Framework for Developing the Jandakot Water Resources Management Strategy

December 2004

The Department of Environment

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# Framework for Developing the Jandakot Water Resources Management Strategy

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Executive Summary

In October 2001, the Western Australian Planning Commission released the draft Jandakot Structure Plan (JSP) which includes the localities of Oakford, Mandogalup, Casuarina, Wellard, Anketell, Wandi, Bertram, Oldbury and The Spectacles.

The area covered by the JSP was left without strategic planning direction following a decrease in the boundaries of the Jandakot Underground Water Pollution Control Area.

A key outcome of the JSP is the preparation of a Water Resources Management Strategy (WRMS) for the area.

Parsons Brinckerhoff were engaged to undertake the preparation of the WRMS for the JSP.

During the study it became apparent that an overall and comprehensive WRMS could not be completed, at this stage, due to a substantial gap in understanding of the water resources in the study area. Primarily, insufficient data exists to deliver a high quality WRMS with sufficient technical rigour to satisfy key government stakeholders.

This report summarises the completed work and recommends an outline for the preparation of a water resource management strategy (WRMS). It deals mainly with water quality issues. Water quantity will be addressed in a Stormwater Management Strategy and be dealt with as part of the preparation of the final WRMS that will be regional over the whole JSP area. In relation to water quality objectives, this report:

- Provides an overview of the nature of water bodies within the study area and those potentially affected by the development proposed in the JSP.
- Reviews available information on the quality of surface water and groundwater in the study area, as well as the water quality of receiving water bodies.
- Proposes water quality-related objectives that can be used immediately as ‘modelling objectives’ and/or ‘conceptual design objectives’ for stormwater management activities in the study area.
- Makes recommendations on future water quality monitoring activities (both pre- and post-development).

There are four aquifers of hydrogeological interest in the study area, collectively termed “Superficial Formations”. These are the Tamala Limestone, Bassendean Sand, Guildford Formation and the Gnangara Sand.

The southern flank of the Jandakot Mound is situated in the centre of the study area, protected by the Jandakot Mound Underground Water Pollution Control Area (UWPCA). Bassendean Sand largely underlies the mound.

Groundwater flow in the study area generally radiates from the centre of the mound to the east, south and west.
The number of existing groundwater monitoring bores in the study area is currently insufficient to accurately determine localised groundwater levels, enable groundwater modelling for base flow estimates or analyse existing groundwater quality conditions.

Installation of additional monitoring bores is required for:

- The assessment and modelling of groundwater level fluctuations over time to determine safe floor levels for development;
- The determination of hydrogeological parameters of proposed development sites, including local and regional groundwater flow directions, groundwater level fluctuations, likely impacts of development on groundwater dependant ecosystems, etc; and,
- The assessment of groundwater quality, including resident catchment and aquifer conditions, short-term mobilisation of nutrients and contaminants resulting from development works, long-term impacts on groundwater quality from development.

The dominant soils of the JSP study area are pale deep sands of the Bassendean Dune System which to the east are underlain by clayey soils of the Guildford Formation. On the eastern side of the study area soils of the Guildford Formation are near the surface. In the west there are significant areas of pale brown, yellow or orange Karrakatta or Cottesloe sands and also swamp deposits.

Three areas within the study area were chosen for soil nutrient analysis to assess the potential for release of phosphorus during earthworks or subdivisional construction. These locations were at the proposed Oakford Village, in Casuarina just east of the Kwinana Freeway and an area in Mandogalup and Anketell adjacent to the Kwinana Freeway.

Some of the samples (coffee rock) were consistent with exposure to significant inputs of phosphorous and it is likely that such material could present a risk of phosphorous release if disturbed. There are many sites throughout the study area where coffee rock has been encountered and further investigation should be carried out via a more extensive survey combined with detailed sampling and analysis of representative soil profiles.

In suburbs such as Mandogalup and Anketell, the Karrakatta, Cottesloe and swamp soils have been used for intensive horticulture. Soils have received extremely high fertiliser inputs and soil profiles may have very high concentrations of phosphorous.

A conceptual stormwater management strategy (Figure 6) has been developed for the study area. Local alterations to the regional water movement network may be considered by the Department of Environment, if they are consistent with the objectives and outcomes of the strategy.

Wetlands in the JSP area not only include lakes with open water but areas of seasonally, intermittently or permanently waterlogged soil. Because of the flat and low-lying nature of much of the JSP area, significant areas would originally have been classified as wetland. Rural and low-density urban developments in the area mean that few of the original wetlands retain significant ecological values. Regionally, only around 15% of the wetland area has retained high ecological values. These are conservation category wetlands and are listed in various publications.

Background on wetland classification and management requirements for wetlands of the Swan Coastal Plain together with commentary on its application for the study area is provided.
Government and industry stakeholder consultation was undertaken during the preparation of the Jandakot WRMS.

A data acquisition plan assigning tasks, responsibilities and timeframe for the collection of regional data necessary to undertake the preparation of a comprehensive WRMS for the JSP area has been recommended and is described in Section 8 of the report.

The key to successful water resources planning and hence rezoning for the JSP lies in the preparation of the regional WRMS. A funding mechanism is a key issue that needs to be addressed since funds were not available from the Department of Environment to continue this study to its conclusion.

Metropolitan Regional Scheme amendment approvals will require the prior approval of the regional WMS. Facilitation of the necessary funding and commencement of water resources monitoring is a matter of high priority to landowners, developers and the Government to meet housing needs in the short to medium term.
1. Introduction

In October 2001, the Western Australian Planning Commission released the draft Jandakot Structure Plan (JSP) which includes the localities of Oakford, Mandogalup, Casuarina, Wellard, Anketell, Wandi, Bertram, Oldbury and The Spectacles.

The area covered by the JSP was left without strategic planning direction following a decrease in the boundaries of the Jandakot Underground Water Pollution Control Area.

A key outcome of the JSP is the preparation of a Water Resources Management Strategy (WRMS) for the area. Appendix F of the JSP outlined guidelines for the preparation of the WRMS.

In June 2002, Parsons Brinckerhoff (PB) were engaged by the Water and Rivers Commission (WRC) to undertake the preparation of the WRMS for Jandakot (RFT No WM 62080).

A Project Advisory Committee comprising the following stakeholders have provided guidelines to PB in the preparation of the WRMS:

- Water and Rivers Commission.
- Department for Planning and Infrastructure.
- Town of Kwinana.
- Shire of Serpentine–Jarrahdale.
- Department of Environmental Protection.
- Water Corporation.
- CALM.
- Urban Development Institute of Australia.

During the course of the study it became apparent that a WRMS could not be completed in the original form requested due to a substantial gap in understanding of the water resources in the study area. Primarily, insufficient data exists to deliver a high quality WRMS with sufficient technical rigour to satisfy key government stakeholders.

This report presents a summary of our findings and provides an outline of the tasks necessary to comprehensively undertake a WRMS.
2. Water Quality Objectives

2.1 Introduction

2.1.1 Aims of this Section

The aims of this section are to:

- Provide a brief overview of the nature of water bodies within the study area and those potentially affected by the development proposed in the draft Jandakot Structure Plan (see Appendix A).
- Briefly review available information on the quality of surface water and groundwater in the study area, as well as the water quality of receiving water bodies.
- Propose water quality-related objectives that can be used immediately as ‘modelling objectives’ and/or ‘conceptual design objectives’ for stormwater management activities in the study area.
- Make recommendations on future water quality monitoring activities (both pre- and post-development).
- Highlight recommended future work.

2.1.2 Background to the Project and Site

2.1.2.1 The Project

In December 1994, the boundaries of the Jandakot Underground Pollution Control Area (UWPCA) were reviewed. This review resulted in a reduction of the UWPCA area, leaving a significant area of land without a strategic plan for its use. Consequently a draft Jandakot Structure Plan (Western Australian Planning Commission, 2001) was prepared to provide strategic planning direction to this area. This Plan is summarised in Appendix A, and includes significant areas of urban land use.

In recognition of the potential risk to the health of wetlands, the Serpentine River and the Peel Inlet-Harvey Estuary posed by urban development in the catchment, a Water Resources Management Strategy was requested by the Western Australian Planning Commission. This strategy will allow the draft Jandakot Structure Plan to be reviewed, amended (where necessary) and adopted. The Water Resources Management Strategy’s principal aim is to “ensure sustainable and efficient water use is practised and any environmental impact from development within the study area is minimised”.


With respect to water quality related issues, the project brief requires that the final Water Resources Management Strategy must:

- protect regionally significant wetlands, watercourses and vegetation;
- protect water quality in the Serpentine River and Peel Inlet-Harvey Estuary from additional nutrient inputs from surface and groundwater sources;
- manage water quality aspects of peak stormwater events;
- establish water quality objectives for the Water Corporation drainage system;
- maintain and enhance water quality, where possible;
- maintain and enhance water related environmental, recreational and cultural values and opportunities;
- identify key water-quality related issues; and
- report on strategies and methodologies that will ensure water quality in wetlands and watercourses are maintained or enhanced (WRC, 2002).

2.1.2.2 The Study Area

The location of the study area and main water bodies is shown in Figure 2.1. In addition, the proposed land use and key environmental features of the study area are shown in Appendix A (the draft Jandakot Structure Plan). From a water quality perspective, key features of the study area are summarised below, with water quality information summarised in Chapter 2.2:

- Surface water from the study area drains south to the Serpentine River and the Peel Inlet–Harvey Estuary. Both these water bodies are currently under significant stress, primarily from a high nutrient loading and subsequent environmental impacts (e.g. eutrophication). In addition, the Peel Inlet-Harvey Estuary contains one of the most important wetland systems in southwest Western Australia which is RAMSAR listed (Evangelisti et al., 1994). Management of water quality from the proposed development within the study area (see Appendix A) will need to focus upon phosphorus and nitrogen as the primary pollutants of concern.

- Many Water Corporation drains exist within the study area, being part of the Mundijong Drainage District. The western half of the site is drained by the Peel Main Drain, which leaves the study area at the corner of Millar and Johnson Roads (see Appendix B for photographs). The eastern half the site is drained by the Birrega Main Drain, which flows along the eastern boundary of the study area before turning south to flow to the Serpentine River (see Appendix B for photographs). This drain receives water from Beenyup Brook and other significant creeks around the Byford area. During a site inspection in mid October 2002, water was flowing steadily through the Birrega Main Drain, while flows were barely noticeable in the Peel Main Drain within the study area. For a detailed history of these drains, see WAPC (2001).

- The study area contains several significant wetlands, the most important of which are the Spectacles Wetlands. These wetlands are conservation category wetlands, wetlands classified under the Environmental Protection (Swan Coastal Plain Lakes)
Policy 1992, part of the Beeliar Regional Park and have been listed on the Directory of Important Wetlands in Australia (CALM, et al., 2001). Locations of all significant wetlands are also shown on the map in Appendix A. Despite the significance of the Spectacles Wetlands today, it was once drained and cleared for agriculture (AWWA, 1991). Consequently, the Peel Main Drain flows directly through the wetlands, significantly influencing its hydrology and water quality.

- The study area is located at the southern portion of the Jandakot Groundwater Mound that produces radiating groundwater flows that head west-southwest in the vicinity of the Spectacles Wetlands and flow south east in the eastern part of the site. Superficial groundwater is generally within one to three metres below the surface of the study area, but can extend up to 12 metres below the surface in areas of topographic highs (WAPC, 2001). Localised areas or ‘hot spots’ of groundwater pollution are known to occur within the study area (e.g. plumes of nutrient-enriched groundwater associated with market gardens)\(^1\).

- Soils across the site are generally leached, grey siliceous sands and may become pale yellow in the dune sequences. Most of the eastern side of the study area is deep Bassendean Sands, while on the western side of the study area Tamala Limestone weathers to form Karrakatta or Cottesloe Sand (WAPC, 2001). The soils typically have a low ability to absorb nutrients, having a low clay and iron content, with the exception of some alluvial soils in the east and those with some calcium carbonate in the west (i.e. those associated with the Tamala Limestone)\(^2\). Previous soil investigations have reported no evidence of acid sulphate soils.

- The Spectacles Wetlands are the only water bodies that have been extensively studied within the study area from a water quality perspective\(^3\). In 1997, the Water and Rivers Commission undertook a comprehensive hydrogeological and nutrient balance investigation (see Shams, 1997). Key findings included:
  
  - The upper section of the Peel Main Drain in the study area that enters the wetlands is not often hydraulically connected to groundwater, due to clayey sediments.
  
  - Although the main groundwater flow direction at the Spectacles Wetlands is west-southwest, the Kwinana wastewater treatment plant to the west of the wetlands was thought to create a small groundwater mound, so that locally, groundwater was thought to flow east. This local groundwater mound was thought to transport nutrients and pathogens from the treatment plant to the northern and largest ‘eye’ of the wetlands. Note however that subsequent hydrogeological investigations (Woodward Clyde, 2000) have found “infiltrating effluent at the KWTP [Kwinana wastewater treatment plant] does not reach the wetlands (p. 1-1).

\(^1\) See WAPC (2001) and Shams (1997).
\(^2\) This information is based on previous investigations.
\(^3\) This paper focuses on the Spectacles Wetlands due to their significance, size and available water quality data. However, it should be noted that the site contains many other smaller “conservation category” wetlands (see Appendix A for a map of these wetlands).
- Groundwater flows at an approximate rate of 76 metres per year near the wetlands.
- Approximately forty-eight percent (48%) of water flowing into the wetlands is from the Peel Main Drain, while the remainder is from groundwater.
Figure 2.1: The Jandakot study area and main water bodies
2.1.2.3 Draft Jandakot Structure Plan

The Western Australian Planning Commission in consultation with the Shire of Serpentine-Jarrahdale, Town of Kwinana, stakeholders and the community have prepared a draft Jandakot Structure Plan (see Appendix A). The purpose of the Structure Plan is to provide a strategic direction for the long-term land use in the area surrounding the southern part of the Jandakot groundwater area.

Major influences for the Structure Plan include existing land use and buffers, transport and infrastructure, environmental issues (wetlands, bushland, flora and fauna, pollution, land form, etc.), liveable neighbourhoods principles, water sensitive design and community views and expectations.

The draft Jandakot Structure Plan was available for public comment from October 2001 to the end of December 2001. The proposed Water Resource Management Strategy and comments from the public submissions will be used to finalise the Jandakot Structure Plan.

The likely development process for the study area and timeframe is briefly discussed in Chapter 2.4 and Figure 2.2, as it affects the timing of recommended water quality-related monitoring.

2.1.2.4 Caveats

This chapter draws upon existing information and data to provide guidance on how water quality should be managed in the future development of the study area. It is acknowledged however that in some areas, the available data are limited. In particular, there is a lack of:

- good water quality data for relatively un-impacted surface water quality reference sites;
- groundwater quality in general across the study area; and
- information relating to localised 'hot spots' of groundwater contamination.

Lack of information regarding the location, nature, significance and rate of movement of plumes of nutrient-enriched groundwater are particularly of concern, as they may impact the quality of water bodies within and downstream of the site in future and complicate the interpretation of water quality monitoring results. Without this basic information, the significance of this issue cannot currently be assessed or predicted using water quality modelling tools.

To overcome some of the limitations identified during this study, recommendations have been made on future work in Chapter 7.
2.2 The Nature of Surface and Groundwater Quality

2.2.1 Surface Water Quality

Typical water quality-related problems experienced by shallow wetlands and drains around the Jandakot Mound in the past have been broadly summarised in WAWA (1991). These include algal blooms, heavy growth of some macrophytes, unpleasant odours from decomposing algae, bird deaths from botulism and plagues of non-biting midges. In addition, poor water quality draining from the site has the potential to significantly affect the health of downstream waterways (e.g. the Serpentine River and the Peel Inlet-Harvey Estuary).

This Chapter briefly summarises what is known about the water quality of water bodies within the study area, immediately upstream of the study area and downstream of the study area. Such background information is needed to adequately set water quality-related objectives for the development of the study area.

2.2.1.1 Catchment Level Information

Surface water draining from the study area enters the Peel Main Drain in the west or the Birrega Main Drain in the east. These constructed drains direct surface water to the Serpentine River, then finally into the Peel Inlet-Harvey Estuary system. The study area is part of the Murray Basin.

Of primary concern to the health of the Peel Inlet-Harvey Estuary is the export of nutrients (particularly phosphorus) from the catchment to the estuary, and the effects of subsequent eutrophication. For more information on this issue, see the Environmental Protection (Peel Inlet-Harvey Estuary) Policy 1992 and the Peel-Harvey Coastal Plain Catchment Statement of Planning Policy 1992.

In the report titled Waterway, Estuarine, Catchment and Landscape Health: Project 1 – Status and Trend in Surface Water Quality (WRC & L&WRDC, 2000) an overview is given of the water quality of the Murray Basin. At the catchment level, data indicates that salt and nutrient (TN and TP) concentrations are generally increasing in the rivers of the Murray Basin, however that the time of investigation the majority of rivers and streams (>75%) had low nutrient concentrations (i.e. TN <1.0 mg/l and TP <0.1mg/l). That is, nutrient levels were generally acceptable for the environmental values these waterways supported.
2.2.1.2 The Peel Main Drain, Birrega Main Drain and Spectacles Wetlands

2002 Surface Water Quality ‘Snap Shot’

As part of this study, a ‘snap shot’ surface water quality sampling exercise was undertaken during the winter of 2002 (3 September 2002) when flows were present in both the Peel Main Drain and the Birrega Main Drain. Data for total nitrogen (TN) concentrations, total phosphorus (TP) concentrations, total suspended solids (TSS) concentrations, conductivity, pH and flow rates are presented graphically in Appendix C. Conclusions from this data are given below:

Total nitrogen (TN)

- In general, TN concentrations were relatively low in the Peel Main Drain (i.e. around the relevant ANZECC & ARMCANZ (2000) guideline \(^4\) for TN of 1.2 mg/l), while concentrations were elevated in the Birrega Main Drain (e.g. 2.4 - 6 mg/l).

- In the Peel Main Drain, concentrations of TN were relatively low (i.e. below the relevant ANZECC & ARMCANZ (2000) guideline \(^4\) for TN) downstream of the two main wetland complexes that the drain bisects (i.e. the Spectacles Wetlands and the Bollard Bulrush Swamp). Given higher concentrations of TN upstream of these wetlands, it is likely that these wetlands are performing a treatment function for TN in surface water. This hypothesis is supported by the work of Shams (1997) which is summarised later in this Chapter.

- The surface water outlet leaving the site with the greatest flow (i.e. the Peel Main Drain at Millar Road) was meeting the relevant ANZECC & ARMCANZ (2000) guideline \(^4\) for concentrations of TN.

- Elevated nutrient levels in some drains can be explained by the current land use activities in the study area (e.g. grazing of dairy cattle, the keeping of horses, market gardens, etc.), the lack of effective riparian buffer zones, soil type and hydrogeology.

Total phosphorus (TP)

- TP concentrations in surface water varied greatly across the study area.

- Overall, TP concentrations were greater in drains on the eastern side of the study area.

- Surface water in the Birrega Main Drain was highly enriched with TP, with concentrations in the range of 0.65 - 2.5 mg/l.

- The feeder drains that direct surface water from the eastern side of the study area to the Birrega Main Drain were also enriched with TP (i.e. in the range of 0.13 - 0.325 mg/l).

- TP concentrations in surface water downstream of the two wetland complexes on the Peel Main Drain were relatively low (i.e. below the relevant ANZECC & ARMCANZ guideline \(^4\))

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\(^4\) The ANZECC & ARMCANZ (2000) guidelines relate to the protection of aquatic ecosystems in SW Australian freshwater lowland rivers/waterways and wetlands and are provided for reference value only. These water quality guidelines relate to ambient water quality (i.e. the receiving waters into which drainage or groundwater flows).
[2000] guideline for TP) compared to upstream values. Once again, it is likely that the Spectacles Wetlands and the Bollard Bulrush Swamp are performing a treatment function for TP in surface water.

- The surface water outlet leaving the study area with the greatest flow (i.e. the Peel Main Drain at Millar Road) was meeting the relevant ANZECC & ARMCANZ (2000) guideline for concentrations of TP (i.e. 0.065 mg/l).

**Total suspended solids (TSS)**

- TSS concentrations across the study area were generally very low (i.e. all below 7.9 mg/l).
- Once again, it is likely that the Spectacles Wetlands and the Bollard Bulrush Swamp are performing a treatment function for TSS, with concentrations of TSS in surface water being lower downstream than upstream of these wetlands.
- Low TSS concentrations can be explained by the soil type of the region (i.e. generally sandy), the abundance of permeable surfaces and low velocity flows in drainage channels.

**pH**

- pH was generally low across the study area with all samples being less than 7.2 and five of 10 samples being less than 6.2. The relevant ANZECC & AMCANZ (2000) guideline is 6.5 - 8.0.
- One particularly acidic sample (3.9) was taken from the north-east corner of the study area in a drain along Nicholson Road (see Appendix B for a photograph of this drain). It is possible that this acidity is due to animal wastes, with nutrients also being elevated at this location. Knowledge about local soil types does not support the conclusion that acid sulphate soils may be present across the study area (i.e. they are generally sandy and iron poor).
- Although the pH was generally low in surface water's, acidity is not known to be a major threat to the environmental values of downstream receiving waters (e.g. the Serpentine River or the Peel Inlet-Harvey Estuary) unlike nutrients.

**Conductivity/salinity**

- Conductivity was elevated in the west of the study area, along the Peel Main Drain. Along this drain, levels of conductivity in surface water were commonly within the range of 907 – 1347 µS/cm. In the east of the site, along the Birrega Main Drain, levels were typically around 650 – 685 µS/cm. Typical levels of conductivity in both these drains exceeded the relevant ANZECC & ARMCANZ (2000) water quality guideline for rivers (i.e. 120 - 300 µS/cm). These elevated salinity levels may be due to historical clearing of vegetation, leading to a rise in groundwater and leaching of salts from the soil. Urban development is unlikely to exacerbate this issue, particularly if groundwater levels are kept at or below pre-development levels.
- Conductivity appeared to increase downstream of the two major wetland systems on the Peel Main Drain and was generally high (e.g. within the range of 907 - 1347 µS/cm). These levels are within the range of the relevant ANZECC & ARMCANZ...
(2000) water quality guideline for wetlands (i.e. 300 - 1500 µS/cm). Elevated conductivity downstream of wetlands may be due to evaporation and/or the influence of groundwater.

**Peel Main Drain**

Surface water quality data for all drains and wetlands within the study area was sought from the Water Corporation and the Water and Rivers Commission. No data were available from the Water Corporation, however there was a significant data set in the Water and Rivers Commission’s WIN database for three sites along the Peel Main Drain:

- one immediately up-stream of the Spectacles Wetlands (i.e. site 614013);
- one between the two ‘eyes’ of the Spectacles Wetlands (i.e. site 614095); and
- one immediately down-stream of the Spectacles Wetlands (i.e. site 614078).

Summary statistics for this data are given in Table 2.1. Key conclusions from this data are:

- The median concentrations of all nutrient species shown in Table 2.1 (i.e. NH$_3$-NH$_4^+$, NO$_x$, TKN, TN, TP, P [sol]) were lower in surface water below the wetlands than above the wetlands, indicating the wetlands may perform a valuable treatment function.

- Of these nutrient species, only median concentrations for TP and TN exceeded relevant ANZECC & ARMCANZ (2000) guidelines at the outlet from the wetlands. Of these, phosphorus is suggested as being the most significant pollutant, given the median concentration of TP was almost twice the relevant guideline value for the protection of aquatic ecosystems, and the management of phosphorus is the priority for the Peel Inlet-Harvey Estuary.

- Turbidity was generally low, with median values from all three sites being less than 7.9 NTU.
Table 2.1: Surface water quality data around the Spectacles Wetlands (from the WRC's WIN database)

<table>
<thead>
<tr>
<th>WRC Site Reference (and Sampling Period)</th>
<th>NH3-N/NH4-N (sol) (mg/l)</th>
<th>Chlorophyll a (mg/l)</th>
<th>N (sum sol ox) (mg/l)</th>
<th>N (tot k jel) (mg/l)</th>
<th>N (sol) (TN-filt) (mg/l)</th>
<th>N (tot) (TN, pTN) (mg/l)</th>
<th>P (sol) (mg/l)</th>
<th>P (tot) (TP, pTP) (mg/l)</th>
<th>Turbidity (NTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Up-stream of the Spectacles Wetlands</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>614013 (7/1976 - 11/2000)</td>
<td>Median 0.173</td>
<td>0.003</td>
<td>1.570</td>
<td>2.066</td>
<td>3.774</td>
<td>3.671</td>
<td>0.322</td>
<td>0.483</td>
<td>5.700</td>
</tr>
<tr>
<td></td>
<td>Mean 0.173</td>
<td>0.005</td>
<td>1.909</td>
<td>1.973</td>
<td>3.657</td>
<td>3.635</td>
<td>0.260</td>
<td>0.465</td>
<td>12.659</td>
</tr>
<tr>
<td></td>
<td>Max 0.489</td>
<td>0.019</td>
<td>4.700</td>
<td>3.102</td>
<td>7.419</td>
<td>6.232</td>
<td>0.500</td>
<td>0.968</td>
<td>222.300</td>
</tr>
<tr>
<td></td>
<td>Min 0.019</td>
<td>0.000</td>
<td>0.350</td>
<td>0.580</td>
<td>1.590</td>
<td>1.386</td>
<td>0.046</td>
<td>0.095</td>
<td>0.220</td>
</tr>
<tr>
<td></td>
<td>n 26</td>
<td>18</td>
<td>41</td>
<td>50</td>
<td>25</td>
<td>8</td>
<td>26</td>
<td>65</td>
<td>133</td>
</tr>
<tr>
<td><strong>In the Spectacles Wetlands</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>614095 (6/1994 - 7/1998)</td>
<td>Median 0.065</td>
<td>0.004</td>
<td>0.368</td>
<td>1.779</td>
<td>2.186</td>
<td>1.525</td>
<td>0.069</td>
<td>0.146</td>
<td>4.500</td>
</tr>
<tr>
<td></td>
<td>Mean 0.103</td>
<td>0.016</td>
<td>0.466</td>
<td>1.905</td>
<td>2.282</td>
<td>1.543</td>
<td>0.095</td>
<td>0.186</td>
<td>4.500</td>
</tr>
<tr>
<td></td>
<td>Max 0.350</td>
<td>0.190</td>
<td>2.775</td>
<td>5.345</td>
<td>5.405</td>
<td>2.451</td>
<td>0.408</td>
<td>0.591</td>
<td>4.900</td>
</tr>
<tr>
<td></td>
<td>Min 0.009</td>
<td>0.000</td>
<td>0.005</td>
<td>0.585</td>
<td>0.653</td>
<td>0.671</td>
<td>0.014</td>
<td>0.033</td>
<td>4.100</td>
</tr>
<tr>
<td></td>
<td>n 23</td>
<td>17</td>
<td>26</td>
<td>25</td>
<td>22</td>
<td>4</td>
<td>23</td>
<td>39</td>
<td>2</td>
</tr>
<tr>
<td><strong>Down-stream of the Spectacles Wetlands</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>614078 (7/1992 - 11/1997)</td>
<td>Median 0.036</td>
<td>0.004</td>
<td>0.040</td>
<td>1.652</td>
<td>0.966</td>
<td>1.839</td>
<td>0.026</td>
<td>0.114</td>
<td>7.900</td>
</tr>
<tr>
<td></td>
<td>Mean 0.040</td>
<td>0.004</td>
<td>0.111</td>
<td>1.621</td>
<td>1.063</td>
<td>1.959</td>
<td>0.033</td>
<td>0.128</td>
<td>7.233</td>
</tr>
<tr>
<td></td>
<td>Max 0.083</td>
<td>0.016</td>
<td>1.349</td>
<td>3.453</td>
<td>1.671</td>
<td>2.308</td>
<td>0.076</td>
<td>0.267</td>
<td>12.500</td>
</tr>
<tr>
<td></td>
<td>Min 0.000</td>
<td>0.000</td>
<td>0.008</td>
<td>0.482</td>
<td>0.508</td>
<td>1.729</td>
<td>0.004</td>
<td>0.026</td>
<td>1.300</td>
</tr>
<tr>
<td></td>
<td>n 25</td>
<td>19</td>
<td>27</td>
<td>46</td>
<td>25</td>
<td>3</td>
<td>26</td>
<td>61</td>
<td>3</td>
</tr>
</tbody>
</table>
### Reference values (ANZECC & ARMCANZ [2000] Guidelines)

<table>
<thead>
<tr>
<th></th>
<th>(rivers)</th>
<th>(wetlands)</th>
<th>(rivers)</th>
<th>(wetlands)</th>
<th>(rivers)</th>
<th>(wetlands)</th>
<th>(rivers)</th>
<th>(wetlands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>0.08</td>
<td>0.04</td>
<td>0.15</td>
<td>0.04</td>
<td>0.15</td>
<td>0.04</td>
<td>0.15</td>
<td>0.065</td>
</tr>
<tr>
<td>Turbidity</td>
<td>3 - 5</td>
<td>30</td>
<td>-</td>
<td>1.2</td>
<td>1.5</td>
<td>0.03</td>
<td>0.03</td>
<td>0.06</td>
</tr>
<tr>
<td>Chloride</td>
<td>1.2</td>
<td>1.5</td>
<td>1.2</td>
<td>1.5</td>
<td>1.2</td>
<td>1.5</td>
<td>1.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Nitrate</td>
<td>0.04</td>
<td>0.03</td>
<td>0.04</td>
<td>0.03</td>
<td>0.04</td>
<td>0.03</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td>Sulfate</td>
<td>10 - 20</td>
<td>10 - 100</td>
<td>10 - 20</td>
<td>10 - 100</td>
<td>10 - 20</td>
<td>10 - 100</td>
<td>10 - 20</td>
<td>10 - 100</td>
</tr>
</tbody>
</table>

**Note:**

**Bold values** = median concentrations exceed both ANZECC & ARMCANZ (2000) guidelines relating to the protection of aquatic ecosystems in SW Australian freshwater lowland rivers/waterways (<150m in altitude) and wetlands.

**Source:** WRC's WIN database.
The Spectacles Wetlands

It is recognised that the Spectacles Wetlands are only some of the study area’s ‘conservation category’ wetlands (see Appendix A). However, they are the most significant in terms of size and environmental values. They are also the only wetlands for which meaningful water quality data are available. Consequently, they are the focus of this section with respect to wetlands.

Shams (1997) investigated the quality of surface water flowing into the Spectacles Wetlands from the Peel Main Drain, the water quality within the Spectacles Wetlands, and the water quality flowing out of the Spectacles Wetlands. This data is summarised below in Table 2.2.

Table 2.2: Surface water quality data around the Spectacles Wetlands (from Shams, 1997)

<table>
<thead>
<tr>
<th>Water Quality Parameter</th>
<th>Hope Valley Road1</th>
<th>Spectacles Wetlands2</th>
<th>Thomas Road3</th>
<th>Reference value ANZECC &amp; ARMCANZ4</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN (mg/l)</td>
<td>5.627</td>
<td>12.695</td>
<td>1.332</td>
<td>1.2 (river)</td>
</tr>
<tr>
<td></td>
<td>2.184</td>
<td>4.776</td>
<td>1.524</td>
<td>1.5 (wetland)</td>
</tr>
<tr>
<td></td>
<td>3.019</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.101</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₃ (mg/l)</td>
<td>3.000</td>
<td>0.017</td>
<td>0.013</td>
<td>0.150 (river) - NO₃</td>
</tr>
<tr>
<td></td>
<td>0.545</td>
<td>1.856</td>
<td>0.01</td>
<td>0.100 (wetland) - NO₃</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.342</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.01</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NH₄-N (sol) (mg/l)</td>
<td>0.174</td>
<td>2.895</td>
<td>0.018</td>
<td>0.08 (river) – NH₄+</td>
</tr>
<tr>
<td></td>
<td>0.354</td>
<td>0.153</td>
<td>0.021</td>
<td>0.04 (wetland) – NH₄+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.185</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.067</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TKN (mg/l)</td>
<td>2.453</td>
<td>9.783</td>
<td>1.301</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1.285</td>
<td>2.767</td>
<td>1.493</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.492</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.024</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TP (mg/l)</td>
<td>0.586</td>
<td>0.500</td>
<td>0.082</td>
<td>0.065 (river)</td>
</tr>
<tr>
<td></td>
<td>0.375</td>
<td>0.518</td>
<td>0.086</td>
<td>0.060 (wetland)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.416</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.207</td>
<td></td>
</tr>
<tr>
<td>Ortho-P (mg/l)</td>
<td>0.323</td>
<td>0.198</td>
<td>0.027</td>
<td>0.04 (river)</td>
</tr>
<tr>
<td></td>
<td>0.046</td>
<td>0.202</td>
<td>0.040</td>
<td>0.03 (wetland)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.182</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.321</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Notes:

This location represents the Peel Main Drain as it enters the wetlands. Sampling occurred between August and November 1995.

Data derived from Murdoch University, see Shams (1997). Sampling occurred between April 1995 and February 1996.

This location represents the Peel Main Drain as it leaves the wetlands. Sampling occurred between August and November 1995.

For reference value only. The ANZECC & ARMCANZ (2000) guidelines for protection of aquatic ecosystems – SW Australian freshwater lowland rivers/waterways and wetlands (i.e. <150m in altitude). These water quality guidelines relate to ambient water quality (i.e. the receiving waters into which drainage or groundwater flows).

Bold values = median concentrations that exceed both ANZECC & ARMCANZ (2000) guidelines for lowland rivers (<150m in altitude) and wetlands.
Shams (1997) reviewed water quality data collected previously in 1991 and her own data (as shown in Table 2.2) and concluded that:

- Nitrate was the major nitrogen species in surface water flowing into the Spectacles Wetlands, while TKN (Total Kjeldahl Nitrogen or ammonia nitrogen + organic nitrogen) was the dominant nitrogen species in the drain water flowing out of the wetlands. That is, the physical, chemical and biological processes in the wetlands play a role in transforming the nitrogen species.

- Of the total nutrient loading to the wetlands, 71% of phosphorous (i.e. ~ 1.207 tonnes) and 84% of nitrogen (i.e. ~ 10.08 tonnes) was lost due to denitrification, assimilation and retention processes in the wetlands.

- Total nitrogen concentrations in the Spectacles Wetlands increased from 1991 to 1995, with ammonia, nitrate and organic nitrogen contributing significantly towards the total nitrogen concentration in the wetlands.

- Total phosphorus concentrations in the Spectacles Wetlands in 1991 and in 1995-96 were moderate to high compared to other wetlands in the region.

- Fifty-eight percent (58%) of the total nitrogen loading on the wetlands came from the Peel Main Drain, while the equivalent figure for total phosphorus was 80%. The total loading on the wetlands for TN was 12 tonnes per year, while for TP it was 1.7 tonnes per year.

### Upstream Water Quality

In addition to the surface water quality results provided in Appendix C, three surface water ‘grab samples’ were collected by Parsons Brinkerhoff from Beenyup Brook in the Byford area as part of another urban stormwater management study in September and October 2001.

This data can be used as a broad indicator of water quality in the Birrega Main Drain before it becomes heavily impacted by activities on the Swan Coastal Plain and is provided for reference value only.5

Water quality data are summarised in Table 2.3 below, with elevated results in bold:

---

5 Ideally, a relatively un-impacted surface water reference site would be available with a good water quality data set. However, such a site was not identified during this study.
Table 2.3: Surface water quality up-stream of the Birrega Main Drain (i.e. in Beenyup Brook)

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Beenyup Brook (24/10/01)</th>
<th>Beenyup Brook (14/09/01)</th>
<th>Beenyup Brook (24/10/01)</th>
<th>Water Quality Guideline (for reference only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS (mg/l)</td>
<td>16</td>
<td>-</td>
<td>&lt;5</td>
<td>50-75*</td>
</tr>
<tr>
<td>TP (mg/l)</td>
<td>0.08</td>
<td>&lt;0.05</td>
<td>0.02</td>
<td>0.065 (ANZECC &amp; ARMCANZ 2000 guidelines)</td>
</tr>
<tr>
<td>Ortho-P (mg/l)</td>
<td>0.015</td>
<td>&lt;0.05</td>
<td>&lt;0.003</td>
<td>0.04 (ANZECC &amp; ARMCANZ 2000 guidelines)</td>
</tr>
<tr>
<td>TN (mg/l)</td>
<td>0.82</td>
<td>-</td>
<td>0.37</td>
<td>1.2 (ANZECC &amp; ARMCANZ 2000 guidelines)</td>
</tr>
<tr>
<td>NO_x-N (mg/l)</td>
<td>0.02</td>
<td>&lt;0.05</td>
<td>0.02</td>
<td>0.15 (ANZECC &amp; ARMCANZ 2000 guidelines)</td>
</tr>
<tr>
<td>NH_3-N (mg/l)</td>
<td>0.041</td>
<td>&lt;0.1</td>
<td>0.019</td>
<td>-</td>
</tr>
<tr>
<td>Kjeld-N (mg/l)</td>
<td>0.8</td>
<td>1.2</td>
<td>0.35</td>
<td>-</td>
</tr>
</tbody>
</table>

Comments: Shortly after wet weather

Notes:
The ANZECC & ARMCANZ (2000) guidelines provide a turbidity guideline (‘trigger value’) of 10-20 NTU for protection of aquatic ecosystem values, but do not give an equivalent guideline for TSS. A literature review by the CRC for Catchment Hydrology that examined the results of urban stormwater quality investigations from over 500 locations worldwide found that: 1 TSS (mg/l) = 12.5 x (turbidity in NTU)^0.6 (Hugh Duncan, pers. comm., 2001).

Bold values = median concentrations that exceed ANZECC & ARMCANZ (2000) guidelines for the protection of aquatic ecosystems in lowland rivers (<150m in altitude).

Note that at the sampling locations, the Brook still had a natural channel form, some riparian vegetation, and was impacted to a limited extent by rural and urban land uses.
The surface water quality results given in Table 2.3, although limited, broadly indicate that:

- the concentrations of nutrients in Beenyup Brook upstream of study area (i.e. before the Brook becomes Birrega Main Drain and flows along the eastern boundary of the study area) are considerably lower than those concentrations measured in Birrega Main Drain as part of this study (see Appendix C); and
- with respect to nutrients, the water quality in Beenyup Brook is generally 'good', given the nature of the land use in the catchment.

### 2.2.2 Groundwater Quality

As reported in WAPC (2001), groundwater contamination is a potentially significant issue for the study area, as there are many potential sources (e.g. market gardens, piggeries, chicken farms, pesticide storage areas and dairies) and some areas of known contamination. There is also the potential for contaminated groundwater to be drawn into sensitive wetlands such as the Spectacles Wetlands, given the relatively rapid rate of groundwater flow into such wetlands. However, the exact nature of, location of, and risk associated with this contamination has not yet been well identified.

While the proposed development within the study area (as defined by the draft Jandakot Structure Plan) will gradually remove many of these pollution sources (e.g. market gardens) and should generally improve groundwater quality, there will be a legacy of shallow groundwater pollution that will remain for many years. Those involved with post-development water quality monitoring and the setting of final development conditions should bear in mind that ‘hot spots’ of groundwater pollution that were created prior to development may take decades to find their way to surface waters and be picked up by surface water quality monitoring regimes. The nature of such ‘hot spots’ is currently poorly understood.

The quality of regional, ambient groundwater from the Jandakot Mound has been broadly summarised in WAWA (1991). This report states that nitrate, fluoride, boron and heavy metals are generally in low concentrations. Phosphorous concentrations, with the exception of a few locations, are less than 0.1 mg/l.

Shams (1997) investigated groundwater quality around the Spectacles Wetlands in the west of the study area. She found nitrogen and phosphorus concentrations to be generally low in groundwater but found some significant ‘hot spots’ around sources such as market gardens and the Kwinana wastewater treatment plant. For example, she found that:

- The ambient consideration of total nitrogen in groundwater surrounding the Spectacles Wetlands was less than 1.0 mg/l, while elevated concentrations of 2 to 123 mg/l were found locally around market gardens.
- The ambient concentration of oxidisable nitrogen (i.e. NO\(_3\) + NO\(_2\)) in groundwater surrounding the Spectacles Wetlands generally ranged between 0.008 and 0.4 mg/l.

---

6 This terminology is taken from WRC & LWRRDC (2000), where the boundaries for ‘good’ surface water quality included <1.0mg/l TN and <0.1mg/l TP.

7 Later hydrogeological work by Woodward Clyde (2000) has reportedly demonstrated that the plant is not impacting the wetlands.
while elevated concentrations of up to 120 mg/l were found around market gardens. Oxidisable nitrogen was generally concentrated towards the upper part of the superficial aquifer.

- The ambient concentration of total phosphorus in groundwater surrounding the Spectacles Wetlands was less than 0.5 mg/l, while elevated concentrations of 5 to 34 mg/l were found around market gardens.

- Ortho-phosphate concentrations in groundwater surrounding the spectacles was between 7 and 31 mg/l in market garden areas, with concentrations being elevated towards the top of the superficial aquifer. Outside of market garden areas concentrations ranged from 0.01 to 0.1 mg/l. Generally low concentrations of ortho-phosphate in groundwater towards the west of the site was thought to be due to phosphorous retention by the Tamala Limestone.

Shams' work also concluded that the Spectacles Wetlands are a “groundwater dominated system”. However, this conclusion is a little misleading given Shams found surface water contributed 48% of the water flow into the wetlands and over the decade prior to Shams’ (1997) investigation, there was a trend of increasing surface flow into the wetland from the Peel Main Drain.

‘Hot spot’ contamination of groundwater identified during Shams’ (1997) study was estimated to reach the Spectacles Wetlands in approximately 2010. There may however be many more existing, localised plumes of nutrient-enriched groundwater in the region. This currently represents a major area of uncertainty that should be investigated further (see Chapter 2.5).

Shams (1997) calculated the approximate loading of nutrients on the Spectacles Wetlands. Loading of total nitrogen was estimated to be 12 tonnes/year (of which 58% was from the Peel Main Drain and 42% from groundwater) while total phosphorus was 1.7 tonnes/year (of which 80% was from the Peel Main Drain and 20% from groundwater). Given that:

- surface water inputs dominate this nutrient balance;
- there was a trend of increasing run-off into the wetlands from the Peel Main Drain during the late 1980s and early 1990s; and
- the proposed change in land use will significantly minimise the potential for ongoing groundwater pollution,

it is recommended that the focus of this Water Resource Management Strategy in the vicinity of the Spectacles Wetlands should be on preventing future stormwater contamination (both in terms of pollutant loads and concentrations).\(^8\)

Some of the raw groundwater quality data from Shams’ (1997) work is presented in Table 2.4 to indicate typical groundwater quality associated with background and impacted areas, as well as associated nutrient speciation. Two groups of data have been selected from the relevant Water and Rivers Commission data set:

\(^8\) In simple terms, pollutant loads need to be controlled primarily to protect the health of the Peel Inlet-Harvey Estuary; while concentrations need to be controlled primarily to protect the health of ecosystems in wetlands, creeks/drains and the Serpentine River.
Data from two groundwater bores within the study area that are less than 10 years old, sample shallow groundwater (i.e. <10m depth) and represent 'background/ambient' groundwater based on Shams’ analysis (i.e. bore SP1-2C approximately 500m east of the largest ‘eye’ of the Spectacles Wetlands and bore SP2-2C approximately 1.5km north east of the largest ‘eye’ of the Spectacles Wetlands).

Data from a shallow groundwater bore sampling a nutrient-enriched groundwater plume associated with a market garden (i.e. Anketell Site 1A approximately 2km east of the largest ‘eye’ of the Spectacles Wetlands). These data represent a ‘hot spot’ of groundwater contamination.

Table 2.4 also includes two groups of reference values to help interpret the data. These being:

- groundwater quality data gathered by Gerritse et al. (1990) as part of a CSIRO urban groundwater quality study that assessed groundwater quality in established, 'typical urban' areas just south of Whiteman Park (in Perth) in Bassendean Sands; and
- conservative ANZECC & ARMCANZ (2000) guidelines for the protection of aquatic ecosystems in surface water bodies, as the groundwater will eventually enter the local wetlands, drain/creek systems and the Serpentine River.
### Table 2.4: Example of typical groundwater quality data within the study area

<table>
<thead>
<tr>
<th>Water Quality Parameter</th>
<th>Background/ambient shallow groundwater1</th>
<th>Nutrient-enriched shallow groundwater/’hot spot’2</th>
<th>Reference value - typical urban3</th>
<th>Reference value – ANZECC &amp; ARMCANZ4</th>
</tr>
</thead>
<tbody>
<tr>
<td>TN (mg/l)</td>
<td>Mean = 0.87</td>
<td>Mean = 58.83</td>
<td>1.451</td>
<td>1.2 (river)</td>
</tr>
<tr>
<td></td>
<td>Median = 0.79</td>
<td>Median = 62.47</td>
<td></td>
<td>1.5 (wetland)</td>
</tr>
<tr>
<td>N (total oxidisable) (mg/l)</td>
<td>Mean = 0.44</td>
<td>Mean = 57.04</td>
<td>0.201</td>
<td>0.150 (river)</td>
</tr>
<tr>
<td></td>
<td>Median = 0.33</td>
<td>Median = 60.81</td>
<td></td>
<td>0.100 (wetland)</td>
</tr>
<tr>
<td>NH3-N/NH4-N (sol) (mg/l)</td>
<td>Mean = 0.17</td>
<td>Mean = 0.18</td>
<td>0.35</td>
<td>0.08 (river)</td>
</tr>
<tr>
<td></td>
<td>Median = 0.11</td>
<td>Median = 0.19</td>
<td></td>
<td>0.04 (wetland)</td>
</tr>
<tr>
<td>TP (mg/l)</td>
<td>Mean = 0.16</td>
<td>Mean = 15.21</td>
<td>-</td>
<td>0.065 (river)</td>
</tr>
<tr>
<td></td>
<td>Median = 0.15</td>
<td>Median = 12.56</td>
<td></td>
<td>0.060 (wetland)</td>
</tr>
<tr>
<td>Ortho-P (mg/l)</td>
<td>Mean = 0.09</td>
<td>Mean = 13.66</td>
<td>0.006</td>
<td>0.04 (river)</td>
</tr>
<tr>
<td></td>
<td>Median = 0.07</td>
<td>Median = 11.61</td>
<td></td>
<td>0.03 (wetland)</td>
</tr>
<tr>
<td>pH (in situ) (pH units)</td>
<td>Mean = 6.6</td>
<td>Mean = 5.33</td>
<td>6.8</td>
<td>6.5 – 8.0 (river)</td>
</tr>
<tr>
<td></td>
<td>Median = 6.7</td>
<td>Median = 5.30</td>
<td></td>
<td>7.0 – 8.5 (wetland)</td>
</tr>
</tbody>
</table>

Notes:
- For reference value only. These data are taken from Gerritse et al. (1990). Note that these data are taken from an urban area in Perth in Bassendean Sands that had an established urban land use (with no water sensitive design elements), and was predominantly sewerized at the time of sampling. The data are mean concentrations from 14 bores.
- For reference value only. The ANZECC & ARMCANZ (2000) guidelines for the protection of aquatic ecosystems – SW Australian freshwater lowland rivers/waterways and wetlands. These water quality guidelines relate to ambient water quality (i.e. the receiving surface waters into which groundwater flows). These guidelines are relevant where groundwater flows into freshwater aquatic ecosystems (e.g. creeks, wetlands).

2.3 Recommended Water Quality-Related Conceptual Design and Modelling Objectives

The purpose of this Chapter is to describe in a quantitative and qualitative manner, objectives relating to stormwater and groundwater quality that should be used during:

- the conceptual design of urban stormwater quality management measures (e.g. bioretention systems, vegetated swales, etc.) that could be used in the study area to protect waterway-related environmental values; and
- pollutant export modelling to quantitatively test whether a particular suite of these management measures can be used within the framework provided by the draft Jandakot Structure Plan (WAPC, 2002) to suitably protect the environmental values in receiving waters both within and downstream of the study area.

This information is presented to allow pollutant export modelling to proceed in the short term (i.e. before several years of high-quality water quality monitoring data are available and final water quality objectives have been set by the Department of Environment). Such modelling is to be done as part of a future study.

To develop water quality related conceptual design and monitoring objectives, a basic methodology has been adopted from the National Water Quality Management Strategy. This methodology is explained and results are presented in Table 2.5. More details on the methodology can be obtained from the:

- National Water Quality Management Strategy Guidelines for Urban Stormwater Management (ARMCANZ & ANZECC, 2000); and
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000).

This methodology reflects national urban stormwater quality management policy, has been successfully used in a number of projects around Perth, and has been excepted by the Department of Environment.

Importantly, it should be understood that two sets of water quality-related objectives are needed for this development:

1. Broad Water Quality-Related Conceptual Design and Modelling Objectives: Objectives that are needed in the short term to guide decision making on the nature of the best management practices (BMPs) to be used to manage stormwater and shallow groundwater quality (i.e. the conceptual design of structural best management practices to minimise stormwater pollution). Clearly, unless some numerical objectives are used at this point, the conceptual design of BMPs and modelling process will be without direction.

2. Final Water Quality Objectives: At Jandakot, some water quality data is available for surface water and groundwater (see Chapter 2.2) but it would be premature to set final water quality objectives for the study area based only on this limited information. It is suggested that at least two years of high-quality, pre-development water quality ambient shallow monitoring data is required to suitably characterise the quality of
surface water and groundwater and to decide upon final water quality objectives for
the site. These objectives would be used during the development assessment
process for proposed developments within the study area and could also be linked
with conditions of development.

This document only concerns the first set of these objectives. The second set will be
developed by the Department of Environment once a substantial set of pre-development
monitoring data is available from the monitoring activities described in Chapter 2.4. It is
however a goal of this Chapter to propose broad water quality-related conceptual design
and modelling objectives that are unlikely to be significantly modified once the final water
quality objectives have been set.

This two-tiered approach to setting water quality-related objectives has recently been
accepted by the Department of Environment (formerly the Water and Rivers Commission)
as being an acceptable and pragmatic approach for three other large urban
developments in the greater Perth region.

The recommended water quality related-conceptual design and modelling objectives are
provided in Table 2.7. Note that it is recommended that future investigations be done to
identify, characterise and assess the significance of existing groundwater contamination
(i.e. ‘hot spots’ of nutrients) and develop appropriate remedial strategies using processes
that are typically used for ‘contaminated sites’. It is not recommended that future urban
stormwater infrastructure in the study area (that is funded by developers) be used to
affect remedial works on existing plumes of contaminated groundwater.
### Table 2.5: Steps to develop short-term water quality-related conceptual design and modelling objectives for the Jandakot study area

<table>
<thead>
<tr>
<th>Step</th>
<th>Outputs for the Jandakot study area</th>
</tr>
</thead>
</table>
| Identify the affected water bodies (i.e. those that may receive stormwater and/or shallow groundwater from the study area). | The potentially affected water bodies are:  
- the Peel Main Drain;  
- the Birrega Main Drain;  
- wetlands within the study area, especially the Spectacles Wetlands;  
- the Serpentine River;  
- the Peel Inlet-Harvey Estuary; and  
- shallow groundwater (likely to be used for irrigation post-development). |
| Define the environmental values for the water bodies potentially affected. | See Table 2.6. Note these environmental values:  
- Have been proposed based upon background reports, knowledge of the catchment and a site inspection.  
- Only relate to water quality issues.  
(Based on an understanding of the waterways and wetlands within the study area there is sufficient confidence in the conservative nature of the proposed environmental values in outlined Table 2.6). |
| Gather relevant information (e.g. relevant monitoring data and scientific knowledge). | A brief review of existing and relevant stormwater and groundwater quality information is given in Chapter 2.2. Relevant background documents are listed in Chapter 8. |
| Determine the level of protection desired for the receiving waters. | Using the terminology in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000. page. 3-1.10), the proposed level of protection is as follows:  
- For the open drainage network, shallow groundwater, the Serpentine River and the Peel Inlet-Harvey Estuary: "To maintain the ecosystem features of these receiving water bodies in a 'moderate to slightly disturbed' state and to seek continuous improvement."  
(Ideally, future opportunities would also be taken to consult with the community on this proposed level of protection as part of a government or community-group-managed catchment planning exercise). |

---

9 Environmental values (EVs) are particular values or uses of the environment that are important for a healthy ecosystem or for public benefit, welfare, safety or health. They may include the protection of aquatic ecosystems, the ability to swim safely, the ability to irrigate from a waterway, etc.

10 In Section 3.1.3.1 of the ANZECC & ARMCANZ (2000) guidelines, only three levels are provided from which to assign a level of protection. These are:  
- "high conservation/ecological value systems" (e.g. pristine rivers in national parks);  
- "slightly to moderately disturbed systems" (ecosystems that have been adversely affected to a relatively small but measurable degree by human activity); and  
- "highly disturbed systems" (measurably degraded ecosystems of lower ecological value).
Framework for Developing the Jandakot Water Resources Management Strategy

Step | Outputs for the Jandakot study area
--- | ---
Identify key environmental concerns (e.g. pollutants of concern) for the receiving waters. | The primary pollutants of concern are:
- nutrients (phosphorus and nitrogen) primarily due to the impacts of algal blooms in wetlands, the Serpentine River and the Peel Inlet-Harvey Estuary (see the Peel-Harvey Coastal Plain Catchment Statement of Planning Policy 1992 and the Environmental Protection [Peel Inlet-Harvey Estuary] Policy 1992);
- sediment (particularly fine sediment in stormwater which, in urban areas, has the potential to adsorb phosphorus and toxicants such as heavy metals and pesticides); and
- gross pollutants (e.g. litter which can cause aesthetic impacts and wildlife entanglement, and excessive organic matter which can decay and reduce dissolved oxygen levels in water bodies).

Define management goals for the receiving waters, stormwater quality and/or groundwater quality. | The following water quality related, long-term management goals are proposed for the study area:
- To ensure that stormwater run-off and shallow groundwater migration from the proposed development area does not adversely affect the desired environmental values of waterways and wetlands within and downstream of the study area.
- To ensure that surface water quality, groundwater quality and ecological health of water bodies that receive drainage from the study area are maintained or improved as a result of development.
- To ensure that all water resources management strategies and plans used at the site represent current best practice, particularly with respect to nutrient management.

Note that these proposed goals reflect principles and directions obtained from the project brief, Peel-Harvey Coastal Plain Catchment Statement of Planning Policy 1992, the Environmental Protection (Peel Inlet-Harvey Estuary) Policy 1992, the State Water Quality Management Strategy (Government of WA, 2000), the current national water quality guidelines for fresh and marine water quality (ANZECC & ARMCANZ, 2000), the Beeliar Regional Park Draft Management Plan (CALM et al., 2001), and discussions with officers from the Department of Environment.

Identify appropriate guidelines for selected water quality indicators (e.g. TN, TP). | A range of ‘guidelines’ and reference information have been used for this project to determine the significance of water quality data sets. These include:
- Existing surface water quality and groundwater quality from relatively unimpacted areas within the site and upstream of the site (see Chapter 2.2).
- The quality of groundwater in urbanised areas with a similar soil type on the Swan Coastal Plain (see Gerritse et al., 1990).
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000), given the current lack of high-quality reference site data, endorsed urban stormwater quality objectives/targets for Perth, and the lack of site-specific scientific assessments that recommend water quality objectives).

The values from these sources of information are presented in Tables 2.1 – 2.4.

---

Management goals are usually long-term objectives that can be used to broadly assess whether the corresponding environmental value is being maintained. According to ANZECC & ARMCANZ (2000) “they should be structured so that they can become the key objectives to be achieved through management plans and therefore should relate to particular parts of the environment that can be measured”. For more information, see ANZECC & ARMCANZ (2000).
Framework for Developing the Jandakot Water Resources Management Strategy

<table>
<thead>
<tr>
<th>Step</th>
<th>Outputs for the Jandakot study area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determine a set of water quality–related conceptual design and monitoring objectives for the study area.</td>
<td>The proposed water quality-related conceptual design and monitoring objectives for stormwater and shallow groundwater from the study area are given in Table 2.7.</td>
</tr>
</tbody>
</table>
Table 2.6: Proposed environmental values of affected water bodies within and downstream of the Jandakot study area

<table>
<thead>
<tr>
<th>Environmental Values to Protect or Achieve</th>
<th>Healthy aquatic ecosystems</th>
<th>Primary industries</th>
<th>Recreational water quality &amp; aesthetics</th>
<th>Drinking water</th>
<th>Industrial water</th>
<th>Cultural &amp; spiritual values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant Water Bodies that May be Affected</td>
<td>Irrigation and general water use</td>
<td>Stock drinking water</td>
<td>Commercial fishing</td>
<td>Aquaculture</td>
<td>Human consumers of aquatic foods</td>
<td>Navigation of commercial vessels</td>
</tr>
<tr>
<td>The Peel and Birrega Main Drains (and associated wetlands)</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Spectacles Wetlands (and other ‘conservation category’ wetlands in the study area)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Serpentine River (downstream of the junction with Birrega/Peel Drains)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Peel Inlet-Harvey Estuary*</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Shallow groundwater within the study area</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Notes on EVs 1 2 3 4 5 6 7

See following page for notes...
Notes for Table 2.6:

1. This EV includes:

   Maintenance of ecological functions, ecological integrity and ecological processes upon which ecosystems depend (both in the water body and in associated wetlands).

   Provision of habitat for locally indigenous fauna, including migratory and/or threatened species.

   Provision of habitat for locally indigenous flora, including threatened species.

   Maintenance of diversity and abundance of locally indigenous fauna and flora.

2. This EV is only acceptable in waters classed as “navigable waters” under the State’s Navigable Waters Regulations.

3. This EV includes recreational fishing and navigation of recreational vessels.

4. This EV includes walking, cycling, photography, bird watching, and scenic amenity.

5. This EV concerns drinking water with treatment.

6. This EV includes the provision of a source of water for incorporation into industrial processes and to use for cooling, heating, washing and evaporative activities.

7. This EV includes:

   The concept of landscape (e.g. protection of fringing vegetation, pools, beaches, sand spits, foreshore cliffs).

   Values of indigenous Australians as well as the broader Australian community.

8. The Peel Inlet-Harvey Estuary contains one of the most important wetland systems in the southwest of WA with international obligations for environmental wildlife and cultural value protection. It is listed under the RAMSAR convention (Evangelisti et al., 1994). Nutrients, particularly phosphorus, represent a major threat to the health of the system.

It is possible that ambient water quality may have to improve to protect these EVs in the longer term.

This table should be considered as a draft until broader consultation has occurred with the community. EVs have been proposed based upon knowledge of the site and background reports (e.g. the Beeliar Regional Park Draft Management Plan, the Jandakot Draft Structure Plan, the Peel-Harvey Coastal Plain Catchment Statement of Planning Policy 1992, the Environmental Protection [Peel Inlet-Harvey Estuary] Policy 1992, a report on an investigation into Aboriginal significance of wetlands and rivers in the Perth-Bunbury region, etc.).

EV categories have been derived from ANZECC & ARMCANZ (2000) and only relate to water quality.

Although the maintenance of environmental flows is not a water quality related environmental value, after a review of local literature it is suggested that the maintenance of the Spectacles Wetlands’ current hydrologic regime should be a primary objective during the design of stormwater/groundwater management strategies and infrastructure for the site.
### Table 2.7: Proposed water quality-related conceptual design and modelling objectives for the Jandakot study area

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Water Quality-Related Design and Modelling Objectives</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stormwater</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General objective</td>
<td>Maximise the control of pollutants at the source (especially nutrients), as well as maximise infiltration of treated stormwater and re-use of treated stormwater.</td>
<td>These are common-sense principles and consistent with the current policy of the Department of Environment.</td>
</tr>
<tr>
<td>General objective</td>
<td>Ensure stormwater and shallow, ambient groundwater quality is at least maintained and preferably improved as a result of development. Wetlands will need to continue to provide an ongoing partial treatment function.</td>
<td>See below for a quantitative description of this objective for modelling purposes.</td>
</tr>
<tr>
<td>General objective</td>
<td>Locate drainage away from known sources of soil or groundwater contamination (i.e. ensure surface water drainage is isolated from enriched groundwater plumes).</td>
<td>See the groundwater Chapter of this document.</td>
</tr>
<tr>
<td>General objective</td>
<td>Ensure no new drainage is constructed directly to Conservation (C) category wetlands (e.g. the Spectacles Wetlands), but where there is existing drainage that supports environmental values of these wetlands, maintain the existing hydrologic regime.</td>
<td>Although not a water quality-related objective, changes to the hydrologic regime (in terms of flow rate, timing and volume) of conservation category wetlands is a significant risk to their health and should be minimised.</td>
</tr>
<tr>
<td>General objective</td>
<td>Promote rehabilitation of Resource Enhancement (R) category wetlands by preventing or minimising direct connection of stormwater to these water bodies. However, where existing drainage supports environmental values in these wetlands, seek to maintain the existing hydrologic regime.</td>
<td>Wetland locations and their categories are given in the draft Jandakot Structure Plan (see Appendix B). It is suggested that the only R category wetland within the site that is clearly dependent on the existing network of main drains is Bollard Bulrush Swamp, off Bertram and Wellard Roads, in the southwest corner of the site. The Peel Main Drain transects this wetland.</td>
</tr>
<tr>
<td><strong>Total phosphorus (TP),</strong></td>
<td>When undertaking pollutant export modelling for the study area, seek to ensure:</td>
<td>For modelling objective # 1 note that Shams (1997) estimated the TN and TP loads entering the Spectacles Wetlands to be 12 tonnes/year and 1.7 tonnes/year, respectively. Of the TN load, 58% originated from the Peel Main Drain (the remainder being from groundwater). Of the TP load, 80% originated from the Peel Main Drain (the remainder being from groundwater). Pollutant export rates to use in the modelling exercise can be obtained from Kelsey (2001).</td>
</tr>
<tr>
<td><strong>Total nitrogen (TN) and total suspended solids (TSS)</strong></td>
<td>the predicted average annual loads of TP, TN and TSS leaving the site and entering the Spectacles Wetlands in stormwater are minimised and are no greater than predicted existing loads; and if practicable using best practice urban stormwater management practices</td>
<td>For modelling objective # 2, these figures are based on the surface water quality results obtained as part of a ‘snap shot’ water quality survey undertaken as part of this study (see Appendix C), indicating that these concentrations are realistic objectives for major drains flowing out of the study area during periods of steady flow (i.e. they are being met now in several of the drains, including the largest drain in the study area – the Peel Main Drain). These objectives are also consistent with relevant ANZECC &amp; ARMCANZ</td>
</tr>
<tr>
<td><strong>[modelling objectives]</strong></td>
<td>median concentrations of TN and TP in stormwater leaving the site are reduced to 1.2 and 0.065 mg/l, respectively.</td>
<td></td>
</tr>
</tbody>
</table>
### Aspect | Water Quality-Related Design and Modelling Objectives | Comments
---|---|---
Framework for Developing the Jandakot Water Resources Management Strategy | Guidelines (2000) for the protection of aquatic ecosystems in South West Australian freshwater lowland rivers and waterways. The clause of practicality is imposed on modelling objective # 2 as it is acknowledged that such objectives can be difficult to meet for some site conditions even when expressed as ‘medians’. Once pollutant export modelling occurs, the practicality of achieving these ideal objectives using the latest best management practices can be determined. It is noted that modelling objective # 2 is stringent and may not be achievable at all sites in the Perth region. However, recent pollutant export modelling by Ecological Engineering Pty Ltd on the Swan Coastal Plain indicates such objectives are challenging (especially for nutrients), but can be achieved at some sites via best practice water sensitive urban design. It is strongly recommended based on the national experience of Ecological Engineering Pty Ltd that both load and concentration-based objectives be set for modelling purposes to minimise the loads of pollutants entering the Peel Inlet-Harvey Estuary system, and to maintain good water quality in the immediate receiving environments for the majority of the time. | 

| All nutrient species | Minimise loads and concentrations in stormwater and shallow groundwater. | - |

| Turbidity | Minimise the potential for elevated turbidity in stormwater. | - |

| Dissolved oxygen | Minimise the potential to generate low DO levels in stormwater. | - |

| pH | Minimise the potential to generate very low and/or very high pH levels in stormwater and shallow groundwater. | - |

| Salinity | Minimise the potential to generate saline conditions in stormwater and shallow groundwater. | - |

Gross pollutants | Ensure no anthropogenic (man made) material > 5mm in any dimension leaves the study area (or enters conservation category wetlands) via treated stormwater that drains from a treatment system designed to treat at least the 1:6 month ARI storm event. Based on Guidelines on Identifying and Applying Water Quality Objectives in Brisbane City (BCC, 2000) – guideline to protect aquatic ecosystems and prevent aesthetic impacts. Note that the 1:6month Average Recurrence Interval (ARI) storm events in Perth represents 99% of the average annual run-off volume (Wong, 2001). This design criteria is relatively conservative on a national basis but has been suggested by the Department of Environment. | - |
<table>
<thead>
<tr>
<th>Aspect</th>
<th>Water Quality-Related Design and Modelling Objectives</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>groundwater by minimising changes to the pre-development hydrogeological regime where rising groundwater tables may become saline and drain to surface waters.</td>
<td></td>
</tr>
<tr>
<td>Heavy metals</td>
<td>Minimise loads and concentrations of heavy metals in stormwater and shallow groundwater.</td>
<td></td>
</tr>
<tr>
<td>(especially Cu, Pb, Zn)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oils and grease</td>
<td>Minimise visible films or odour in stormwater.</td>
<td></td>
</tr>
<tr>
<td>Pathogens</td>
<td>Minimise the potential for pathogens (e.g. bacteria, viruses, parasitic protozoa and helminths) to discharge from the site during periods when primary or secondary activities in downstream waterways (e.g. the Peel Inlet-Harvey Estuary) are likely.</td>
<td></td>
</tr>
<tr>
<td>Shallow Groundwater</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutrients (N and P)</td>
<td>Ensure the quality of shallow groundwater (for TP, FRP/Ortho-P, TN, NO₃⁻, NH₄⁺) as expressed by median concentrations is no greater than the highest of the following values:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▪ The pre-development shallow groundwater/recharge water quality (needs to be better characterised using the monitoring regime outlined in Chapter 2.4).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▪ Concentrations found in comparable urbanised areas of Perth (see the values shown in Table 2.4 from Gerritse et al. [1990]).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▪ Guideline values for the protection of freshwater ecosystem health (see the values shown in Table 2.4 from ANZECC &amp; ARMCANZ, 2000).</td>
<td></td>
</tr>
<tr>
<td><strong>Interim advice only</strong></td>
<td>More information is needed on the current quality of shallow groundwater across the site. This objective is strongly based on pragmatism. It recognises that:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▪ it may take considerable period of time to improve groundwater quality to concentrations approaching ANZECC &amp; ARMCANZ guidelines (if ever);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▪ existing groundwater quality is poor in some areas but recharge water quality should improve quickly following development and help to improve those areas that currently suffer from nutrient-enriched groundwater;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▪ some low-level groundwater contamination is expected in urban areas, but is not considered to be a major threat to receiving water bodies within the study area, unlike stormwater; and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>▪ groundwater moving into the study area from up-gradient may be contaminated.</td>
<td></td>
</tr>
</tbody>
</table>
| Nutrients (N and P) | Minimise inputs of nitrogen (N) and phosphorus (P) to groundwater via infiltration of stormwater. This can be done through the use of best management practices such as:

- xeriscaping (resource sensitive landscaping);
- shallow groundwater irrigation;
- directing shallow, nutrient-rich groundwater (that has been contaminated by development) to stormwater treatment systems;
- controlling fertiliser use and the type of fertiliser;
- use of targeted garden/lawn care educational programs such as the successful ‘Master Gardener’ programs run in the US;
- promotion of fertigation;
- the manipulation of development density to reduce the net lawn/garden area;
- soil amendment (e.g. the use of a loam top-soil over sand); and/or
- nutrient management plans for open space. | The focus should be on source reduction of P, as unlike N, the potential for attenuation of P concentrations will be minimal as shallow groundwater moves through the Bassendean and Karrakatta Sands.
For more details on relevant source control techniques, see Whelans et al. (1994), Taylor and Wong (2002), Davies (2001) and DoE (in prep). |
| --- | --- | --- |
| Nutrients (N and P) | Promote groundwater conditions that promote denitrification (i.e. pH in the range of 5 - 7, the redox potential <300mV, and high concentrations of TOC in the range of 15 – 70 mg/l). | See Gerritse et al. (1990) and McFarlane (1983).
Some of these parameters can be manipulated. For example, the use of constructed wetlands in Perth has been found to increase concentrations of total organic carbon (TOC) in local groundwater. |
| Nutrients (N and P) | Where groundwater is extracted for irrigation, extract that portion of the shallow groundwater that is enriched with nutrients. | Likely to be the top of the water table down-gradient of the source (see Davies, 2001; Shams, 1997). |
2.4 Recommended Water Quality Monitoring Regime

2.4.1 Introduction

The development of the study area, as defined in the draft Jandakot Structure Plan (see Appendix A), is likely to take several decades although the exact timing is uncertain. Planners have estimated that 50% of the total population will have moved into the study area within 25 years (Allen, 2002).

Given the likely protracted and staged nature of development, it is recommended that water quality monitoring occurs in stages, rather than over the entire development period. Stages of monitoring that would be linked to stages of development. This will ensure monitoring resources are used most efficiently.

The typical stages of development for the study area are shown in Figure 2.2. This figure also indicates the likely timeframe associated with major stages in the development process. The recommended monitoring regime has been developed with an awareness of these stages and timeframe.

Four types of water quality related monitoring are recommended for the study area given the proposed development and site conditions. These have been developed in consultation with the Department of Environment and are briefly described below.

2.4.2 Ecological Health Monitoring

The Spectacles Wetlands are a significant environmental asset within the study area and potentially under threat from proposed urbanisation. Monitoring the health of these wetlands over time using aquatic macro-invertebrates is recommended as a cost-effective strategy. This recommendation is consistent with those in the Beeliar Regional Park Draft Management Plan (CALM et al., 2001).

It is understood that Murdoch University undertakes ecological health monitoring of some wetlands in the region (see CALM et al., 2001) and would be best suited to undertake this role. Funding recommendations for all monitoring activities are provided in Chapter 2.4.6 below.

It is recommended that seasonal macro-invertebrate monitoring (i.e. four times a year):

- occur for at least two years prior to major development up-stream of the Spectacles Wetlands (i.e. in the period between the finalisation of the Jandakot Structure Plan and the commencement of land development);
- does not occur during periods when major development (i.e. earthworks) is occurring up-stream of the Spectacles Wetlands;

---

12 It is understood that Murdoch University’s aquatic macroinvertebrate research has generally involved discrete projects, rather than a comprehensive, regional monitoring program (CALM, 2003). However, Murdoch University clearly have the relevant expertise and background knowledge to undertake this type of monitoring in the region, and if funded to do so, may be able to leverage of these resources to enhance their research projects.
- occur for two years after each stage of major development has been completed up-stream of the Spectacles Wetlands (if the period between development stages is greater than 2 years); and

- occur for two years after the final stage of major development is completed up-stream of the Spectacles Wetlands.

The primary objective of this monitoring would be to determine whether the wetland’s health, as indicated by macro-invertebrate assemblages, is being maintained or improved as a result of land use changes in the wetlands’ catchment.

### 2.4.3 Stormwater Pollutant Load Monitoring

Ensuring there is no increase in nutrient loads leaving the study area and entering sensitive waterways such as the Peel Inlet-Harvey Estuary or the Spectacles Wetlands are important objectives that need to be monitored.

To do this, it is recommended that two gauging stations and auto-samplers be established. Crump weirs or similar should be installed in the open channels upstream of any road culverts. Both would be on the Peel Main Drain, with one being located near Anketell Road (as the drain enters the Spectacles Wetlands) and the other being located on Millar Road where the drain leaves the study area prior to the Peel Sub N drain confluence. The former station aims to gather data that can be used to assess the loads of pollutants (and flows) entering the Spectacles Wetlands, while the latter station can be used to indicate how successful urban stormwater minimisation and treatment measures have been to minimise pollutant loadings on downstream receiving waters.

It is recognised that the monitoring station at Millar Road would only monitor stormwater draining from approximately half the study area (i.e. the western half). However, this portion of the study area contains the largest area of land to be urbanised as well as the most sensitive ecological and social values. In addition, the significant cost of establishing, maintaining and decommissioning gauging stations and auto-samplers on all of the drainage points leaving the eastern side of the study area cannot be justified. Trends over time may be gained by an appropriately designed grab sampling program for other drains.

It is recommended that the Department of Environment establish and maintain these specialist monitoring assets, with monitoring to occur during the following periods:

- monitoring to occur for at least two years prior to major development up-stream of the auto-samplers (i.e. in the period between the finalisation of the Jandakot Structure Plan and the commencement of land development);

- monitoring would not occur during periods when major development (i.e. earthworks) is occurring up-stream of the auto-samplers;

- monitoring to occur for two years after each stage of major development has been completed up-stream of the auto-samplers (if the period between development stages is greater than 2 years); and

- monitoring to occur for two years after the final stage of major development is completed up-stream of the auto-samplers.
To minimise costs, monitoring parameters would include:

- Flow (at all times).
- TN and TP for at least 10 run-off events per monitoring period (as defined above).
- Nutrient species (e.g. ortho-P, TP, NO$_x$, TKN, NH$_4$+ TN) for at least three run-off events per monitoring period (as defined above).

To ensure high-quality data is collected from this form of monitoring and such data are appropriately analysed, it is recommended that the Department of Environment install the stations as well as collect and analyse the data. Funding recommendations are provided in Chapter 2.4.6.

### 2.4.4 Groundwater Recharge Monitoring

Groundwater quality is a significant issue for the study area. ‘Hot spots’ of nutrient-enriched groundwater currently exist and will move towards receiving waters (e.g. wetlands and drains) at a rate in the order of 36 – 76 metres per year (Shams, 1997). These ‘hot spots’ are however, poorly defined and understood. In addition, urbanisation has the potential to contaminate groundwater, particularly where infiltration is being widely used as a means of disposing or storing stormwater.

To determine whether shallow groundwater quality is slowly improving with time or at least not degrading as a result of development, two monitoring options are presented below, with the first option being recommended:

1. Fixed groundwater bores (preferred option):

   This option would involve installation of a series of groundwater monitoring bores (greater than 10 for each stage of development) that sample both shallow and deeper parts of the superficial aquifer in a similar manner as undertaken by Shams (1997). These bores would be located in areas of the study area potentially affected by urbanisation (with exact locations being randomly chosen) and monitor water quality quarterly for DO, Eh, pH, EC, ortho-P, TP, NO$_x$, TKN, NH$_4$+ and TN. The aim of the monitoring would be to demonstrate that the quality of the shallowest and most recently recharged groundwater is generally improving or being maintained across the site.

   Monitoring would occur during the following periods:

   - monitoring to occur for at least two years prior to major development (i.e. in the period between the finalisation of the Jandakot Structure Plan and the commencement of land development);
   - for each bore, monitoring would not occur during periods when major development (i.e. earthworks) is occurring in the immediate vicinity of the bore; and
   - for each bore, monitoring to occur for two years after major development has been completed in the immediate vicinity of the bore.

Again, it is recommended that the Department of Environment install these bores, as well as collect and analyse the data to ensure technical standards are high, impartiality is achieved, and regional benefit can be obtained from the resulting data and knowledge.
Funding recommendations are also provided in Chapter 2.4.6. Groundwater intercepted by Birrega Main Drain will also be assessed through continuous discharge monitoring.

2. Suction cup lysimeters:

This type of monitoring would also aim to demonstrate that the quality of the shallowest and most recently recharged groundwater is generally improving or at least being maintained across the site.

Recharge water would be sampled at the top of the saturated zone with suction cup lysimeters approximately two days after a significant rainfall event. The lysimeters extract water using negative pressure. At least 20 monitoring sites are recommended for each stage of development and each sampling event. Sampling would occur quarterly.

The lysimeters could be installed using hand augers in locations with shallow groundwater. Sites would be randomly selected within the regions of the study area where groundwater is potentially affected by urbanisation. The sites would be randomly selected for each sampling event both prior to development and after development (i.e. monitoring would not occur at fixed locations).

Monitoring would occur during the following periods:

- monitoring to occur for at least two years prior to major development (i.e. in the period between the finalisation of the Jandakot Structure Plan and the commencement of land development);
- for each sampling location, monitoring would not occur during periods when major development (i.e. earthworks) is occurring in the immediate vicinity; and
- for each sampling location, monitoring to occur for two years after major development has been completed in the immediate vicinity.

For each major development stage, statistics would be undertaken at the completion of sampling to demonstrate whether the data support the conclusion that there has been a general improvement, maintenance or degradation in shallow groundwater/recharge water quality.

This option has the disadvantage of being un-tested on the Swan Coastal Plain, although the Department of Environment have recently been involved in the development of this method. The method has also been recommended in recently finalised ‘urban water management strategy study’ to the north east of the site (see JDA et al., 2002).

If this option is adopted, it is recommended that Department of Environment install the equipment as well as collect and analyse this data. Funding recommendations are also provided in Chapter 2.4.6.

2.4.5 BMP Monitoring

Assuming development proceeds, various best management practices (BMPs) will be proposed for the study area to minimise stormwater pollutant loads, groundwater pollution and variations in hydrology. Some of these may be structural (e.g. gross pollutant traps, bioretention systems, vegetated swales, groundwater reuse, etc.) while others non-structural (e.g. education on fertiliser use, nutrient management plans for
public open space, soil amendment, xeriscaping, use of local laws, etc.). The Western Australian stormwater management manual is currently being updated to provide local stakeholders with the latest advice on the use of such BMPs (DoE, in prep).

Monitoring is recommended to ensure that the proposed BMPs are fully implemented as approved (e.g. in accordance with conditions associated with the subdivision approval, the outline development plan, and detailed urban water management plans). Such monitoring would occur immediately upon completion of each development stage in accordance with specific, reasonable and relevant development conditions. Standard development conditions could be developed to ensure these conditions are technically sound and consistently applied across the study area.

It is recommended that Council undertake this form of compliance monitoring as they would for conditions relating to developer contributed assets (e.g. the construction of minor roads and drainage). The resources to allow Council to undertake this task would be generated from development application fees. If however, Council feels that specialist skills are needed for this form of monitoring, and independent engineering firms could be engaged to undertake the task.

2.4.6 Recommendations for Future Water Quality Work

The development of numerical objectives and strategies to manage surface and groundwater quality across the study area is currently hampered by a lack of high quality data on groundwater quality and to a lesser extent surface water quality.

In particular, little is known about the nature, location, rate of movement and risks associated with isolated plumes of nutrient-enriched groundwater that have occurred primarily as a result of market gardening activities. These are of concern as they may ‘break through’ into surface waters in the future, leading to elevated concentrations and loads of nutrients in downstream aquatic environments. Without information on these plumes, making predictions on the future water quality (e.g. through pollutant export modelling) is subject to increased levels of uncertainty.

The following tasks are recommended to progress the management of water quality in the study area, assuming development occurs as outlined in the draft Jandakot Structure Plan:

1. Break the study area down into smaller planning units (e.g. 6 or 7) that are likely to represent future stages of development.
2. Begin baseline water-quality related monitoring as outlined in this section to generate a better understanding of current conditions in all planning units.
3. Undertake projects to identify, characterise and assess the risks associated with nutrient-enriched groundwater plumes using assessment methodologies typically used for ‘contaminated sites’. This work would enable pollutant export modelling of the study area to include loads generated from groundwater plumes when modelling various post-development scenarios. This work would also enable remedial strategies to be prepared, if necessary.
4. Analyse the data collected and finalise the water-quality related objectives initially proposed as “conceptual design and modelling objectives” in this chapter.
5. Undertake separate pollutant export modelling exercises for each of the 6 to 7 planning units across the study area to determine those BMPs needed to meet finalised water-quality related objectives. This modelling would consider pollutants from ambient shallow groundwater, ‘hot spots’ of nutrient-enriched groundwater, as well as stormwater from the various post-development land uses.

6. Report on the recommended best management practices that should be applied by developers when developing the 6 – 7 planning units.
Figure 2.2: The likely development process at the Jandakot study area and time frame

Draft Jandakot Structure Plan adopted (2001)


Finalisation of the Jandakot Structure Plan

Local government town planning scheme amendments

Metropolitan region scheme rezoning

Landowner(s) prepare outline development plan(s) including detailed drainage and nutrient management plans

Local government initiates rezoning

Formal environmental assessment, as required by the EPA

WAPC transfers land from the ‘Urban Deferred’ to the ‘Urban’ zone

Local government rezoning is finalised and the outline development plan(s) approved

Landowner(s) submit subdivision application(s)

WAPC approves subdivision application(s)

Land development proceeds in stages

Land development complete (estimate: by 2025 - 2050)

Maintenance period (public stormwater-related assets maintained by developers)

3. Site Characteristics

3.1 Geology and Hydrogeology

A conceptual hydrogeological cross section, compiled from drill logs of Water and Rivers Commission monitoring bores, is presented as Figure 1. There are four aquifers of hydrogeological interest in the study area, collectively termed “Superficial Formations”; the Tamala Limestone, Bassendean Sand, Guildford Formation and the Gnangara Sand. Further information on the hydrogeology of the Perth Basin and the Jandakot Mound is available in Davidson (1995).

- Tamala Limestone

  The Tamala Limestone is present in the west of the study area as a cream to yellow calcareous sand. Weathering and leaching of the Tamala Limestone often results in a grey to white, fine to coarse grained, poorly sorted residual sand at the surface. Conversely, concentration of leached calcite can form well-cemented hardpan layers, or calcrete. The Tamala Limestone is cavernous in places, forming karstic terrain, thus the hydraulic properties of the Tamala Limestone can vary widely within a very small area.

  The Tamala Limestone typically has a very high horizontal and vertical hydraulic conductivity and transmissivities have been measured up to 10,000 m²/day in areas of karstic formations in the limestone. Recharge to the Tamala Limestone is by direct infiltration of rainfall, and a small component of lateral flow from the Bassendean Sand. Discharge from the Tamala Limestone is largely to the ocean, although a small component of downward percolation into the Gnangara Sand is anticipated.

- Bassendean Sand

  The Bassendean Sand is of shallow marine origin, pale grey to white, fine to coarse grained, sub-rounded to rounded quartz sand with minor fine grained black heavy minerals scattered throughout. The Bassendean Sand is present over much of the site to depths of up to 40 metres below ground level (mbgl). The transmissivity of the Bassendean Sand ranges between 200 and 1000 m²/day.

  Layers of friable limonite cemented sands, or “coffee rock”, are present within the Bassendean Sand unit close to the watertable, resulting in localised variations in transmissivity.

  Recharge to the Bassendean Sand is by direct infiltration of rainfall. Horizontal and vertical hydraulic conductivity are generally high; it is estimated that recharge by infiltration is up to 25% of rainfall at the Jandakot Mound. Discharge from the Bassendean Sand is dominantly by lateral flow into the Tamala Limestone and percolation to the underlying Gnangara Sand. The Guildford Formation also receives vertical flows from the Bassendean Sand.
### Guildford Formation

The Guildford Formation is present in the east of the study area as brown silty and sandy clays with lenses of fine to coarse grained, poorly sorted, quartz sand. The Guildford Formation is dominantly fluvial in origin, eroded from the granitic basement rocks that outcrop at the Darling Scarp.

The Guildford Formation has a low horizontal hydraulic conductivity and a very low vertical hydraulic conductivity. Recharge to the Guildford Formation occurs via infiltration of rainfall from the overlying Bassendean Sands, and by direct infiltration where the formation outcrops in the east of the study area.

The Guildford Formation tends to maintain a moist profile as a result of slow infiltration of recharge by direct downward percolation. Groundwater discharges from the Guildford Formation into the Gnangara Sand, the Ascot Formation and the Osborne Formation, although discharge is very slow.

### Gnangara Sand

The Gnangara Sand is overlain conformably by the Bassendean sand, interfingers with the Guildford Formation to the east and rests unconformably on the Ascot Formation. The sands are fluvial in origin, pale grey, fine to very coarse grained, very poorly sorted, sub-rounded to rounded quartz and abundant in feldspar.

The Gnangara Sand has a high horizontal and vertical hydraulic conductivity and is recharged by downward percolation from the Bassendean Sand and the Tamala Limestone, and a very minor component of lateral flow from the Guildford Formation. Groundwater discharges from the Gnangara Sand by downward percolation into the Ascot Formation.

### 3.2 Groundwater

#### 3.2.1 Groundwater Levels

Groundwater contours for the superficial formations are shown in Figure 2 and hydrographs for Water and Rivers Commission monitoring bores in the superficial aquifers are shown in Figure 3.

Groundwater in the superficial formations is typically between surface level and 3 metres below ground level (mbgl). Seasonal fluctuations of up to one metre are recorded in the majority of superficial formation bores consistent to variations in rainfall and abstraction patterns from local groundwater users.

A general declining trend is evident in water levels measured in the majority of superficial monitoring bores, most likely due to increased demand on the superficial aquifers by small-scale domestic and commercial users.

#### 3.2.2 Groundwater Flow Direction

The southern flank of the Jandakot Mound is situated in the centre of the study area, protected by the Jandakot Mound Underground Water Pollution Control Area (UWPCA).
Bassendean Sand largely underlies the mound with the central areas a saturated thickness of approximately 40m. Recharge by infiltration at the Jandakot Mound is up to 25% of rainfall and groundwater flows radially from the centre of the mound.

Groundwater flow in the study area generally radiates from the centre of the mound to the east, south and west under an average hydraulic gradient of approximately 1:400 in the Bassendean Sands. Hydraulic gradients increase to as much as 1:75 in wetland areas, e.g. close to the Spectacles wetlands, and are as low as 1:600 in the west of the study area in the Tamala Limestone.

### 3.2.3 Groundwater Use

There are over 1000 bores drilled in the study area. Davidson (1995) estimates that approximately 62,000m$^3$ is abstracted per day for the irrigation of market gardens on the western flank of the Jandakot Mound. The distribution of licensed groundwater users is shown on Figure 4 and summarised on Table 3.1.

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Licensed Allocation (kL/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial</td>
<td>25,123,255</td>
</tr>
<tr>
<td>Leederville</td>
<td>1,808,225</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bore Type</th>
<th>Number of Registered Bores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Irrigation</td>
<td>137</td>
</tr>
<tr>
<td>Industry</td>
<td>39</td>
</tr>
<tr>
<td>Groundwater Exploration</td>
<td>18</td>
</tr>
<tr>
<td>Monitoring</td>
<td>249</td>
</tr>
<tr>
<td>Private Domestic</td>
<td>209</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>408</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1060</strong></td>
</tr>
</tbody>
</table>

It is not possible to determine total abstraction from the superficial aquifers, as private domestic bores do not require licensing or monitoring. The private bores in the study area generally target the Bassendean Sand aquifer.

### 3.2.4 Groundwater Monitoring Bores

The number of existing groundwater monitoring bores in the study area (See Figure 5) is currently insufficient to determine groundwater levels, enable groundwater modelling for base flow estimates or analyse existing groundwater quality conditions.

Installation of additional monitoring bores is required for:

- The assessment and modelling of groundwater level fluctuations over time to determine safe floor levels for development;

- The determination of hydrogeological parameters of proposed development sites, including local and regional groundwater flow directions, groundwater level
fluctuations, likely impacts of development on groundwater dependant ecosystems, etc; and,

- The assessment of groundwater quality, including resident catchment and aquifer conditions, short-term mobilisation of nutrients and contaminants resulting from development works, long-term impacts on groundwater quality from development.

### 3.3 Implications for Development

Factors requiring consideration in the development of the site include:

- Shallow seasonally fluctuating water table;
- Stormwater and groundwater management and nutrient export; and
- Potential problem soils.

#### Seasonally Fluctuating Water Table

The water table in the study area fluctuates seasonally by up to 1 metre. Areas of impeded drainage, particularly in the vicinity of wetlands, may become waterlogged during the winter months. Monitoring of water levels for establishment of annual average maximum groundwater level is necessary for proposed developments.

#### Nutrient export

The export of nutrients from the site is dealt with in detail in Section 2. Of interest is the deterioration in water quality that occurs when groundwater is exposed as surface water. Under the current groundwater and surface water flow regimes, surface water from the site drains to the south by the Peel and Birrega Main Drains. Flow through the Spectacles wetlands is by recharge from groundwater from the east and discharge to groundwater to the west.

#### Engineering Properties of Soils

Proposed developments will require investigation to determine the presence of problematic soils. The surficial soils of the study area are generally composed of Bassendean Sand, however, the presence of problem soils such as organic rich sands, isolated lenses of peat and clays cannot be ruled out.

It is recommended the following data collection program be implemented at proposed developments:

- Installation of groundwater-monitoring bores within proposed development boundaries to enable monitoring of groundwater levels, nutrient concentrations, and modelling of groundwater flow directions and hydraulic gradients;
- All bores should be logged for hydrogeological and geotechnical parameters. Detailed geotechnical investigations are not required during this phase of work, however, samples of organic rich material should be collected for analysis if encountered;
Monthly monitoring of water levels for establishment of annual average maximum groundwater level (AAMGL); and

Quarterly collection of groundwater samples for groundwater quality analysis, as per Table 3.2 below.

### Table 3.2: Groundwater Quality Analysis Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Parameter</th>
<th>Parameter</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Oxygen</td>
<td>Total Phosphorous</td>
<td>Nitrate and Nitrite</td>
<td>Total Kjeldahl Nitrogen</td>
</tr>
<tr>
<td>Redox Potential</td>
<td>pH</td>
<td>Total Nitrogen</td>
<td>Nitrogen as Ammonia</td>
</tr>
<tr>
<td>pH</td>
<td>Electrical Conductivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ortho-Phosphorous</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Dissolved oxygen must be measured in-situ prior to sampling, as any disturbance of the water column will result in an erroneous reading. Down-hole water parameter probes should be used to record dissolved oxygen concentrations prior to sampling of each bore.

A suggested schedule of drilling, monitoring and sampling works is shown below as Table 3.3.

### Table 3.3: Investigation Schedule

<table>
<thead>
<tr>
<th>Month</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month 1</td>
<td>Drilling and construction of groundwater monitoring bores, groundwater level monitoring and sampling for water quality analysis</td>
</tr>
<tr>
<td>Month 2</td>
<td>Groundwater level monitoring</td>
</tr>
<tr>
<td>Month 3</td>
<td>Groundwater level monitoring</td>
</tr>
<tr>
<td>Month 4</td>
<td>Groundwater level monitoring and sampling for water quality analysis</td>
</tr>
<tr>
<td>Month 5</td>
<td>Groundwater level monitoring</td>
</tr>
<tr>
<td>Month 6</td>
<td>Groundwater level monitoring</td>
</tr>
<tr>
<td>Month 7</td>
<td>Groundwater level monitoring and sampling for water quality analysis</td>
</tr>
<tr>
<td>Month 8</td>
<td>Groundwater level monitoring</td>
</tr>
<tr>
<td>Month 9</td>
<td>Groundwater level monitoring</td>
</tr>
<tr>
<td>Month 10</td>
<td>Groundwater level monitoring and sampling for water quality analysis</td>
</tr>
<tr>
<td>Month 11</td>
<td>Groundwater level monitoring</td>
</tr>
<tr>
<td>Month 12</td>
<td>Groundwater level monitoring</td>
</tr>
</tbody>
</table>

Note: Groundwater monitoring may need to include wetland level monitoring.

### 3.4 Soil and Land Capability Assessment

A soil and land capability assessment has not yet been carried out in detail for the development area. The land resources were briefly assessed by the Department of
Agriculture in 1986 (Wells et al, 1986), however the study is now outdated and inconclusive. The Department of Agriculture has the ability to produce land capability maps for the area based on their GIS database, however, the resulting map will need to be ground-truthed before development can be planned according to land capability.
4. **Soil Nutrient Status**

4.1 **Sampling Strategy, Sample Preparation and Analysis**

The dominant soils of the JSP study area are pale deep sands of the Bassendean Dune System which to the east are underlain by clayey soils of the Guildford Formation. On the eastern side of the study area soils of the Guildford Formation are near the surface. In the west there are significant areas of pale brown, yellow or orange Karrakatta or Cottesloe sands derived from Tamala Limestone and also peaty or sandy silts associated with swamp deposits.

In suburbs such as Mandogalup and Anketell, the Karrakatta, Cottesloe and swamp soils have been developed for intensive horticulture (market gardens) for many years. Nutrient levels in the dune soils have been investigated previously (refer Section 3.3) and therefore were not sampled for this project.

Parts of the study area with grey-white or pale sands have been used for grazing or for market gardens. These soils have extremely low nutrient retention capacities so leached fertiliser phosphorus (P) may have accumulated in coffee rock that often underlies Bassendean sands. Where there is future soil disturbance, for example during earthworks or subdivisional construction, there is potential for release (desorption) of P. Hence the P status of representative soil profiles needed to be assessed.

Three areas were chosen for soil sampling:

Area 1: The proposed Oakford Village with pale shallow sands over sandy clay soils.

Area 2: Casuarina just east of the Kwinana Freeway with peaty or silty sands with reported common occurrence of coffee rock.

Area 3: An area of sandy silt (swamp) soils in Mandogalup and Anketell, adjacent to the Kwinana Freeway.

A total of 29 exploratory auger holes were dug to a maximum depth of about 1 metre to describe soils and to recover one sample of potentially P-retentive subsoil from each hole. The number of holes dug in Areas 1 to 3 were 7, 12 and 10 respectively. Based initially on soil profile descriptions 14 samples were nominated for examination, but only 7 of these were considered likely to have a significant P-retention capacity and to warrant chemical analysis. Four of these were yellow or orange sands and three were described as black clayey sands, probably similar to coffee rock (CR). None of the 7 samples analysed were from the proposed Oakford Village area. Brief soil profile descriptions and sampling depths for the 7 sites are given in Table 4.1.

Samples were dried at 40-50°C, aggregates were gently crushed and sieved to less than 2mm. The fine material was analysed for bicarbonate extractable phosphorus (Bic P), phosphorus retention index (PRI) and total phosphorus (Total P). PRI gives an indication of the short term P-retention capacity of soil, Bic P is a measure of exchangeable (potentially leachable) P and Total P is a measure of background (native) P plus accumulated P. The value of PRI is lowered by adsorption of P, and hence results
for PRI and Bic P must be considered together to assess the potential for soil either to release P or to accumulate further inputs of P. This is done by calculating the current equilibrium concentration of P in the soil solution (Pss) of saturated soils. The model used for this is not applicable to soils with PRIs greater than about 50.

A similar analysis approach to assess levels of accumulated nitrogen (N) was not carried out because N is converted rapidly to the nitrate form which is not adsorbed by soils and is rapidly leached during winter or is denitrified under waterlogged conditions.

4.2 Results

Results are presented in Table 4.1.

Samples of yellow-orange sands had PRI values of 3.1-8.4, low Bic P concentrations of 2-5 mg/kg and low Total P concentrations of 33-52 mg/kg. Calculated concentrations of Pss were 0.02 mg/l or less, indicating that soils at those sites had been exposed to small inputs of P.

Table 4.1 Results of phosphorus soil analyses for samples from the Jandakot study area, converted to values of P in soil solution (Pss) and P retention ratings.

<table>
<thead>
<tr>
<th>Site (Refer Fig. 5)</th>
<th>Soil Description and Sample Depth (cm)</th>
<th>PRI</th>
<th>Bic P (mg/kg)</th>
<th>Total P (mg/kg)</th>
<th>Calc Pss</th>
<th>P Retention Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Black c/sand 30-50</td>
<td>269</td>
<td>32</td>
<td>146</td>
<td>Nd</td>
<td>Not classified</td>
</tr>
<tr>
<td>18</td>
<td>Yellow sand 80-100</td>
<td>3.6</td>
<td>2</td>
<td>33</td>
<td>&lt;0.01</td>
<td>Low</td>
</tr>
<tr>
<td>20</td>
<td>Black c/sand 80-100</td>
<td>30</td>
<td>7</td>
<td>37</td>
<td>&lt;0.01</td>
<td>High</td>
</tr>
<tr>
<td>23</td>
<td>Orange sand 90-110</td>
<td>3.1</td>
<td>4</td>
<td>20</td>
<td>0.02</td>
<td>Low</td>
</tr>
<tr>
<td>25</td>
<td>Black c/sand 60-80</td>
<td>328</td>
<td>63</td>
<td>543</td>
<td>Nd</td>
<td>Not classified</td>
</tr>
<tr>
<td>26</td>
<td>Orange sand 80-100</td>
<td>4.2</td>
<td>5</td>
<td>52</td>
<td>0.02</td>
<td>Low</td>
</tr>
<tr>
<td>29</td>
<td>Orange sand 70-90</td>
<td>8.4</td>
<td>4</td>
<td>31</td>
<td>&lt;0.01</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

1. Calc Pss = Estimate of P in soil solution, calculated from PRI and Bic P.
2. PRI = Phosphorous Retention Index.
3. Bic P = Bicarbonate extractable P
4. P retention ratings are based on both the calculated Pss and the classifications for PRI given in Methods for Analysis of Phosphorus in WA Soils, DG Allen and RC Jeffery, Chemistry Centre WA Report No. 37, March 1990

By comparison two of the three black clayey sand (CR) samples had very high PRI values but also high to very high concentrations of Bic P and Total P. It was not possible to calculate Pss for these samples. Further analysis to measure Pss directly would be required. Also it was not possible to classify these samples with regard to their future P-retention capacity, because interpretation is complicated by the current P-status. The results for two samples of CR indicate exposure to significant inputs of P. It is likely that such material could present a risk of P release if disturbed.

It is important to note that two of the three CR samples recovered for this project had high concentrations of P, but there are many sites throughout the study area where CR has
been encountered (See Figure 5 Coffee Rock Locations), including in the south-western and western parts of the study area that are planned for urban development.

It is strongly recommended that further investigation be carried out of CR distribution and chemical properties via a more extensive survey combined with detailed sampling and analysis of representative soil profiles. The survey should concentrate on soils in areas that are likely to have received nutrients exported from intensive horticulture or intensive animal industries or affected by effluent disposal.

4.3 Soils Used for Intensive Horticulture (Market Gardens)

In the west of the study area there are significant areas of pale brown, yellow or orange Karrakatta or Cottesloe sands derived from Tamala Limestone and also peaty or sandy silts associated with swamp deposits. These have been developed for intensive horticulture (market gardens) for many years.

In 1990 a survey of 35 market gardens on the Swan Coastal Plain was carried out (McPharlin IR and Jeffery RC, unpublished, Survey of Soils Under Vegetable Production on the SCP) to ascertain both the level of fertiliser use on vegetable crops and the effect of high nutrient inputs on the chemical properties of market garden soils. The range of annual rates of N and P application as given by the vegetable growers were found to be 180-5620, mean 1260 kg/ha/year of N and 75-990, mean 310 kg/ha/year of P. One reason for the wide range of nutrient applications was variation in the rate of application of poultry manure (PM), which could vary from 20-200m$^3$/ha, equivalent to 200-2000 kgN/ha and 70-700 kgP/ha.

In the past vegetable growers generally have not taken account of residual nutrients in the topsoil when planning the fertiliser program for the following crop. If the average rates of nutrients had been applied each year the residual nutrients available for leaching would have been about 1000kg/ha of N and 260kg/ha of P each year.

4.3.1 Phosphorus

Analysis of market garden soils showed not only that there were generally very high concentrations of Bic P in the cultivated layer but that at most sites soil profiles to a depth of 100cm were saturated with P, with profile PRI values of <0 (negative). It was estimated that the concentration of P in soil leachate would generally have been in excess of 10mg/l.

By combining data for Total P in soils with the annual rate of P exported in crops (50kg/ha) and assuming an average P application rate of 310kg/ha/year it was possible to estimate the cumulative rates of P leached over time to beyond a depth of 100cm for different PRI categories of Coastal Plain soils. For example:

PRI <1 P leached = 1080 kg/ha after 5 years and 4530 kg/ha after 20 years
PRI 1-3 P leached = 680 kg/ha after 5 years and 4090 kg/ha after 20 years
PRI 3-7 P leached = negligible after 5 years and 2910 kg/ha after 20 years
Therefore areas that have been important for vegetable production have soils that have been exposed to extremely high fertiliser inputs and that P-retentive soil profiles may have high concentrations of P that could be released if there is future soil disturbance.

4.3.2 Nitrogen

It was indicated above that in the past an average level of residual fertiliser N available for leaching in market garden soils would have been about 1000kg/ha per year. Nitrogen applied to vegetable crops either pre-planting in PM or post-planting in inorganic fertilisers is converted rapidly to the nitrate form. Nitrate-N is not adsorbed by soils and is rapidly leached in sandy soils during winter and even during summer cropping due to inefficient irrigation systems in many market gardens (Milani S, 1990, *Irrigation Survey: Horticulture and the Environment Conference*).

As a consequence nitrate-N concentrations in excess of 10mg/L are commonly found in groundwater beneath horticultural properties (Paulin R, Lantzke N, McPharlin IR and Hegney M, 1995, *Making Horticulture Sustainable*). A survey of 28 market gardens on the Swan Coastal Plain identified 8 properties with irrigation water containing 10-50 mg/L of nitrate-N. Most of these were older market gardens with bores exploring the shallow groundwater. High concentrations of nitrate-N are more likely under properties on Spearwood and Karrakatta sands. A significant degree of denitrification occurs in the watertable under Bassendean sands which greatly reduces the degree of nitrate-N enrichment of groundwater.

4.4 Summary

The dominant soils of the JSP study area are pale deep sands of the Bassendean Dune System which to the east are underlain by clayey soils of the Guildford Formation. On the eastern side of the study area soils of the Guildford Formation are near the surface. In the west there are significant areas of pale brown, yellow or orange Karrakatta or Cottesloe sands and also swamp deposits.

Three areas were chosen for soil sampling, at the proposed Oakford Village, in Casuarina just east of the Kwinana Freeway and an area in Mandogalup and Anketell adjacent to the Kwinana Freeway. A total of 29 exploratory auger holes were dug to a maximum depth of about 1 metre to describe soils and to recover one sample of subsoil from each hole for analysis. The primary aim was to assess the potential for release of phosphorus (P) during earthworks or subdivisional construction. Only 7 samples were considered likely to have significant P-retention capacity and to warrant chemical analysis. None were from the proposed Oakford Village area.

Four subsoil samples of yellow-orange sands had low-moderate PRI values, and low concentrations of Bic P and Total P. Calculated concentrations of Pss were 0.02 mg/l or less, indicating that soils at those sites had been exposed to small inputs of P.

Two of the three coffee rock (CR) samples had very high PRI values but also high to very high concentrations of Bic P and Total P, consistent with exposure to significant inputs of P. It is likely that such material could present a risk of P release if disturbed. There are many sites throughout the study area where CR has been encountered and further
investigation should be carried out via a more extensive survey combined with detailed sampling and analysis of representative soil profiles.

In suburbs such as Mandogalup and Anketell, the Karrakatta, Cottesloe and swamp soils have been used for intensive horticulture for many years. Soils have received extremely high fertiliser inputs and P-retentive soil profiles may have very high concentrations of P. Also nitrate-N concentrations in excess of 10mg/L are commonly found in shallow groundwater beneath horticultural properties. High concentrations of nitrate-N are more likely under properties on Spearwood and Karrakatta sands.
5. Planning Approach and Considerations

5.1 Introduction

The JSP process has produced a number of proposed urban areas which have resulted from an examination of opportunities and constraints in the Jandakot area. However the future urban areas identified are frequently traversed by major powerlines, gas pipelines, main drains and interspersed with wetlands.

The freeway further divides the study area longitudinally.

Notwithstanding these constraints, the structure plan seeks to identify walkable catchments served by a series of proposed neighbourhood or local centres.

The JSP divides the study area into five urban precincts. The structure plan indicates that as detailed planning proceeds, it is expected that the pattern of urban structuring will be modified to suit local conditions.

The existing rural drainage pattern flows generally north to south discharging into the Peel Main Drain.

In formulating the WRMS for the area, the study area has been divided into stormwater management sub-catchments.

Though these do not necessarily correspond with the urban precincts it has been possible to plan for stormwater management on an urban precinct basis subject to recognising the need to plan across sub-catchment boundaries.

Within these urban precincts, stormwater management corridors have been identified based upon one or more of the following criteria:

- The existing rural drainage line;
- And/or where topography allows:
- The location of a stormwater management corridor at the periphery of walkable catchments;
- The location of a stormwater management corridor focussing on the neighbourhood/local centre;
- The location of a stormwater management corridor adjacent and parallel to power or gas line easements or other service corridors.

A landscaped swale with gentle sides is envisaged with natural areas set aside for conservation, active areas for recreation and pathways to provide connectivity through the precinct. Stormwater drains parallel to power line easements should probably be screened by vegetated buffers on the side adjacent to future urban areas and comply with Wester Power requirements.

Where a stormwater corridor is draining through a swale or general valley type terrain it is envisaged raising urban development on both sides overlooking an area of linear open...
space comprising both passive and active recreation areas. Those connecting local neighbourhood centres would be expected to focus upon aesthetic and functional space to:

- Enhance the setting of the centre; and
- Make the centre the focus for a pedestrian/cycle route from the servicing catchment.

Where they are parallel to service easements, the type (particularly the height) of any proposed vegetation and the option for sharing an easement would need to be negotiated with the servicing authority.

Unless wholesale bulk earthworks are to be undertaken the uniformity of the walkable catchments will need to change to suit topographic and drainage requirements.

5.2 The Water Resource Management Concept

As a result of the above a schematic and conceptual stormwater management strategy was developed.

Figure 6 illustrates the proposals and Section 5.3 below details them on an urban precinct basis. Figure 7 indicates the location of the Water Corporation main drains.

However it should be noted that while this plan achieves stormwater management objectives, there are many other options. Given the preference of individual landowners either acting independently or collectively there may be equally effective alternative outcomes.

5.3 Stormwater Management by Urban Precinct

5.3.1 Area 1: Mandogalup (North of Anketell Road) Area 360 hectares

This urban precinct lies between Anketell Road and Rowley Road and comprises five walkable catchments.

With some recontouring the three northernmost catchments can be designed to discharge attenuated stormwater into the northern end of the Peel Main Drain system through appropriate stormwater management corridors as described above.

To the south of these a localised low point forms a logical location for sub-regional flood storage incorporating an appropriately sized wetland for water quality treatment. It may also be designed to incorporate active recreation within the flood storage area.

To the west of this precinct lies Alcoa’s residue disposal operations with potential associated groundwater contamination issues (D Smith, per comms.).

Surplus stormwater would be directed southwards into the existing rural drain system (which would need to be upgraded and possibly relocated in places) before it crosses Anketell Road and then discharges via the Peel Main Drain through “the Spectacles”.

5.3.2 Area 2: Bertram/Wellard (West of Kwinana Freeway) Area 360 hectares

This urban precinct lies between Anketell Road and Millar Road, however “the Spectacles” wetland occupies the northern section between Anketell and Thomas Roads and no urban development is planned in this area.

All six of the proposed walkable catchments for urban development lie south of Thomas Road.

This area is bounded on the west by the proposed southern metropolitan railway line and on the east by the Kwinana Freeway.

The Peel Main Drain traverses the precinct in a manner which results in four of the six catchments directly abutting the drain. The Town of Kwinana are proposing to establish a nutrient stripping basin near the Peel Main Drain immediately to the north of Bertram Road, Bertram.

A stormwater management corridor is proposed around the eastern perimeter of Bollard Bullrush Swamp which provides better access to the remaining two catchments and an alternative for the others.

It also allows the drainage regime established through Bollard Bullrush Swamp to remain unchanged if this is considered desirable.

A sliver of proposed urban land in the north east of the precinct which does not correspond to the walkable catchment concept can be connected to tributary existing east-west rural drainage lines which connect to the Peel Main Drain.

The schematic corridor lines in Figure 6 have again been located at the periphery of walkable catchments where possible or servicing neighbourhood or local centres where the opportunity exists.

5.3.3 Area 3: Wandi/Anketell (North of Thomas Road and east of Kwinana Freeway) Area 230 hectares

This unit is bounded on the east by the Jandakot Rural Water Protection Zone.

As an urban development corridor, it is dissected by a series of wetlands and service easements.

Attempts at defining walkable catchments in this area have been made difficult by the shape of the corridor and the above constraints.

As a result it has not been possible to match stormwater management corridors with an idealised version of community living.

Generally drainage is from north-east to south-west. Corridors are variously shown along service easements, on the perimeter of wetland buffers or utilising existing rural drains (relocated in some instances).

Sub-catchment topography requires that part of the network will need to be orientated to the north west initially prior to its connection to the main drainage network.
Because of the presence of a number of wetlands in this area the precise location of corridors can only be determined following an assessment of the localised hydrology of the area and a determination of appropriate buffers for conservation category wetlands. Part of this assessment will also need to establish the options for management and development for resource enhancement and multiple use wetlands respectively.

5.3.4 Area 4: Casuarina/Wellard (Thomas Road, east of Kwinana Freeway) Area 300 hectares

This urban precinct comprises five walkable catchments, many of which are dissected by wetlands, a quarry and service easements.

Generally drainage is to the west. A rural drainage system in the northern corner of the area and the south of the area currently drains this area including an EPP wetland in the south.

The proposed stormwater management corridor network, again within topographic constraints seeks to parallel service easements where possible and utilise the existing rural drainage network, although in the southern portion the relocation of the network to parallel the service easement would mean that the existing rural drainage network could remain unchanged or abandoned, if further investigations considered this to be desirable.

5.3.5 Area 5: Oakford Village (Corner Thomas and Nicholson Roads) Area 200 hectares

This urban precinct comprises three walkable catchments along Thomas Road at its intersection with Nicholson Road.

This is seen as a long term development option due to the remoteness of sewerage and the need to plan around multiple use wetlands.

While no detailed investigations were made of this area it is envisaged that stormwater management could be reasonably arranged in this area with excess being directed to the Birrega Main Drain.

Because of the low lying nature of some of the land, significant bulk earthworks would be expected to shape urban development interspersed by appropriately located, landscaped and designed stormwater management corridors.

5.4 Ongoing Planning

The design of all the urban precincts in the Jandakot Structure Plan will be constrained by, and be dependent upon stormwater design outcomes.

Inevitably this means, after the regional WRMS is approved that affected landowners will need to co-operate to prepare a detailed stormwater management strategy for the precinct in which their land falls.

While the above concept provides a framework, and the final WRMS will provide a Stormwater Management Strategy that can be relied upon individual developers will need to address the detailed location of major stormwater management corridors, the size and
location of detention basins, the design and landscaping of swales and the need for piped drains in some instances.

Where wetlands are involved, appropriate buffers will need to be established for conservation category and resource enhancement wetlands and design options for multiple use wetlands.

This will provide a structure for abutting urban development and will probably be an interactive process to achieve a potential outcome for walkable catchments.

As a guide to landowners this Framework recommends:

1. The acceptance of the general schematic stormwater layout as sufficient for the acceptance of the Jandakot Structure Plan by the WAPC and as a preliminary guide to Government agencies and landowners.

2. However further investigation are required into:
   a) The establishment of a regional stormwater detention area in Urban Precinct 1 and an associated village centre;
   b) The desirability or otherwise of abandoning the route of the Peel Main Drain through the Spectacles and its replacement with a perimeter drain to the east along the freeway;
   c) The desirability or otherwise of abandoning the route of the Peel Main Drain through the Bollard Bullrush Swamp and the use only of the proposed perimeter drain; and
   d) The management of stormwater in Urban Precincts 3 and 4, to ensure that conservation wetlands in this area are adequately buffered.

3. Landowners will need to demonstrate consistency with the approach adopted in this Strategy and in the final WRMS in the knowledge that they will need to demonstrate to the Department of Environment’s (formerly Water & Rivers Commission) satisfaction that the above matters have been adequately addressed (Refer Section 6 for complete methodology).

4. Subject to the above being satisfactorily completed, an overall structure plan to be prepared by the landowners including environmental assessment documentation, local area drainage and nutrient management plans.

As a guide to planning authorities, the Strategy recommends:

1. Having carried out the above investigations to the Department of Environment’s satisfaction the DoE as the lead agency advise the WAPC that it has no objection to the subject land being rezoned to urban deferred. (This assumes that the investigations listed in Item 2 above have been completed or are not relevant to the proponent’s proposal and provided that the establishment of any necessary headworks outside of the rezoned area can be agreed with the DoE). The rezoning may be recommenced before the finalisation of the final WRMS, however it is not to be approved until the Final WRMS is approved.
2. Having been so advised the WAPC can consider transferring urban deferred land to the urban zone when landowners demonstrate the availability of servicing through an “Infrastructure Provisions Submission”, through the preparation of an outline development plan and subject to an environmental assessment, if required by the EPA.

3. Subject to the satisfactory completion of the above, that the Town of Kwinana and Shire of Serpentine-Jarrahdale amend their town planning schemes as required and provide for:
   - “Infrastructure” contributions as a condition of subdivision.
   - Council management of contributions.
   - Authority to acquire land and enter into negotiations to implement proposals.
   - Provision for expanded infrastructure items.
   - Requirements for the refinement of Outline Development Plans by landowners and/or Councils, prior to subdivision and land development.
   - Detailed financial matters to facilitate development and compensation in a fair and equitable manner.

4. Following the successful completion of the above, the subdivision process as detailed below can follow.
   - Landowner submits application in accordance with the approved Outline Development Plan.
   - WAPC approves subdivision with conditions included to implement Environmental Assessment Conditions set by the Minister for Environment (if any) and Local government implementation measures.
   - Land development proceeds.
6. Wetland Assessment

6.1 Protecting Important Receiving Environments

Wetlands in the JSP area not only include lakes with open water but areas of seasonally, intermittently or permanently waterlogged soil. Because of the flat and low-lying nature of much of the JSP area, significant areas would originally have been classified as wetland. Rural and low-density urban developments in the area mean that few of the original wetlands retain significant ecological values. Regionally, only around 15% of the wetland area has retained high ecological values. These are conservation category wetlands and are listed in various publications (EPA 1993, Hill et al. 1996, GovWA 1997, MfP 1998).

The Government’s position is that conservation category wetlands are accorded the highest priority for protection and conservation. For consistency with the Wetland Conservation Policy for WA (1997) and the Ramsar Convention (UNESCO 1971), the Government has adopted the following definition for wetlands: areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth to which at low tide does not exceed six metres.

However, the provisions of this statement, limited in their extent of reference to the Swan Coastal Plain, only apply to dampland, sumpland, lakes, floodplain and palusplain wetlands. It excludes constructed wetlands.

The following background on wetland classification and management requirements is based on a Department of Environment (DOE) position statement for wetlands of the Swan together with commentary on its application for the Jandakot Structure Plan (JSP) area.

6.2 Wetland Classification

A classification system developed by the Semeniuk Research Group was employed for wetland classification on the Swan Coastal Plain (Hill et al. 1996). This system has been adopted by Government and classifies wetlands based on landform and water permanence, the various types of which are presented in Table 6.1 below.

<table>
<thead>
<tr>
<th>Wetland Type</th>
<th>General Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin Wetlands</td>
<td>Dampland = seasonally waterlogged basin.</td>
</tr>
<tr>
<td></td>
<td>Sumpland = seasonally inundated basin.</td>
</tr>
<tr>
<td></td>
<td>Lake = permanently inundated basin.</td>
</tr>
<tr>
<td></td>
<td>Artificial basins (e.g. dams, reservoirs).</td>
</tr>
<tr>
<td>Flat Wetlands</td>
<td>Floodplain = seasonally inundated flat.</td>
</tr>
<tr>
<td></td>
<td>Palusplain = seasonally waterlogged flat.</td>
</tr>
</tbody>
</table>
Wetland evaluation is the process of assessing the level of significance of a wetland (see Hill et al. 1996). An appropriate management category is assigned to the wetland based on the evaluation, which provides guidance on the nature of the management and protection the wetland should be afforded (see Table 6.2 below).

### Table 6.2: Wetland categories and management objectives

<table>
<thead>
<tr>
<th>Management Category</th>
<th>General Description</th>
<th>Management Objectives</th>
</tr>
</thead>
</table>
| C – Conservation (incorporates EPA Bulletin 686 categories H and C) | Wetlands support a high level of ecological attributes and functions. | Highest priority wetlands. Objective is preservation of wetland attributes and functions through various mechanisms including:  
  - reservation in national parks, crown reserves and State owned land,  
  - protection under Environmental Protection Policies, and  
  - wetland covenanting by landowners.  
These are the most valuable wetlands and the Commission will oppose any activity that may lead to further loss or degradation. No development. |
| R - Resource enhancement (incorporates EPA Bulletin 686 categories O and R) | Wetlands which may have been partially modified but still support substantial ecological attributes and functions. | Priority wetlands. Ultimate objective is for management, restoration and protection towards improving their conservation value. These wetlands have the potential to be restored to conservation category. This can be achieved by restoring wetland structure, function and biodiversity. Protection is recommended through a number of mechanisms. |
| M - Multiple use (aligned with EPA Bulletin 686 category M) | Wetlands with few important ecological attributes and functions remaining. | Use, development and management should be considered in the context of ecologically sustainable development and best management practice catchment planning through landcare. Should be considered in strategic planning (e.g. drainage, town/land use planning). |

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### 6.3 Wetland Mapping

The Department of Environment (formerly Water and Rivers Commission) is the primary custodian of the State’s wetland mapping database, which includes extensive and detailed mapping of wetlands on the Swan Coastal Plain. The DOE’s wetland database is recognised as the most accurate and up to date reference for wetland mapping on the Swan Coastal Plain. The wetland mapping on the DOE’s database, which incorporates wetland evaluation (management) categories, should be consulted for all wetland queries. This will be particularly important as detailed precinct-level design is undertaken.

Despite its currency, the DOE acknowledges that the database, while the most accurate store of wetland spatial information available, cannot be 100% accurate because of the inherent difficulties involved in monitoring all wetlands for changes over time. Therefore, the DOE allows wetlands to be reassessed if an evaluation category is in genuine dispute. A DOE endorsed assessment protocol is available and must be followed by proponents reassessing wetland management categories.
6.4 Wetland Management Requirements

The Government’s position is that there is a presumption against approving any activity likely to impact on priority management wetlands, including developments that are likely to require, cause, or result in the following: filling, clearing, mining, drainage into or out of, effluent discharge into, pollution of, and degradation to the wetland.

Adequate buffers should be applied according to the principles outlined below. The DOE’s position on conservation category wetlands is no development.

6.4.1 Wetland Buffers and Land Use

Buffers are designed to protect wetlands from potential deleterious impacts while helping safeguard and maintain ecological processes and functions within the wetland and, wherever possible, in the buffer. Buffers also act to protect the community from potential impacts such as nuisance midge problems. Buffer distances are measured from the outside extent of wetland dependant vegetation to the outside edge of any proposed development or activity.

The required buffer distances for wetlands depend on the land use, 50 metres being the minimum buffer distance applied. For a guide to the DOE’s wetland buffer requirements for a range of land uses on the Swan Coastal Plain (Davies and Lane 1995) refer to Table 6.3.

Table 6.3: Buffer Requirements for Developments Around Wetlands

<table>
<thead>
<tr>
<th>Purpose of Buffer</th>
<th>Land Use Example</th>
<th>Recommended Buffer Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of impact of nuisance insects on residents</td>
<td>Residential housing.</td>
<td>800-1,000 m depending on orientation of wetland.</td>
</tr>
<tr>
<td>(e.g. midges).</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protection from nutrient inputs.</td>
<td>Market garden.</td>
<td>200 m on transmissive soils, 100 m on non-transmissive soils.</td>
</tr>
<tr>
<td>Protection from pollution (e.g. petroleum hydro-carbons</td>
<td>Mechanical workshop.</td>
<td>200 m.</td>
</tr>
<tr>
<td>surfactants)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protection from heavy metal contamination.</td>
<td>Mineral processing operation.</td>
<td>200 m.</td>
</tr>
<tr>
<td>Protection from pesticide drift.</td>
<td>Orchard.</td>
<td>200 m.</td>
</tr>
<tr>
<td>Reduction of sedimentation</td>
<td>Timber harvesting operation.</td>
<td>100 m.</td>
</tr>
<tr>
<td>Protection of groundwater quality.</td>
<td>Agricultural composting facility.</td>
<td>2,000 m in direction of groundwater flow for transmissive soils</td>
</tr>
<tr>
<td>Protection of avifauna nesting and roosting sites.</td>
<td>Residential housing.</td>
<td>200-800 m.</td>
</tr>
<tr>
<td>Protection from weed infestation.</td>
<td>Residential housing.</td>
<td>50-100 m.</td>
</tr>
<tr>
<td>Maintenance of natural water levels.</td>
<td>Vineyard.</td>
<td>200 m but dependant on water extraction.</td>
</tr>
</tbody>
</table>
Buffer width recommendations may be varied at the discretion of the DOE as new data becomes available. Guidance on the DOE’s buffer recommendations is received from the State Wetland Coordinating Committee sub-committee on wetland buffers.

6.4.2 Land Use Compatibility

As a general rule, wetland management categories are regarded as equivalent to the States public drinking water source protection areas. Therefore, the wetland management categories of conservation, resource enhancement and multiple use correspond to water source protection areas Priority 1 (P1), Priority 2 (P2) and Priority 3 (P3) respectively, in terms of land use compatibility (Water and Rivers Commission 2001).

6.4.3 Existing and Proposed Activities

The DOE recognises that many activities were established prior to the introduction of this statement. However, this is not considered justification for establishing new or expanding existing land use activities that are incompatible with the wetland management objectives. Proposed activities are required to be compatible with the management requirements of any wetlands that the land use may impact.

For more information contact the Wetlands group, Catchment and Waterways Branch, Policy and Planning Division of the Department of Environment.
7. **Water Resource Management Strategy Methodology**

Table 7.1 presents a recommended outline for the preparation of a water resource management strategy (WRMS) for an urban precinct or outline development plan as part of the JSP area. Some tasks have been completed for the entire JSP area however these tasks may need to be augmented by additional work to suit the scale at which the WRMS is being prepared.

The methodology outlined in Table 7.1 is a general guide to the steps to be taken in preparation of a regional WRMS over the whole JSP area. Table 8.1 is included in Section 8 that demonstrates the information required from lead agencies.

**Table 7.1: WRMS Methodology**

<table>
<thead>
<tr>
<th>Task</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Prepare a brief overview of the nature of water resources within the study area and those potentially affected by the proposed development.</td>
<td>Refer Section 2.1</td>
</tr>
<tr>
<td>2. Review available data on surface water quality, groundwater quality and key water-related environmental values for the site as a whole as well as for each of the six planning units.</td>
<td>Refer Section 2.2</td>
</tr>
<tr>
<td>3. Prepare preliminary water quality-related objectives that can be used immediately as ‘modelling objectives’ and ‘conceptual design objectives’ for pollutant export modelling that is needed to be done for the Water Resource Management Strategy (see Task 8 below). These objectives would relate to each of the study area's six planning units.</td>
<td>Refer Section 2.3</td>
</tr>
<tr>
<td>4. Identify and characterise key 'gaps' in our understanding of the water resources in the study area that should be filled in order to deliver a high quality Water Resources Management Strategy.</td>
<td></td>
</tr>
<tr>
<td>5. Gather additional water quality data to fill critical 'gaps' in knowledge. Specifically undertake land-use history investigations to gather information on the nature of nutrient-rich groundwater plumes (i.e. characterise to such an extent that they can be incorporated into pollutant export modelling).</td>
<td></td>
</tr>
</tbody>
</table>
6. Analyse additional data. Land-use history analysis and plume mapping.

7. Make recommendations on future water-related monitoring activities (both pre- and post-development). Refer Section 2.4

8. Undertake pollutant export modelling (incorporating high level, conceptual, water sensitive urban design) to determine whether the proposed land uses, as set out in the Jandakot draft structure plan, can proceed without adversely affecting environmental values of receiving waters.

9. Commence baseline groundwater-related monitoring activities in each of the planning units. This would involve ambient groundwater level & quality monitoring at key locations. This monitoring would need to occur at least 2 years prior to the commencement of development in each planning unit.

10. Commence baseline surface water-related monitoring activities in each of the planning units. This would involve ecological health and surface water hydrology and pollutant loads at key locations. This monitoring would need to occur at least 2 years prior to the commencement of development in each planning unit.

2. Survey

Task

1. Prepare high resolution digital elevation model (DEM) or undertake site feature survey.
### 3. Groundwater

**Task**

1. Undertake groundwater modelling to establish base flows in main drains and open drains.

2. Establish AAMGL.

### 4. Planning

**Task**

1. Planning input for integration of planning and engineering/environmental requirements. Refer Section 5

### 5. Survey & Ground Truth Wetlands

**Task**

1. Ground truth the myriad of smaller conservation category wetlands throughout the project area to ensure that appropriate buffers and setbacks are established as early as possible in the process. Produce conservation wetlands constraint buffer mapping.

### 6. Soil Chemistry

**Task**

1. Soil Chemistry Analysis. Refer Section 4
7. Surface Water Modelling

**Task**

1. Undertake surface water modelling to determine pre and post development flows, detention storages and flood levels.

8. WSUD

**Task**

1. Incorporate WSUD. This will combine outcomes from the planning, environmental, surface and water quality modelling, and groundwater evaluation to provide constraints mapping and a drainage strategy. The following outcomes are expected:
   - A conceptual design of the stormwater treatment infrastructure setting out where major BMP’s would go, preliminary sizing etc.
   - Multiple use corridor locations.
   - Preliminary fill requirements.
   - Subsoil drainage requirements.
   - Major flow paths.
   - Detention basin storage volumes.

**Notes**

**Item 1 Task 5 Land use history investigations, plume mapping**

It has been found from other investigations (Southern River, Mary Carol Park wetlands, South Jandakot Drainage Scheme) that superficial groundwater enriched with nutrients from historical land uses have the capacity to completely overwhelm stormwater quality management infrastructure. It is essential to locate historical nutrient-rich hot spots as early in the WRMP process as possible. Some information is currently available on the presence of historical nutrient-rich hot spots but this is inadequate.

A survey of historical land uses should be undertaken concentrating on those that may have been associated with producing significant accumulations of nutrient-rich superficial groundwater. Old aerial photos, maps, and plans can be assessed together with groundtruthing and liaison with longer-term residents of the project area. Maps of the location, nature and extent of any historical nutrient-rich hot spots can then be prepared. This information is essential for groundwater and surface water quality modelling and will form the basis of developing appropriate management strategies and guidance for developers at the finer scale.

**Item 5. Survey and Ground Truth Wetlands**

There is currently information available on the nature of larger conservation category wetlands for the project area which can form the basis of determining appropriate development setbacks and buffers. There are a myriad of smaller wetlands throughout the project area for which similar information is not available. The presence of smaller wetlands of conservation significance may have a significant impact on planning development footprints. Some wetlands of lesser conservation significance may be able to be sacrificed while others may need to be protected. The nature of these wetlands and the level of...
protection or buffering required needs to be established because this may strongly influence the nature of walkable neighbourhood layout and stormwater management planning. This information will also be required to guide future local-scale development plans.

A survey of all smaller wetlands to determine the nature of their conservation status should be undertaken. A combination of aerial photos, maps, and plans will be assessed together with strategic groundtruthing and liaison. Maps of the location, nature and extent of any required setbacks and buffers for larger and smaller wetlands for the project area will be prepared.

Item 1 Tasks 9 & 10 Surface Water & Ecological Health

Gauged stations will be needed to monitor surface water hydrology and pollutant loads at key locations. There may be some old monitoring stations along the Peel Drain in the vicinity of the Spectacles Wetlands that may be able to be used, but these will need to be investigated.
8. Data Acquisition Plan

8.1 Regional Data Acquisition

Table 8.1 outlines a data acquisition plan assigning tasks, responsibilities and timeframe for the collection of regional data necessary to undertake the preparation of a comprehensive WRMS for the JSP area.

It is recommended the Table be reviewed by the Lead Agencies and a detailed process and critical path analysis is prepared. At the time of finalising this report a number of the responsibilities had yet to be assigned.

The role of the Lead Agencies will also be to facilitate the acquisition of the pre and post development local area data (see Section 8.2). Both regional and local data collected will then be used for groundwater and nutrient modelling etc.

The estimated costs are indicative only and a guide for funding allocation.

Table 8.1 Recommended Data Acquisition Plan

<table>
<thead>
<tr>
<th>Priority</th>
<th>Task</th>
<th>Lead Agency</th>
<th>Timeframe</th>
<th>Estimated Cost (Excl GST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Current and Historical Land Use (Nutrient Intensive) and Plume Mapping</td>
<td>DPI</td>
<td>0.5 Years</td>
<td>$30k</td>
</tr>
<tr>
<td>A</td>
<td>Groundwater Monitoring</td>
<td>D of E</td>
<td>2 Years</td>
<td>$125k</td>
</tr>
<tr>
<td>A</td>
<td>Surface Water Monitoring</td>
<td>D of E</td>
<td>2 Years</td>
<td>$100k</td>
</tr>
<tr>
<td>B</td>
<td>Groundwater Modelling</td>
<td>Joint Venture Water Corporation / D oE</td>
<td>0.5 Years</td>
<td>$50k</td>
</tr>
<tr>
<td>B</td>
<td>Pollutant Export Modelling</td>
<td>Joint Venture Water Corporation / D oE</td>
<td>0.5 Years</td>
<td>$20k</td>
</tr>
<tr>
<td>A</td>
<td>Digital Elevation Model</td>
<td>DPI</td>
<td>0.5 Years</td>
<td>$20k</td>
</tr>
<tr>
<td>B</td>
<td>Survey &amp; Ground Truth Wetlands</td>
<td>D of E</td>
<td>0.5 Years</td>
<td>$25k</td>
</tr>
<tr>
<td>B</td>
<td>Surface Water Modelling</td>
<td>Water Corporation</td>
<td>0.5 Years</td>
<td>$30k</td>
</tr>
<tr>
<td>C</td>
<td>Integrate Planning and Engineering and Environmental Constraints</td>
<td>DPI</td>
<td>0.5 Years</td>
<td>$25k</td>
</tr>
<tr>
<td>C</td>
<td>Incorporate WSUD/Total Water Cycle Strategy</td>
<td>D of E</td>
<td>0.5 Years</td>
<td>$100k</td>
</tr>
<tr>
<td>B</td>
<td>Cost Recovery Scheme</td>
<td>Town of Kwinana</td>
<td>0.5 Years</td>
<td>$25k</td>
</tr>
</tbody>
</table>
8.2 Local Area Data Acquisition

Notwithstanding the tasks and responsibilities for the collection of regional data and modelling outlined in Table 8.1, local area data acquisition and investigations in accordance with Table 7.1 (pre and post development) is to remain the responsibility of the developer/landowner.

Whilst local area planning can proceed while data is being collected, planning may need to be adjusted when the monitoring results are known.
9. Stakeholder Consultation

Government and industry stakeholder consultation was undertaken as part of the preparation of the Jandakot Water Resources Management Strategy in its current form.

Relevant comments of a technical nature have been incorporated into the body of the report. Many of the comments raised concerns over matters of implementation, process and responsibility.

The Water Corporation stated they would not support the WRMS in the form it was initially proposed. The Corporation wants to see significant additional work undertaken at the regional level before they could quantify the risks, and technical and financial implications to the Corporation and the community. They provided a road map of how the additional investigations and modelling should be undertaken. The key recommendations were included in the report however many of the detailed technical comments on stormwater drainage will be included in the final WRMS.

Department of Planning and Infrastructure and the Town of Kwinana stated that they did not want to see any further delays in the process and expressed concerns over the 2 year predevelopment monitoring that is recommended in the WRMS.

Industry expressed concerns over developers being required to provide reductions over predevelopment water quality and quantity levels.

CALM expressed concerns that maintaining predevelopment hydrological regimes could see unacceptable increases in nutrient loadings to conservation category wetlands.

The consultant team consider we are not in a position to respond to issues and comments of this nature. It is recommended these matters be resolved prior to any public interactions over the WRMS.
10. References


Ministry for Planning and the Western Australian Planning Commission, (1998) Perth's bushplan, W.A.


UNESCO (1971) Article 1, part 1, Convention on wetlands of international significance. Published in Australia in 1976 for the Department of Foreign.


Figure 2

Jandakot Water Resources Management Strategy
Groundwater Contours

Note: Groundwater contours provided by WRC from the Groundwater Atlas and are estimated annual average maximum groundwater levels. The position of the groundwater divide is approximate and may change with season, local abstraction, drainage and additional groundwater level data.

Study Area Boundary
Water Corporation Main Drains
Groundwater contour (1m intervals)
Longterm WRC monitoring bores

SCALE: as shown
DATUM: GDA 94
CLIENT: Department of Environment

File REF: I:\14000\2140053a\Drawings\Fig_2.cdr
Hydrographs - Depth to Water (m)

Hydrographs - Reduced Groundwater Levels (mAHD)

Jandakot Water Resources Management Strategy
Monitor Bore Hydrographs

Figure 3
JANDAKOT STRUCTURE PLAN
CONCEPTUAL STORMWATER MANAGEMENT STRATEGY

FIGURE 6.

Note:
This is an indicative stormwater management strategy. Detailed investigations may necessitate some fine-tuning of this strategy.
Figure 7

Water Corporation Main Drain Locations

Study Area Boundary
Water Corporation Main and Sub Drains
Groundwater contour (1m intervals)
Drain Flow Direction

Peel Main Drain
Birrega Main Drain
Peel Main Drain
Birrega Main Drain
Appendix A

Draft Structure Plan (from WAPC, 2001)
Appendix B

A selection of photographic plates – water bodies of the study area
Plate 1 - The head of the Peel Main Drain, looking south from Rowley Road at the northern boundary of the study area.

Plate 2 - Typical drainage channel in the east of the study area (looking south-east from Nicholson Road). Water draining from this region joins the Birrega Main Drain before flowing to the Serpentine River and the Peel-Harvey Estuary.
Plate 3 - The Birrega Main Drain, looking north from Orton Road. This drain receives water from Beenyup Brook and collects surface water drainage from the eastern half of the site.

Plate 4 - The Birrega Main Drain in October 2002. Looking north from the corner of Duckpond and Mundjong Roads at the south of the study area.
Plate 5 - The Peel Main Drain as it leaves the study area and flows south to the Serpentine River and Peel-Harvey Estuary. Looking north from Millar Road.

Plate 6 - The Peel Main Drain looking south west from Mandogalup Road. This drain enters the Spectacles Wetlands shortly down-stream of this point.
Appendix C

Surface water quality during a ‘snap shot’ sampling event in the winter of 2002 (3 September 2002)
Snap Shot Sampling – Surface Water Quality – Winter 2002
Total Phosphorus (mg/L)
Snap Shot Sampling – Surface Water Quality – Winter 2002
Total Suspended Solids (mg/L)
Snap Shot Sampling – Surface Water Quality – Winter 2002
pH (pH units)
Conductivity (μS/cm)