inappropriate Fire Regimes

Fire is as much part of natural processes acting on Australian forest environments today as it was in the past, evidenced from carbon dating and the physical characteristics of native plants we see today to resist or respond to fire (Underwood and Christensen, 1981). Fire intensity is considered to have the most significant impacts on native vegetation and is usually a function of fire frequency, for example, long periods between fires tends to allow accumulation of fuel loads resulting in higher intensity fires; whereas more frequent burns results in lower fuel loads and less intense fires (Underwood and Christensen, 1981).

Inappropriate fire regimes can have dramatic changes on an ecosystem, with effects exaggerated in fragmented environments. Fauna have no-where to escape the effects of fire, with loss of life and habitat, increasing their vulnerability to predation and decline. Past practices from Aboriginal burning may not have produced marked changes to ecosystem composition around wetlands (e.g. Bickford and Gell, 2005), however today, weed invasion post-fire is an ongoing issue for the Park. Fire also affects soil, which in turn may impact on water quality in wetlands (Figure 26). Battle (2003) found under experimental conditions, water exposed to burnt soil resulted in elevated pH, alkalinity, Dissolved Organic Carbon, ammonium and Soluble Reactive Phosphate concentrations. Combinations of these physico-chemical parameters were found at elevated levels when investigated *in situ.* However, this may not be the case for wetlands on the Gnangara Mound and their organic-rich, pyritic soils, where fire causes oxidisation of the iron sulphides in soil causing acidic conditions. Horwitz *et al.,* (2007) monitored surface and groundwater post-fire at three wetlands on the Gnangara Mound. Post-fire monitoring of groundwater revealed a decline in pH downstream of the fire compared to sites above the fire-affected area. However, while one wetland revealed a significant pH decline (acid conditions), one wetland remained neutral, indicating that buffering at some wetlands was able to attenuate acids produced as a result of the interaction of fire with soil constituents. Surface water chemistry response to fire appears to be more variable. Horwitz *et al.,* (2007) considered the patchy response to fire is likely due to localised differences in physico-chemical and microbial characteristics of the soil. However, if acidification of water does occur, it will result in significant changes in a wetland. Effects include: low nutrients and metal toxicity, precipitation of humic substances leading to water clarity, thus exposing the wetland to greater penetration of UV radiation. These changes will lead to loss of sensitive invertebrate fauna (and likely vertebrate fauna), altering the ecology of wetlands (Horwitz *et al.,*2003).

Effects of fire also occur at a physical level resulting in loss and damage to soil. This is evidenced as exposure of plant roots, cracked soil, remnant pedestals consisting of plant root and minimal remaining soil surrounding the root, and burnt, shallow organic soils at the margins of the wetland (Horwitz *et al.,* 2003). In addition, Horwitz *et al.,* (2003) hypothesise organic-rich soils maintain moist microclimates, lessening the effects of seasonal drying and that inappropriate fire regimes will destroy these refuges.

Figure 26. Inappropriate fire regimes threaten the biodiversity in Yellagonga Regional Park (Photo by Gary Tate).

Some fire-fighting practices can also impact on water quality. Use of fire retardant in ephemeral wetlands is predicted to cause a significant increase in trophic status including changes in water clarity with effects lasting longer than two hydrological cycles, thereby compromising ecological integrity of these systems (Angeler and Moreno, 2006). Foam is used to control some fires in the Park, for example a smouldering log or to assist with wildfires; its use is regulated and controlled by the DEC, with water being the predominant fire-suppressing agent used (J. Haddon, pers. com., 19th August, 2008).

The Park experienced two significant wild fires in 2007 (in March and November) with many smaller arson attacks occurring throughout the Park on an ongoing basis (M. Teraci and J. Haddon pers. com., 19th August, 2008). From the beginning of 2007 to August 2008, there have been at least 60 or more arson attacks in the Park, with the majority of these involving trees, scrub and grassland and to a lesser extent, rubbish fires (Fire Investigation and Analysis Unit, FESA data base accessed 19th August, 2008).

A Fire Management Plan has been implemented for the Park (DEC) and is periodically up-dated. As part of fire management in the Park, the DEC carry out pre-suppression activities, which is an ongoing works program for the Park to reduce fuel loads. This includes slashing, pruning and brush-cutting to maintain fire breaks and weed control. Firebreaks and vehicle tracks have been installed in the park, but after fire suppression activities, vehicle tracks require rehabilitation. Weed control is also a necessary part of fire control activity and is ongoing in the Park by Friends of Yellagonga, the Cities of Joondalup and Wanneroo, and the DEC. However, fire awareness and community education are key to minimising inappropriate fire regimes in the Park and catchment.

7.4 Dieback (*Phytophthora cinnamomi*) and other diseases

Dieback is a disease caused by the introduced soil-borne water mould *Phytophthora cinnamomi* and destroys many Australian native plant species in forests, woodlands and heathlands. *Phytophthora* is listed as a key threatening process to Australian biodiversity under the *Environment Protection and Biodiversity Conservation Act (1999)* (Vear and Dell, 2004). The pathogen is spread mostly by human activity and by water movement, and at present, there is no means to eradicate the pathogen. Control of *Phytophthora* is effected by limiting its spread, utilising various methods that prevent the transfer of soil particles, for example washing / scraping hiking boots, camping gear, vehicle tyres and using dedicated wash-bay facilities.

A number of plant species have been identified in the Park as being susceptible to *Phytophthora* dieback including Jarrah (*Eucalyptus marginata*), *Banksia* sp. and Grasstrees (*Xanthorrhoea sp.*) (Yellagonga Regional Park Management Plan, 2003-2013). Currently, no *Phytophthora* surveys have been conducted in the Park and so its presence or distribution is not known. There is concern there could be an impact on revegetation programs if susceptible species are planted in great numbers (Yellagonga Regional Park Management Plan, 2003-2013). All plants and soils brought into the Park should come from accredited nurseries, such as those that have Nursery Industry Association Accreditation and certified as being free of *Phytophthora* (see Kilgour, 1999). In addition, all planting programs should scrutinise seedlings for the presence of plant disease prior to planting, to reduce the likelihood of plant pathogens being brought / spread in the park.

Recent reports in the West Australian (Thomson, Friday July 4th 2008), have highlighted concerns of the poor health status of native vegetation throughout the Southwest and wheatbelt area of Western Australia. Some trees are being injected with doses of vitamins and minerals, as well as phosphite, a fungicide, to help protect and boost the trees immune response. The cause of decline is not known and current remedies only an interim strategy. Any flora surveys undertaken in the Park and the surrounding catchment should include assessment of health status of vegetation to enable appropriate action to ensure effective management.

7.5 Acid sulphate soils

Acid sulfate soils (ASS) are found naturally in the environment and are common around coastal areas, although they do occur inland. Coastal ASS are the result of historic sea level rises, in particular sea level rises during the Holocene (within the last 10,000 years), where sulfate in the seawater mixed with land sediments containing iron-oxides and organic matter forming extensive areas of iron sulfides. When these iron-sulfide rich soils and sediments come into contact with air (for example, through dewatering, excavation, lowered water table etc), the iron sulfides react with water and oxygen to form iron compounds and sulfuric acid (DEC, Fact Sheet 1).

In Western Australia, ASS typically occurs in water-logged conditions with soil types that include peat, pale grey Bassendean / Spearwood sands, or coffee rock and also in dark organic rich soils / muds. ASS soil maps produced by the DEC and the Department of

Planning and infrastructure (DPI) are based on geology, depth to groundwater and *in situ* investigations. The maps are a guide to the distribution of ASS in Western Australia and are available from the Western Australian Planning Commission's Planning Bulletin 64 (DEC, Fact Sheet 3). It is important to note, that the ASS risk maps only give a broad-scale indication of the areas where ASS are most likely to exist and that they are not intended to give site specific ASS information (i.e. they are to be used at the scale intended). The maps should be used to indicate the need for further site-specific investigations and management strategies for ASS soil disturbance and/or lowering of the water table (DEC, 2008). Acid sulfate soils may exist as '*potential* ASS' which are ASS that have not been disturbed or exposed to air (not oxidised) or may exist as '*actual* ASS' where soils have been disturbed or exposed to oxygen and therefore have become acidic, typically at pH < 3.5.

Disturbance of ASS results in acidification of surface waters, groundwater aquifers and the soil. Acidification enhances the mobility of metals (Van der Welle *et al.,* 2007), in particular, aluminium and arsenic, which are highly toxic to wetland flora and fauna with potential impacts on human health. Acidic conditions in surface and groundwater can cause damage to infrastructure such as retaining walls or boardwalks, and to private dwellings with death of aquatic organisms in acidified wetlands. Disturbed ASS sites are recognised and addressed under the *Contaminated Sites Act (2003).*

Soils of the Park and catchment are described as Potential Acid Sulphate Soils, with soils around the Park predicted to be Class 1 'High Risk ASS' occurring within 3 m of the soil surface. Some ground-truthing for ASS is occurring. Some surveys have occurred on an–as-needs basis for development proposals on privately owned land within the Park. As part of the Gnangara Sustainability Strategy investigations, the DEC and DPI have recently monitored acidity in the soils and ground water in a number of locations between the wetlands of the Gnangara Mound and the dunes east of them. The results of the monitoring are not yet known (E-bulletin for the Gnangara Sustainability Strategy, Jan 2009). Ground-truthing in the Yellagonga catchment is set to occur by June 2009 as part of the DEC's ASS mapping program.

7.6 Fragmentation and Loss of Habitat

The impacts of urbanisation on natural habitat are diverse and complex. On the Swan Coastal Plain, much of the natural landscape has been cleared for urban development with natural habitat, including wetlands, now existing as small islands in a sea of urbanisation. The Park is bisected by Ocean Reef Road and Whitfords Avenue and exists as three fragments of natural habitat. While the terrestrial buffer for the most part is greater than 100m, much of this is highly altered with large areas dedicated to grassed parkland. The provision of adequate terrestrial buffers of natural vegetation is vital for overall health and functioning of wetland ecology.

Edge is a zone of influence on a habitat (Noss and Csuti, 1997) and if physical changes (such as changes in sunlight, wind, moisture or temperature) penetrate even up to 100m into a habitat, then this would be considered 'edge' (Freidenburg, 1998). The effects of 'edge' on a habitat, particularly on small habitat, have many detrimental impacts on the flora and fauna within the habitat such as drying of the soil, easy penetration of predators and weed invasions. As terrestrial buffers are now restricted for many of the wetland habitats on the Swan Coastal Plain, most of these urban wetlands would be considered all 'edge' and edge effects are a key issue for the Park. While changes occur to a patch through the effects of physical changes, fragment size and isolation also contributes to local extinctions (Freidenburg, 1998). Additionally, the surrounding landscape matrix and fire regimes are linked to persistence of native plant populations with urbanisation increasing extinction risk (Williams *et al.,* 2006).

The three fragments of the Park are surrounded by roads and urbanisation, resulting in limited or no provision for terrestrial animals to disperse between habitats, restricting contributions into the gene pool or 'rescue' for declining populations (Noss and Csuti, 199). Wide-ranging animals are those that are typically vulnerable as fragmentation often results in smaller habitats that cannot provide for all their needs, and these animals are the ones killed as they attempt to cross roads seeking alternative habitat (Noss and Csuti, 1997). For example, attempts by the Western Grey Kangaroo (*Macropus fuliginosus*) or snakes, such as Dugites (*Pseudonaja affinis*) – are unlikely to be successful. Kangaroos are often seen killed on Ocean Reef Road.

For other animals, such as freshwater turtles, which leave the water to nest, if inadequate terrestrial buffers surround the wetland, roads present as treacherous barriers as they attempt to cross for nesting activities (with increased mortality or injury) (Figure 27). Roads and traffic density / speed has been proposed to significantly affect population sex ratios in urban turtle populations (Giles *et al.,* 2008). For some amphibian populations, roads have resulted in reduced abundance and diversity at wetlands with the effects of adjacent land use impacting on amphibian abundances up to 200m away and effects on diversity revealed even up to 3000m from the waters edge (Houlahan, 2003). The development and implementation of a strategy to minimise wildlife deaths on roads surrounding the park was given high priority in the Yellagonga Regional Management Plan 2003-2013.

Figure 27. Turtles attempting to cross roads, can be hampered by kerbing (Photo by Gary Tate).

The Gnangara Sustainability Strategy, a multi-government initiative researching and developing a plan for the sustainable use of the Gnangara Mound, have investigated the dedication of habitat patches across the Swan Coastal Plain for large scale ecological linkages to enable movement of wildlife. On a smaller scale, linkages through low-use dry parks in the catchment, as well as viable habitat, may enable movements by terrestrial fauna over larger areas. However, usefulness of ecological linkages is not entirely known or accepted, and should be viewed as only one part of a larger conservation program (Hobbs, 1997).

Proximity of urbanisation to natural habitat can present further impacts, for example, lighting. Lights are known attractants for adult midge, which reach nuisance densities for local residents. Further, short wavelength, low intensity lighting has been shown to cause misorientation in some marine turtle hatchlings (Pendoley, 2005). Given similarities in habitat preferences of the Flatback turtle (*Nattator depressus*) and the Oblong turtle (both animals live in turbid, coloured waters with similarities in light attenuation characteristics under these conditions), urban lighting may cause misorientation in freshwater turtle hatchlings also, affecting their ability to migrate to waterbodies.

High pressure sodium vapour lights are used for some road lighting (in City of Wanneroo they are used along main roads and intersections) and are considered to have less disruptive impact on turtle orientation than mercury vapour, metal halide or fluorescent lights (see Pendoley, 2005). Whilst the City of Wanneroo are currently phasing out mercury vapour lights, replacement metal halides also emit high concentrations of short wavelength light which are implicated in misorientation of turtle hatchlings and are highly attractive to adult midges.

7.7 Climate Change

The effects predicted to occur on inland aquatic environments as a result of climate change are varied and numerous, and some of these changes have already been covered in previous sections (for example, declining water levels). Climate change is predicted to alter abundance, diversity and distributions of aquatic biota such as diatoms and invertebrates, with warming proposed to lead to increases in growth and reproductive rates and changes to inter-specific relationships (for example, predator / prey relationships) in zooplankton (Schindler, 2001). Higher order animal groups are also experiencing changes in species diversity and abundances. Severe declines have been observed in once common species, for some northern hemisphere amphibian populations, where desiccation of ponds and warmer temperatures are now being experienced (McMenamin *et al.,* 2008). Warming is also predicted to promote greater invasions of exotic fauna into aquatic environments (Schindler, 2001). Climate change is predicted to result in reduced water quality due to concentration of pollutants as water levels decline with the mobilisation of some heavy metals as they become more volatile under warmer conditions (Schindler, 2001; Swichtenberg, 2002).

In the fossil charcoal and pollen records, community shifts in terrestrial vegetation were dynamic as vegetation altered in response to drying or wetter conditions, occurring over centuries, and involved replacement of one native species with another native species (Bickford and Gell, 2005). Bickford and Gell (2005) consider changes seen today from recent human disturbances are not part of a natural continuum of environmental change and adaptation by ecosystems, as we attempt to replace one ecosystem with another. In response to climate change, vegetation is predicted to contract to refuge sites, with loss of sensitive species and replacement by more tolerant species resulting in changed ecosystem function (Wolf *et al.,* 2008).

The Indian Ocean Climate Initiative (IOCI) have completed 10 years (stage 1 and 2) of research to understand, interpret and forecast the effects of oceanic and atmospheric systems influencing climate of the Southwest region of Western Australia. This research has highlighted the need to adapt management of both land and water resources to a changing climate with a greatly reduced rainfall for the region (Ryan and Hope, 2006).

7.8 Introduced Animals

Occasional sightings of foxes are made in the vicinity of and within the Park along with rabbits and wild cats (Yellagonga Regional Park Management Plan, 2003-2013). The European red fox (*Vulpes vulpes*) is a non-selective feeder and survives well in a fragmented environment, and particularly well in urban environments (Saunders *et al.,* 1995). In Perth urban wetlands, the species has been implicated in the lack of and reduced recruitment of Oblong Turtles (*Chelodina oblonga*) into some urban wetlands due to significant numbers of depredated turtle nests observed (Giles *et al.,* 2008).

While the fox is a declared animal and must be controlled by the land-owner or a local government under the *Agriculture and Related Resources Protection Act 1976,* they need to be removed simultaneously with cats and rabbits. Although foxes and cats are non-selective feeders, both prefer rabbits. Foxes appear to exert some predatory / competitive control over wild cats and, if only foxes are removed, wild cats will slip into this ecological niche (Risbey, 2000). Quite apart from their introduced status, the interconnectivity between all three species drives the need for simultaneous control.

Whether cats are domestic, strays or wild, all take native fauna. Risbey (2000) found prey selection was similar between strays and wild cats, with the order of preference being:

1. Mammals
2. Invertebrates
3. Birds
4. Reptiles

Domestic cats are no exception. In a study of wildlife shelters in the eastern states from June 1987 to June 1992, Dowling *et al.,* (1994) found that of cats, dogs and foxes; cats were responsible for 75% of admissions of wildlife to shelters, with 97 native species involved. Similar trends were found to Risbeys (2000) work, with 61 percent of the 97 species being mammalian, 38 percent birds, and 1 percent reptiles. More than half the animals delivered to the animal shelters were from attacks in the metropolitan area with the majority (66.6 percent) of the animals attacked by cats, dying after admission (49 percent requiring euthanasia and 51 percent dying as a result of injuries sustained). Most died within 24 hours of admission.

While some responsible cat owners have placed bells around the necks of their cats in an attempt to thwart predatory attempts, bell-wearing has been found of little use, with similar proportions of cats with bells preying on wildlife to those without bells (Paton, 1991). While cats are popular companion animals, education and responsible pet ownership, are key to reducing impacts on native fauna (Figure 28). Community education on the adverse effects of pets and introduced animals on native fauna was given a high priority rating in the Yellagonga Regional Park Management Plan 2003-2013, however, this has not yet occurred.

In addition to the predatory effects of wild cats on native fauna, recent investigations by Adams (2003) have revealed that wild cats carry an array of parasites. For example, Toxoplasmosis (from the protozoan *Toxoplasma gondii*), with many of these potentially impacting the viability of native mammalian fauna populations, with predicted devastating effects particularly for small populations that exist within the fragmented landscape.

Figure 28. Cat at Lake Goollelal. Whether they are domestic, stray or wild, all will prey on native wildlife, threatening the biodiversity in Yellagonga Regional Park (Photo by Gary Tate).

Unleashed dogs chase and disturb wildlife and can upset other park users as they may present as a threat, or nuisance to those walking their own, leashed dogs, or to cyclists on dual-use pathways. A recent case study of dog walkers in Perry's Paddock in The Park was undertaken as part of a larger study for the National Sustainable Tourism (CRC funded) (Hughes, 2007). The project was aimed at enhancing the role of important communications in order to manage visitors in protected areas. Hughes (2007) believes that visitor impacts in protected areas, can be minimised by developing and delivering communications based on visitor beliefs associated with walking dogs on a lead, for example, signage related to peer group expectations.

No dedicated areas are available to dog owners to allow dogs to run off their leads in the Park, contributing to the issue. The Yellagonga Regional Park Management Plan 2003-2013 has a medium priority strategy to review the current gazetted dog exercise areas, with a high priority given to exclude dogs and other pets from the lakes and wetlands of the Park. This review and exclusion has not yet occurred.

Other introduced animals in the Park include the European honey-bee (*Apis mellifera*), the Silver Gull (*Larus novaehollandiae*), Pigeons (Family – Columbidae) and Geese (Family – Anatidae). It is also likely, the Argentine Ant (*Linepithema humile*) may still be present. The European honey-bee was introduced into Western Australia around the mid 1800's and provides an important service pollinating crops for agricultural and horticultural industries today. However, in recent times, many domestic bees have been swarming to start new colonies in natural habitats, such as tree hollows or other suitable nesting sites, reverting to their wild type, which is more aggressive than the domestic bee (Allan, 2000). The European honey-bee is present within the Park with detrimental effects predicted for native flora and fauna within the Park (Yellagonga Regional Park Management Plan, 2003-2013) (Figure 29). Wild bee control is undertaken by the DEC and pigeon control has been undertaken by City of Joondalup on an 'as-needs' basis.

Figure 29. The European honey-bee (*Apis mellifera*), forming wild colonies in the woodlands of Yellagonga Regional Park. Wild bee colonies take over tree hollows, preventing use by native bird species that require tree hollows for nesting during spring (Photo by Gary Tate).

The Department of Agriculture and Food, Western Australia has attempted to eradicate the Argentine ant (*Linepithema humile*), which is an ecological pest. The species is still found widely throughout the Perth metropolitan area, nesting outside buildings, in lawns, or moist low-lying areas and at the base or within trees (Davis and Widmer, 2006).

While no surveys have been conducted for this species within the Park, it is highly likely it is present. The Argentine ant is of concern for the fauna of the Park as they will attack nesting birds and chicks, hatching eggs and other native fauna such as frogs (Davis and Widmer, 2006), including *C. oblonga* turtle hatchlings (pers. obs., 2008). Given the vast area ant nests can occur across, and their interconnectedness (Davis and Widmer, 2006), identification of their distribution throughout the catchment and their control requires a co-ordinated effort by local community, local government and state authorities.

The other introduced animal predicted to have devastating impacts on Western Australian wetlands is the Cane toad (*Bufo marinus*), which is predicted to cross the Western Australia from the Northern Territory by the 2008 / 2009 wet season (P.Mawson, DEC, pers.com., 2008). Under the *Agriculture and Related Resources Protection Act 1976*, Cane toads are a declared animal and nominated by the Invasive

Species Specialist Group of the IUCN (The World Conservation Union) as being one of the 100 "Worlds Worst" invaders (Martin and Massam, 2005).

Cane toads are non-selective feeders, feeding on invertebrates and out-competing local native aquatic species and are highly toxic to many animals, including their eggs and tadpoles. Domestic pets such as dogs and cats, attempting to bite or ingest the animals, are also susceptible (Gray and Massam, 2007). It is predicted that Cane toads will migrate to the southwest of Western Australia and will devastate communities and threaten biodiversity from the Kimberley to Esperance (Guého, 2004). While there is no urgency to address Cane toads in Yellagonga in the life-time of this plan, forward planning and control strategies are required prior to this animal reaching Perth.

The *Regional Parks Pest and Problem Animal Control Plan (DEC, 2006)* recommends control methods for major pest and problem animals (which may or may not be native). Undertaking regular introduced animal control in the Park may have benefits for the control of midges given the amount of fox depredation of turtle nests (turtle hatchlings are important predators of midge and mosquito larvae). The issue of foxes rabbits and cats must be addressed across the whole of the Swan Coastal Plain supported at State Government level.

7.9 Vandalism and Rubbish dumping

Largely, the Park has been left to the community to utilise and behave appropriately within. However, while the majority of people recreate within the values of the Park, there are some who despoil the Park with graffiti, dumping of rubbish and other forms of vandalism occurring on a regular basis. The DEC engage the services of a contractor to remove graffiti from pathways, buildings and viewing platforms throughout the Park and have an ongoing rubbish removal program (Figures 30 and 31).

Figure 30. Graffiti at Lake Goollelal. Graffitti in the Park is an on-going problem and costs thousands of dollars each year to remove (Photo by Gary Tate).

Figure 31. Rubbish dumped in Yellagonga Regional Park is unsightly and hazardous to park users and wildlife (Photo's by Gary Tate).

Measures have been taken to restrict access to sensitive areas in the Park. Fencing has been installed around the Church Street drain which is currently being revegetated, as well as fencing installed around Trandos property. Bollards have been installed along Goollelal Drive, Kingsley.

A key strategy to reduce negative human impacts in the Park is to foster ownership through community education and programs that highlight the values of the Park (Figure 32). The DEC currently has a Communication Plan promoting visitor use and activities consistent with protecting the Park values. The DEC have also developed a 'Parks for People' – Interpretation Plan for Yellagonga Regional Park (2002)(DEC) which promotes visitor enjoyment and the benefits that are obtained from Parks generally.

Community ownership can be further encouraged through activities such as bus tours highlighting threats, issues, and values in the Park, or installation of more interpretative signage. Other tours maybe similar to those run by the Mindarie Regional Council which have Earth Carers educating the public on "Living with less waste" and highlighting waste disposal, providing strategies to minimise household rubbish. Other programs such as "Adopt a Bushland" encourage school children to look after and learn about caring for Bushland areas,

Figure 32. Viewing platforms, such as the one in Neil Hawkins Park, enhances visitor appreciation of the Park and its wildlife (Photo by Gary Tate).

7.10 Lack of Resources for Effective Management

The Yellagonga Regional Park Management Plan 2003-2013, is a strategic plan to enable "…protection and enhancement of the conservation, recreation and landscape values of the Park". The Department of Environment and Conservation have a responsibility to manage areas of regional parks that are vested in the Conservation Commission of Western Australia, which includes overall responsibility to co-ordinate management of Yellagonga Regional Park (Yellagonga Regional Park Management Plan 2003-2013).

While the DEC accepts its management responsibility, lack of resources presents as a direct threat to undertake required programs necessary to ensure principal management directions, including realisation of the vision and goal for the Park, is achieved. A key role at the local government level, is to strategically and effectively lobby the State Government to provide sufficient resources to the DEC to enable the Department to meet their vested responsibilities for the management of the Park.

8.0 Socio-economic Characteristics of the Yellagonga Catchment

8.1 Community Values

From the community workshop in September 2007 (L. Sands, unpublished summary 2007), the social and ecological values of the Park were rated as the most important to participants followed by the cultural, educational, recreational and historical values. Many local residents view the Park as a sanctuary for those living in the surrounding catchment as well as for the flora and fauna that survive in the Park. It is viewed as a place to relax and unwind, providing a 'sense of place' and a quality of life and aesthetics in an urban environment.

The Park is also a valuable resource for educational institutions including universities and primary schools. Scientific studies can and are being conducted there. The Park also provides less formal education opportunities, where people can learn about and develop an appreciation for Australian flora and fauna and their interactions. The Park is important as a place for recreation such as walking or cycling activities and family activities such as picnics. There is also a long and culturally significant Indigenous history and a colourful European history centred around the Yellagonga wetlands.

8.2 Aboriginal Heritage

8.2.1 Historical Background

Wetlands were, and continue to be, places of great spiritual connection for Aboriginal people in their relationship with the land, water and all living things. Of importance is the relationship between the *Waugal* and flowing water, which is not only a mix of mythical serpent, a totemic ancestor and a God, but it is also a relationship that emphasises the vital connection between running water and all life (in McGuire, 1996).

Wetlands of the Swan Coastal Plain were vital and important resources for the Aboriginal people. They provided a source of fresh drinking water (from soaks and freshwater springs) and, while they were a great source of animal protein such as turtles, crustaceans, amphibians, fish, waterbirds; the main part of the Aboriginal diet was comprised of carbohydrates from fruits, seeds, bulbs, corms and underground tubers and starch-filled stems or rhizomes. The most significant storable staples were the fruit of the Zamia Palm (*Macrozamia reidlei*) (Meagher, 1974; see McGuire, 1996).

Aboriginal women used sticks to dig the rhizomes from out of the ground (such as from *Typha domingensis* or yams *Dioscorea hastifolia*). It is thought, the name Wanneroo has come from the Aboriginal word 'Wanna' or 'Wonna' which referred to the digging stick, with 'roo' meaning 'the place of' (Daniel, 1979) (Figure 33).

Aboriginal populations appear to have been more concentrated around wetland areas rather than coastal areas, utilising wetlands on a seasonal basis, for example, wetlands were used during the summer months but during the winter months when it was more difficult to obtain food from the flooded wetland areas, Aboriginal groups moved inland to the Darling Scarp/ Plateau (see McGuire, 1996). Wetlands were important for Aboriginal society as access tracks, enabling connection between groups on the Swan Coastal Plain for trade and ceremonies (from Kauler, 1997-98; see McGuire, 1996). In the Park, several Aboriginal campsites have been identified (see Kauler, 1997-98). These campsites reveal the importance of the Yellagonga wetlands to the Aboriginal people over a very long period of time. Other Aboriginal sites include scarred trees. While none are currently listed to exist within the Park, several scarred trees exist in the Yellagonga catchment.

Lake Joondalup and the surrounding area (called "Joondal" meaning Gilgie – freshwater crayfish), is a sacred place because of its relationship with Nyitting (creation era) heroes. The island in Lake Joondalup, called Malup Island, is also sacred for the Aboriginal people who had declared this island an important drought refuge, where regular hunting and fishing had been forbidden (in Kauler, 1997-1998).

Today the Park is named after Yellagonga, the well-respected leader of the family group who occupied land north of the Swan River prior to European settlement. After conflict with early European settlers, Yellagonga and his group eventually retreated to Lake Joondalup (Brittain, 1990 quoted in The YRPMP, 2003-2013).

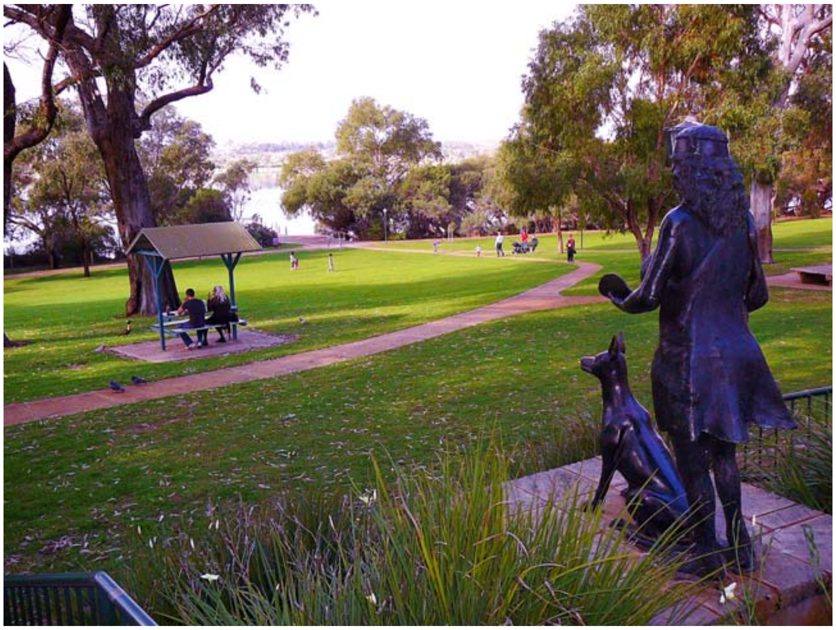

Figure 33. Yellagonga Regional Park is steeped in Aboriginal history. In commemoration of the long association that the Aboriginal people have had with the area, and in celebration of NAIDOC week, a bronzed statue was erected in Neil Hawkins Park in 1998. The statue is of a Bibulmun Yorga woman dressed in a kangaroo skin cloak. She is wearing a piece of material called a yagardi wrapped around her head, and is gathering food as she has a digging stick, and a wooden dish with her and is accompanied by her dog (Statue by the Aboriginal artist and national Aboriginal and Torres Strait artist of the year, Mr Ron Corbett, 1997) (Background information by Barbara Hellriegel, Reference and Local History Team Leader, Joondalup library) (Photo by Gary Tate).

8.2.2 Protection of Wetlands

Today, Aboriginal interests in the Park are protected under the *Native Title Act (1993)* and the *Aboriginal Heritage Act* (*1972*). The *Aboriginal Heritage Act* (*1972*) applies to places and objects of importance to Aboriginal people including those not yet listed. As wetlands were and still are, places of importance to the Aboriginal people, these wetlands are also protected under this Act and are listed Aboriginal sites. As noted by McGuire (1996), alterations to sites can occur either directly, such as draining or altering flow patterns of a water system, or they can be indirect, such as introduction of pollutants (which may be derived from catchment activities).

8.2.3 Today

It was suggested at the July 2008 Community Workshop, that more activities need to be held in the Park to engage local Aboriginal Communities. Proposed activities included celebrating "Sorry Day" or events including oral histories of the Park and cultural displays as well as more interpretative signage throughout the Park on Aboriginal history / significance of the area.

As part of highlighting some of the history of the area, the 28 km Yaberoo Budjara Heritage Trail is currently under improvement. This trail follows the journey of Yellagonga and his tribe's movements through the northern lakes chain between Lake Joondalup in the Park, passing through Neerabup National Park and finishing in Yanchep National Park. The trail was initially suggested by Mr R. Brittain and has been developed by the Heritage Council of WA, City of Wanneroo and the DEC. The trail is divided into five sections of which section two is now completed. Along the way, natural, Aboriginal and other historical features have been showcased (Heritage Council, 1998). This trail was also used as a stock route.

8.3 European Heritage

Daniel (1979) gives a comprehensive account of the European history of Wanneroo and is summarised as follows. In the early days of settlement of the Swan River Colony, Wanneroo was seen as the 'outer' region. The earliest documented foray north of Perth by a European was by John Butler in 1834, who led a small party of four men into the Wanneroo area east of Lake Joondalup searching for lost cattle. Not long after, Sir George Grey travelled north of the settlement to explore the area. Prior to settlement, the area became renowned for hunting and sporting activities. Hunting of kangaroos provided an important protein source for the early settlers in the area, however the city 'weekenders' were also accessing the area and hunting kangaroos to a point where numbers were so reduced there was a complaint delivered to local police in 1916.

European settlement finally spread out from central Perth to the Yellagonga Wetlands region to open up more fertile grounds for gardening and agriculture. The first land in the area was taken up on the southern shores of Lake Joondalup, in a partnership by Thomas Hester, George Hodges, James Dobbins and John Connelly in 1837-38. Other settlers to take up land initially also included William Rogers, Samuel Moore, George Shenton and James Cockman. The old Cockman homestead still exists today on the corner of Wanneroo Road and Woodvale Drive. Wanneroo was, and still is, an important food growing area and access to and from Wanneroo (to reach the markets) was a source of discontent for many years for local residents with a poorly constructed and maintained main road from Wanneroo to Perth city -Wanneroo Road.

Other historical European places and activities of interest included the establishment of the Wesleyan Mission Farm in 1844 on the eastern side of Lake Goollelal to teach Aboriginal children farming and agricultural skills. However, the project was not successful and was later abandoned and relocated to York (Kauler, 1997-98).

The wetlands later became an important watering hole for droving activities from 1850 (Brittain, 1990 quoted in the Yellagonga Regional Park Management Plan, 2003-2013; Hamann,1992), when cattle droving occurred to the north and northwest regions of the state. Slowly, modern services reached Wanneroo. In 1883, Wanneroo became a post town where mail was delivered on horseback, and a telephone system was installed in 1886.

The Italian history for Wanneroo has been well documented by Gava (1978, 1998). Wanneroo was one of the few areas in Western Australia where Italians settled in numbers. They consisted of northern and southern Italians with a range of occupations, in particular rural occupations. Most Italian migrants who came to Wanneroo, worked in market gardens and farms in the area. Integration was difficult because of language barriers, and also government regulations, which required sponsorship of new migrants. Generally, Italians sponsored Italians.

The earliest pioneer to have a continuous association with Wanneroo was Antonio Crisafulli (from 1912). He initially worked on George Leach's market garden before eventually setting himself up on his own property; he is listed as a landowner in the Wanneroo Rates Book from 1924. Crisafulli introduced the smooth-skinned tomato to Western Australia from seeds he had brought from Italy. This resulted in Wanneroo becoming the State's most important tomato-growing region. Similarly, the Vigneron Ezio Luisini, planted many acres of black Shiraz grapes and his vineyard became the largest in the state (Figure 34).

Other success stories included Tony Villanova, who built a general store in 1950, that he later expanded into 22 shops, becoming the modern "Villa" shopping Centre, which opened in 1969. However, for most Italians in Wanneroo, life was hard and successes few. Not least amongst hardships endured were those endured by the Italian women-folk, who often toiled in the market gardens, as well as caring for their families. One prominent name is that of Mrs Rosa Ariti, who was given the Shire of Wanneroo Jubilee key in 1975, to commemorate 50 years in Wanneroo.

The Italian influence from earlier times still remains today and names like Sinagra, Ariti, Conti, Luisini, Mobilia, Villanova, are still seen today with many of these family names as street names or landmark features revealing some of the diversity of the cultural heritage that has helped to shape the Wanneroo area.

Figure 34. Some of the European and Italian heritage in Yellagonga Regional Park. The remains of Perry's Cottage and stables in Perry's Paddock (left), and the former Luisini winery over-looking Lake Goollelal (right) (Photo's by Gary Tate).

8.4 Economic Values

The economic value of wetlands was not valued highly in the community workshop, however, a recent study by Tapsuwan *et al* (2007) identified and quantified, that proximity to a wetland and number and size of a wetland(s) increases the value of a property. The study highlighted the importance of managing groundwater abstraction, including abstraction for private, commercial or agriculture purposes, and the need to understand the economic implications associated with maintaining or losing wetland amenity in urban and peri-urban areas. The Tapsuwan *et al* (2007) study has links with the larger Gnangara Sustainability Strategy currently being undertaken.

Other economic considerations are the current commercial activities existing in the catchment. These include commerce areas, including the main light industrial area in Wangara. Unlike residential value, the value in commercial areas is not in the land so much as it is in the provision of a service and employment. Agricultural based industries for example market gardens and turf growing to the east of Wanneroo Road, have great economic value to Perth and the local area in the provision of fresh fruit and vegetables and, as they are locally–based, reduced transportation costs for distribution. In addition, there is potential for tourism / eco-tourism based industries to be developed based on the values of the Park.

9.0 Relevant Policy and Legislation

International

Legislation
Japan Australia Migratory Birds Agreement (Australia Treaty Series 1981 No.6) (JAMBA)
China Australia Birds Agreement (Australian Treaty Series 1988 No.22)(CAMBA)
Republic of Korea-Australia Migratory Bird Agreement 2007 (ROKAMBA)
The Convention on the Conservation of Migratory Species of Wild Animals or known as the 'Bonn Convention'

Federal

Legislation
Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act)
Threat Abatement Plan for Dieback caused by the root-rot fungus Phytophthora cinamomi
National Strategy for the Conservation of Australia's Biological Diversity
National Action Plan for Salinity and Water Quality 2000
National Greenhouse Strategy
National Local Government Biodiversity Strategy 1999
National Water Quality Management
National Framework for the Management and Monitoring of Australia's Native Vegetation (2000)
Towards Sustainability: Achieving Cleaner Production in Australia 1998
National Weeds Strategy: A strategic Approach to Weed Problems of National Significance
Endangered Species Protection Act 1992 – S.3 Threat Abatement Plan for Predation by Feral Cats

State

Agriculture and Related Resources Protection Act 1976
Environmental Protection Act 1986
Argentine Ant Act 1968
Biological Control Act 1986
Dog Act 1976
Health Act 1911
National Environment Protection Council (Western Australia) ACT 1996
Aboriginal Heritage Act 1972
Native Title (State Provisions) Act 1999
Parks and Reserves Act 1895
Soil and Land Conservation Act 1945
Wetland Conservation Policy 1997
Local Government Act 1995
Town Planning and Development Act 1928
Environment and Natural Resources Policy (State Planning Policy No.2)
Gnangara Groundwater Protection (State Planning Policy No. 2.2)
Planning and Development Act 2005
Water Resources (State Planning Policy 2.9)
Wildlife Conservation (Fauna Protection) Amendment Bill 2002
N.B. *(Proposed Biodiversity Conservation Act for Western Australia to replace Wildlife Conservation Act 1950)*

Regional

Environmental Weed Strategy for Western Australia (CALM 1999)
Bush Forever 2000. Department for Planning and Infrastructure
Perth Biodiversity Project –'Local Government Biodiversity Planning Guidelines for the Perth Metropolitan Region'.
Bushland Policy for the Perth Metropolitan Region (Planning Policy No. 2.8)

Local

Wetlands Protection Policy (being drafted) (CoW)
Draft Local Environmental Plan 2009-2014 (CoW)
Local Biodiversity Strategy (A draft for discussion) (CoW)
Smart Growth Strategy (CoW)
2003 Bushland Assessment
Yellagonga Regional Park- Weed Control and Revegetation Plan 2002
Animals Local Law 1999 *Animals (Amendment) Local Law 2006*
Landscape Enhancement Areas 1999
Tree Preservation Policy (CoW)
Biodiversity Action Plan 2009-2019 (CoJ)
Environment Plan 2007-2011 (CoJ)
Sustainability Policy (CoJ)
Stormwater Drainage Policy (CoJ)

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Appendix 1: Long term rainfall from Bureau of Meteorology, Perth.

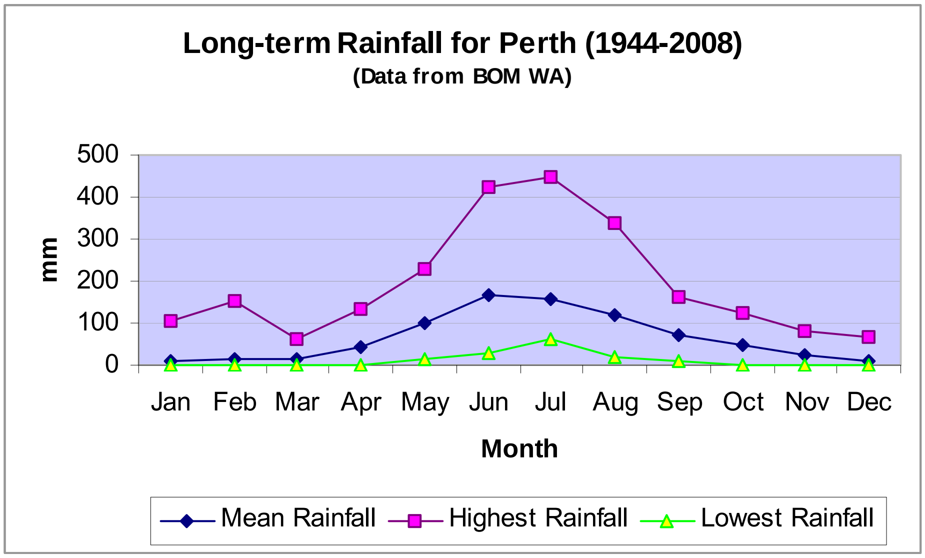
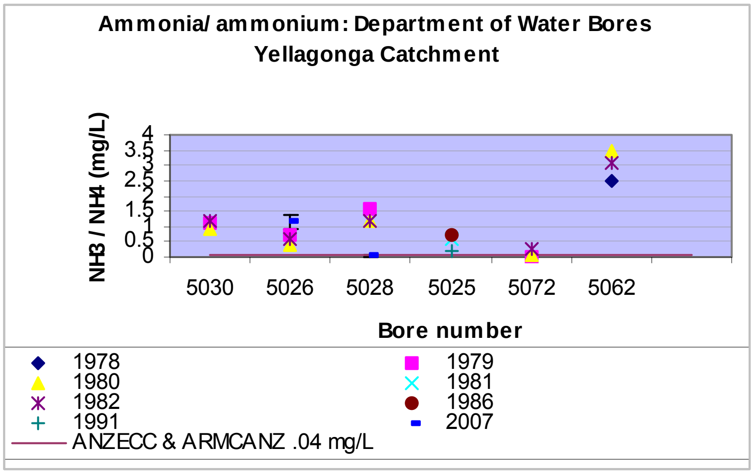
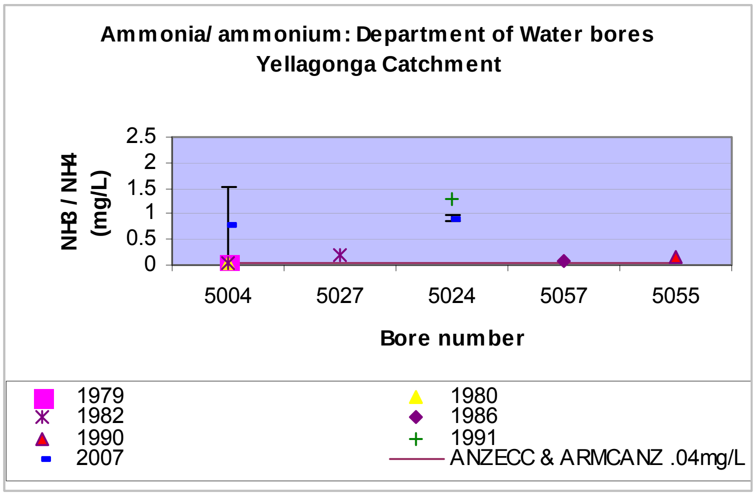


Figure A. Long-term rainfall averages are plotted (1944-2008) including maxima and minima of temperatures from the Perth weather station. Data obtained from the Bureau of Meteorology site.

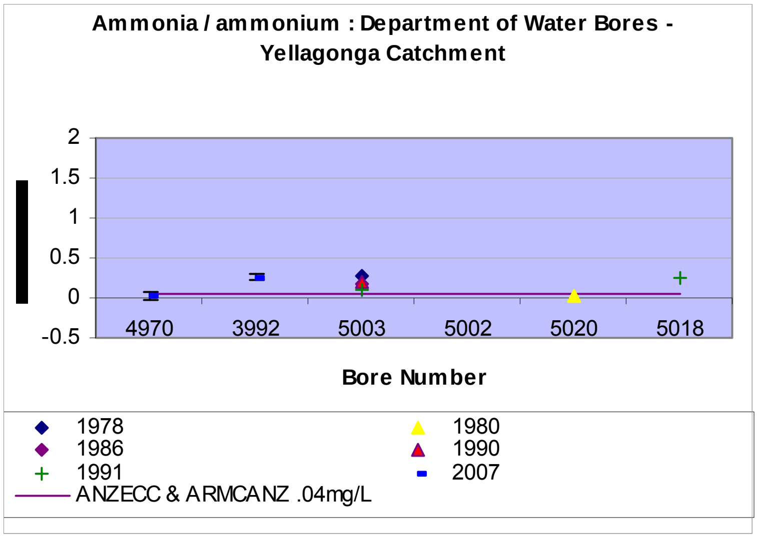
Appendix 2: Groundwater quality data from Department of Water bores east of Yellagonga Regional Park (Bore numbers are WIN site identification numbers)



A.)

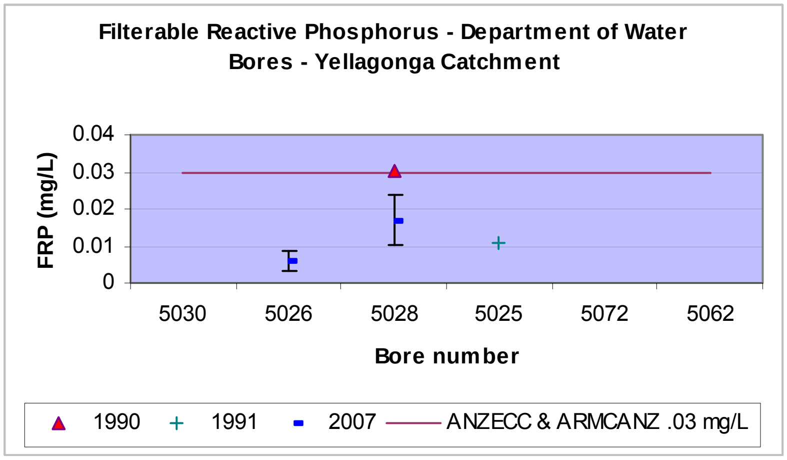


B.)

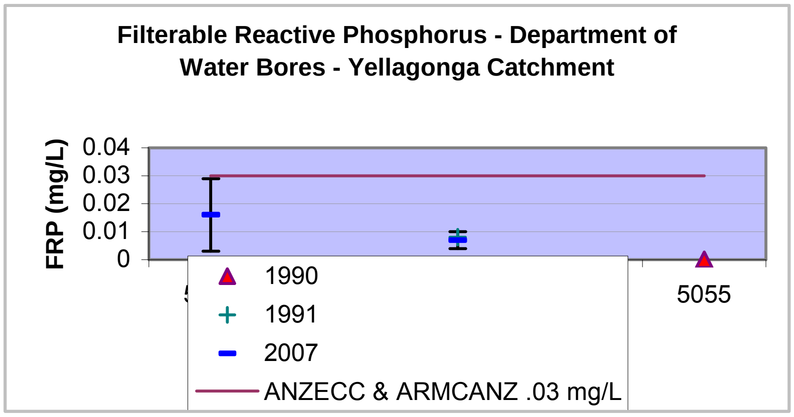


C.)

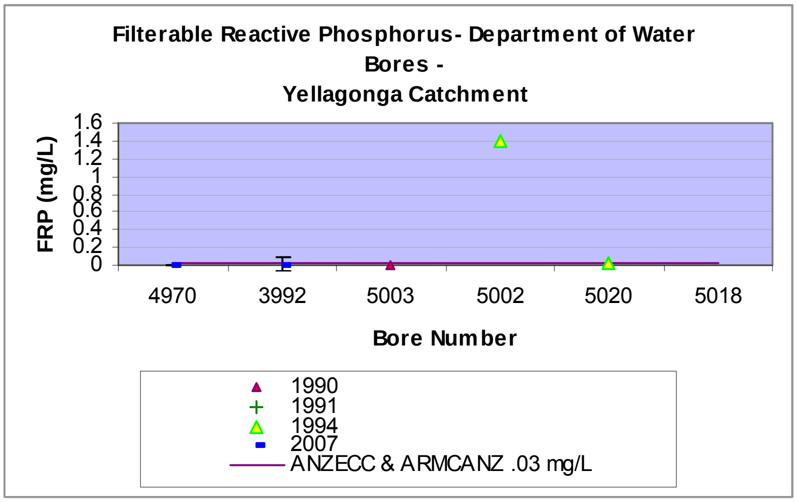
Figure A. Irregular water quality monitoring in Department of Water bores (A-C) from 1978 – 2007 revealed elevated NH_4^+ concentrations (bore numbers are oriented in a north-south direction and the graphs reveal data from east to west with the first graph near the horticultural areas, to midway way between, with the third graph at the eastern edge of Yellagonga wetlands).


Filterable Reactive Phosphorus - Department of Water Bores - Yellagonga Catchment
FRP (mg/L)
0.04
0.03
0.02
0.01
0
5030
5026
5028
5025
5072
5062
Bore number
1990
1991
2007
ANZECC & ARMCANZ .03 mg/L

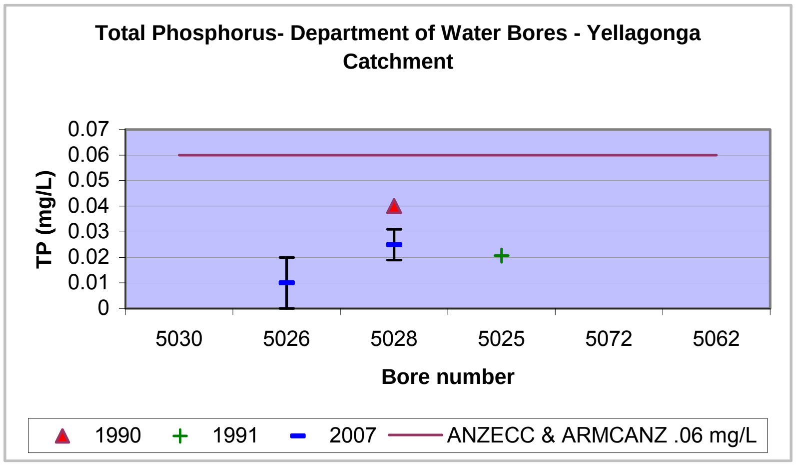
A.)


Filterable Reactive Phosphorus - Department of Water Bores - Yellagonga Catchment
FRP (mg/L)
0.04
0.03
0.02
0.01
0
5055
1990
1991
2007
ANZECC & ARMCANZ .03 mg/L

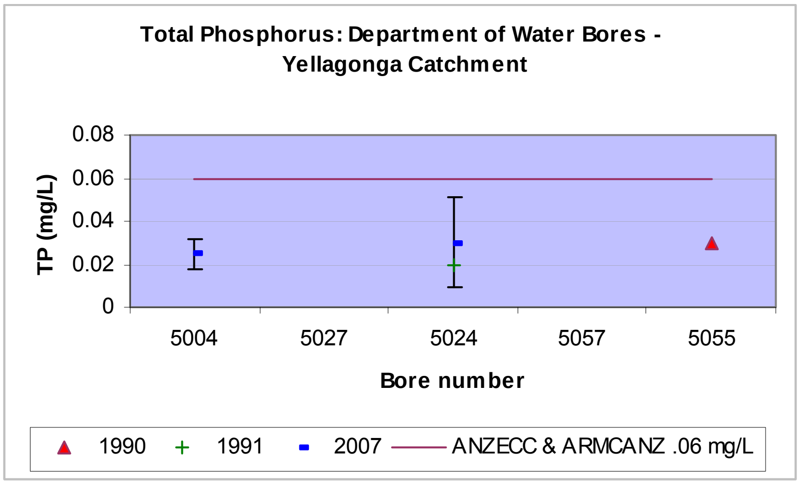
B.)


Filterable Reactive Phosphorus- Department of Water Bores - Yellagonga Catchment
FRP (mg/L)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
4970
3992
5003
5002
5020
5018
Bore Number
1990
1991
1994
2007
ANZECC & ARMCANZ .03 mg/L

C.)


Total Phosphorus- Department of Water Bores - Yellagonga Catchment
TP (mg/L)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
5030
5026
5028
5025
5072
5062
Bore number
1990
1991
2007
ANZECC & ARMCANZ .06 mg/L

D.)


Total Phosphorus: Department of Water Bores - Yellagonga Catchment
TP (mg/L)
0.08
0.06
0.04
0.02
0
5004
5027
5024
5057
5055
Bore number
1990
1991
2007
ANZECC & ARMCANZ .06 mg/L

E.)

F.)

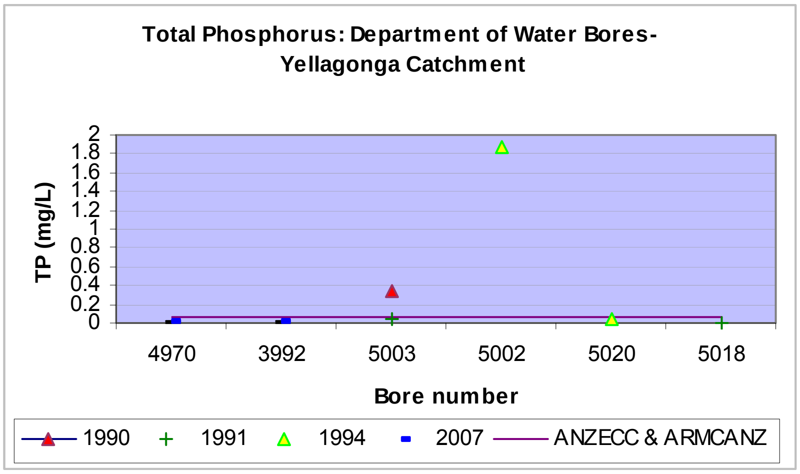


Figure B. Irregular water quality monitoring in Department of Water bores (A-F) from 1978 - 2007. While monitoring has occurred at irregular intervals, and not all sites had data available, there appears to be low Phosphorus concentrations travelling from east to west (i.e bore numbers are oriented in a north-south direction and the graphs reveal data from east to west with the first graph near the horticultural areas, to midway way between, with the third graph at the eastern edge of Yellagonga wetlands).

Total Phosphorus and FRP at bore number 5002 (near Neville Drive) recorded elevated concentrations of phosphorus.

Appendix 3: Drainage detail for drains surrounding Yellagonga Regional Park

Sub-catchment/Outfall/	CoJ/CoW	Equivalent Impervious Area (m2)	Sub-catchment Description & Location	Priority Ranked (1994 Ove Arup)	Priority Proposed by YICMP CRG/TWG	Original Drainage Outlet Type	Original Construction Year (Approx)	Upgraded	Future Works Proposed or Required	Pre/Post Upgrade Monitoring
1	CoW	44 800	Wanneroo Rd Pines		Low	Sump (no piped stormwater drain to sump)	1980		Dpt Main Rds planning to install sump for dual carriageway (2009?)	
2	CoW	14 500	Banyandah Blvd Sth /?Turnwood	16	Low	Piped & grated bubble-up pit	1974	**No upgrade**		
3	CoW	11 700	Banyandah Blvd Nth /? Wallawa	17	Low	Piped & grated bubble-up pit	1974	**No upgrade**		
4a	CoW	??8 640 combined 4a & 4b	Noel Crt	18	Low	Piped Outfall	1979	**No upgrade**		
4b	CoW		Toronto Pl	18	Low	Piped Outfall	1979	**No upgrade**		
5	CoW	3 520	Ottawa Way	20	Low	Piped Outfall	1979	Vegetated swale constructed at end of piped outfall (2006 - 2008)		
6	CoW	4 320	Neville Dve	19	Low	Piped Outfall & grated bubble-up pit	1979	?? Linked to same Vegetated swale constructed at end of piped outfall 5 (2006 - 2008)		
7	CoW	31 520	Christie Crt	10	Low	Piped Outfall	1979	**No upgrade**		
8	CoW	27 360	Dallas Cr	14	High	Piped Outfall	1979	**No upgrade**		
9	CoW	48 000	Church St	6	High	Piped Outfall	1975	Church St & Manbari Cr upgraded detention basin for Oufalls 9 & 10		
10	CoW	17 120	Manbari	15	Low	Piped Outfall	1974			
11	CoW	36 320	Mundaree Pl	9	High	Piped Outfall	1975	**No upgrade**		
12	CoW	57 920	Ariti Ave	4	Medium	Piped Outfall	1978	Constructed wetland & upstream detention basin (inc. bubble-up grates / ?G or S PTs)(2001/2002)		
13	CoW	42 240	San Rosa Rd		Low	Piped Outfall	1990	**No upgrade**		
14	CoW	54 560	Poinciana Pl		Low	two Piped outfalls	1986	**No upgrade**		

Sub-catchment/Outfall/	CoJ/CoW	Equivalent Impervious Area (m2)	Sub-catchment Description & Location	Priority Ranked (1994 Ove Arup)	Priority Proposed by YICMP CRG/TWG	Original Drainage Outlet Type	Original Construction Year (Approx)	Upgraded	Future Works Proposed or Required	Pre/Post Upgrade Monitoring
15	CoJ	69 930	Edgewater Drive		N/A	Sump	1976	No direct discharge and no works required. This sump is achieving its purpose	An upgrade is proposed in the future to improve bio filtration uptake through planting of suitable vegetation	
16	CoJ	54 940	Edgewater Drive		N/A	Sump	1976	No direct discharge and no works required. This sump is achieving its purpose	An upgrade is proposed in the future to improve bio filtration uptake through planting of suitable vegetation	
17	CoJ	27 980	Castlegate Way	13	N/A	Piped Outfall	1989	No direct discharge and no works required. This outfall was joined into the upgrade of Sump 30 and is working effectively.	An upgrade is proposed in the future to improve bio filtration uptake through planting of suitable vegetation	1
18	CoJ	65 760	Duffy Terrace	2	N/A	Piped Outfall	1983	Installed GPT - Cleansall CL750 HG 35A/40A 750mm with bubbleup units in August 2008		Contract to Bioscience issued for Water Quality monitoring from May 2008-April 2009
19	CoJ	82 400	Gollelal Drive	1	N/A	Piped Outfall	1978	Installed GPT - Cleansall CL750 HGA 45A1200mmwith bubble up units in August 2008		Contract to Bioscience issued for Water Quality monitoring from May 2008-April 2009
20	CoJ	30 560	Goollelal Drive	11	N/A	Grated bubble up pit		Installed GPT - Cleansall CL750 HG 24 600mm in August 2008		Contract to Bioscience issued for Water Quality monitoring from May 2008-April 2009
21	CoJ	45 760	Bindaree Tce	7		Grated bubble up pit	1975	2004 Installed GPT and percolations basins and swailes with vegetation for biological takeup. Pipe outfall dicsonnected. No		
22	CoJ / Water Corporation	64 160	Hepburn Ave	3	N/A	Piped Outfall	1975	Installed GPT - Cleansall CL750 HGA 45A1200mm August 2008		Contract to Bioscience issued for Water Quality monitoring from May 2008-April 2009
23	CoJ / CoW / MRWA	34 560	Kingsway Rd			Sump	1975	**No upgrade**		
24	CoJ	41 440	Lakeway Drive	8	N/A	Piped Outfall	1986	Installed GPT - Cleansall CL750 HG 27-30 600mm with bubble up units in August 2008		Contract to Bioscience issued for Water Quality monitoring from May 2008-April 2009

Sub-catchment/Outfall/	CoJ/CoW	Equivalent Impervious Area (m2)	Sub-catchment Description & Location	Priority Ranked (1994 Ove Arup)	Priority Proposed by YICMP CRG/TWG	Original Drainage Outlet Type	Original Construction Year (Approx)	Upgraded	Future Works Proposed or Required	Pre/Post Upgrade Monitoring
25	CoJ	55 200	Whitfords Ave	5	N/A	Piped Outfall	1991	Installed GPT - Cleansall CL750 HGAHG12 375mm with bubbleup units in August 2008		Contract to Bioscience issued for Water Quality monitoring from May 2008-April 2009
26	CoW	30 400	Lancaster Rd	12	Low	Piped Outfall & ?Basin	1975	landscaped compensation basin		
27	CoW	979 000	Wangara		High	Outfall & Sump (for industrial area)	1979	**No upgrade**		
28	CoW	55 200	Woodvale Dve		Low	?Sump / Wet Detention Basin - ?Sump with Spillway		**No upgrade**		
29	CoW	33 410	Ocean Rf Rd @ Perry's Paddock		Medium	Sump with spillway	1978	**No upgrade**		
30	CoJ		Castlegate Way		N/A	Sump		No upgrading required. No dircet discharge occurring sump is achieving its purpose.	An upgrade is proposed in the future to improve bio filtration uptake through planting of suitable vegetation	
31	CoJ	27 980	Edgewater Drive		N/A	?Sump or Swale with overflow		No upgrading required. No dircet discharge occurring sump is achieving its purpose.	An upgrade is proposed in the future to improve bio filtration uptake through planting of suitable vegetation	
32	CoW / CoJ	25 101	Hepburn Ave		Medium	Sump with high level overflow				
33	CoW/CoJ	85 300			Low	Sump		This sump was amalgamated with Sump 32.		
34	CoW		Regent Waters @ Studmaster Park		Low	Constructed Wetland-drainage to grd-water	??	**No upgrade**		

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