Government of **Western Australia**
Department of **Water**

Southern River integrated land and water management plan

Department of Water

January 2009

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For more information about this report, contact the team leader of urban water assessment, Drainage and Waterways Branch, Department of Water.

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Summary

This *Southern River integrated land and water management plan* has been developed in accordance with the memorandum of understanding (MOU) between the Environmental Protection Authority, the then Water and Rivers Commission (now Department of Water), Western Australian Planning Commission, City of Armadale, City of Gosnells, Water Corporation and the Armadale Redevelopment Authority (the MOU group) to facilitate the implementation of the *Southern River/Forrestdale/ Brookdale/Wungong urban water management strategy* (JDA 2002). Under the terms of the MOU, the Water Corporation was made responsible for the coordination and project management of the development of a water cycle plan, in consultation with all parties. The MOU group subsequently recognised the importance of integrating the total water cycle management approach with land development processes and the title of the total water cycle plan was changed to an integrated land and water management plan.

The *Integrated land and water management plan* sets out management requirements for water management at the regional, local and lot scale, including specific targets (design objectives) for the management of surface and groundwater quantity and quality and for potable water use. The *Integrated land and water management plan* also contains requirements for monitoring, auditing and reporting to support an adaptive management approach.

The *Integrated land and water management plan* includes the following strategies to manage potential impacts of land use change on the hydrology and environment of the district structure plan area. These strategies have been endorsed by the MOU group:

Protection of environmental assets from the potential impacts of development

- minimise changes to hydrology to prevent impacts on watercourses and wetlands
- manage and restore watercourses and wetlands
- assess and manage impacts on native flora and fauna
- protect the designated lake environmental management areas.

Surface water management to protect infrastructure and assets and receiving environments

- minimise changes to hydrology to prevent impacts on receiving environments
    - all developments shall retain all flows, generated by constructed impervious surfaces, up to and including the one-year average recurrence interval event
- manage surface water flows from major events to protect infrastructure and assets

  - all developments shall compensate peak flows, in the critical 100-year average recurrence interval event, to the pre-development flow
- apply the principles of water sensitive urban design
- manage groundwater to protect infrastructure and assets, ecosystems and water resources
- manage groundwater levels to protect infrastructure and assets
- maintain groundwater regimes for the protection of groundwater-dependent ecosystems
- manage the shallow aquifer to protect the value of groundwater resources.

Water quality management measures for urban development in the Southern River catchment

- achieve pollutant load reduction in the average annual load of stormwater runoff pollutants estimated to be generated by the development

Targets are to be achieved through adopting a treatment train approach including:

- non-structural measures to reduce applied nutrient loads
- onsite retention of 1-year 1-hour average recurrence interval event
- bioretention structures/systems, (also referred to as rain gardens) are to be sized at 2 per cent of connected constructed impervious areas.

If it is proposed to use a computer stormwater modelling tool to assess a proposed water quality management strategy, the following design targets are recommended:

As compared to a development that does not actively manage stormwater quality, developments should achieve:

  - at least 80 per cent reduction of total suspended solids
  - at least 60 per cent reduction of total phosphorous
  - at least 45 per cent reduction of total nitrogen
  - at least 70 per cent reduction of gross pollutants.
- achieve nutrient load reduction in the average annual load of groundwater pollutants estimated to be discharged from the development

As compared to a development that does not actively manage groundwater quality, the following should be achieved:

  - at least 60 per cent reduction of total phosphorous
  - at least 45 per cent reduction of total nitrogen.
- take an adaptive management approach to water quality management
  - The Department of Water will monitor water quality in the Southern River and the arterial drainage system, particularly the Forrestdale main drain. Should monitoring indicate deterioration, the Department of Water will determine the cause and take corrective action, which

may include recommending treatment measures be included in the arterial drainage system or in and around environmental assets.

- Demonstrating achievement of these design objectives will be by modelling (using the recommended modelling tool). If it is found via monitoring that infrastructure put in place does not perform as anticipated by modelling, then the monitoring data will be used to further calibrate the model for future use. There will be no expectation that developers or service providers will retrofit water quality measures.

Water conservation and improvement in water use efficiency

- achieve potable water consumption targets
  - New developments should aim to achieve a target of less than 100 kilolitres per person per year (kL/person/year) for consumers within Perth. In addition there is an aspirational target of not more than 40-60 kL/person/year for new developments.

An action plan for the implementation of these strategies is presented in Table 3, which identifies, for each action, the lead agency and proposed time for completion.

Forrestdale main drain arterial drainage strategy

The surface and groundwater management strategy for the Forrestdale main drain catchment area, to the west of the Southern River, is presented in a separate report titled *Forrestdale main drain arterial drainage strategy* (Department of Water 2009).

Wungong urban water development area

The surface and groundwater management strategies for the catchment area to the east of the Wungong River and the Birriga drain are presented in documents prepared by the Armadale Redevelopment Authority for the *Wungong urban water redevelopment scheme 2006* (EPA Assessment No. 1647) in response to Ministerial Statement no. 762, published on 4 March 2008.

Integrating urban water management with land use planning

The *Integrated land and water management plan* presents the Department of Water's guidance for the Western Australian Planning Commission, the City of Gosnells, the City of Armadale, the Water Corporation, land developers and other state agencies with regard to water management issues to help development proceed within the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) area.

The *Integrated land and water management plan* also assists in integrating land and water planning as required by *State planning policy no. 2.9: water resources* (Western Australian Planning Commission 2004) and outlined in *Better urban water*

management (Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts 2008).

Implementation

All water management strategies, local structure plans, local planning scheme amendments and subdivision plans prepared for areas of proposed new development should demonstrate compliance with the strategies, objectives and design criteria detailed in this document and the supporting documents: *Forrestdale main drain arterial drainage strategy* (Department of Water 2009) and *Wungong urban water master plan district water management strategy* (Armadale Redevelopment Authority in preparation).

Review of the *Integrated land and water management plan*

It is intended that the Department of Water review the *Integrated land and water management plan* every ten years until development has occurred consistent with the district structure plan.

1 Introduction

The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) provides a guide to the future development of the area, identifying potential development areas, road networks, major community facilities, conservation and bush forever sites (Figure 1).

After review of the draft structure plan, the Environmental Protection Authority expressed concerns that land use changes in the district structure plan area raised important issues pertaining to management of hydrology and nutrients (Environmental Protection Authority 2000). The Environmental Protection Authority requested development of a drainage, nutrient and hydrological strategy for the district structure plan area before the proposed land use changes could be considered acceptable.

In response, the Water and Rivers Commission (now Department of Water), in conjunction with the Western Australian Planning Commission commissioned JDA Consultant Hydrologists to develop the *Southern River/Forrestdale/Brookdale/ Wungong structure plan urban water management strategy* (JDA 2002). The urban water management strategy embraced a stormwater vision of protecting water resources, ensuring an enhanced living environment for the community and providing protection from flooding.

In reviewing the *Urban water management strategy*, the Environmental Protection Authority sought assurances regarding its implementation and requested that a Memorandum of Understanding (MOU) be prepared and signed by all agencies involved in the implementation process. An MOU was prepared in 2003 between the Environmental Protection Authority, the then Water and Rivers Commission (now Department of Water), Western Australian Planning Commission, City of Armadale, City of Gosnells, Water Corporation and Armadale Redevelopment Authority (the MOU group) to facilitate the implementation of the *Urban water management strategy*.

Under the terms of the MOU, the Water Corporation was made responsible for the coordination and project management of the development of a water cycle plan, in consultation/ agreement with all parties.

The aims of the water cycle plan were to achieve the intent and recommendations of the *Urban water management strategy*. It was intended to be performance-based and detail the urban water management requirements of the Water Corporation and the cities of Armadale and Gosnells in relation to total water cycle management, including water conservation, excess water management during storm events, water quality, monitoring, reporting and cost recovery.

Early in the process of addressing implementation of the *Urban water management strategy* and total water cycle management, the importance of integrating the holistic

total water cycle management approach with land development processes was recognised. This was reflected in the title of the total water cycle plan being changed to an integrated land and water management plan.

The aim of the *Integrated land and water management plan* is to ensure that the environmental and social values of all forms of water are considered and managed appropriately for all development within the district structure plan area. The MOU group's objective for the *Integrated land and water management plan* was to provide guidance to state and local government agencies and the land development industry on the range of water management issues to be addressed as part of the structure planning and subdivision process.

The scope of the *Integrated land and water management plan* is intended to cover all aspects of total water cycle management, including:

- protection of significant environmental assets within the district structure plan area, including meeting their water requirements and managing potential impacts from development
- water demands, supply options, opportunities for conservation and demand management measures, and wastewater management
- surface runoff, including peak event (flood) management and water sensitive urban design principles to be applied to frequent events
- groundwater, including the impact of urbanisation, variation in climate, installation of drainage to reduce groundwater levels, potential impacts on the environment and the potential to use groundwater as a resource
- nutrient management, which includes source control of pollution inputs by catchment management and management of nutrient exports from surface runoff and groundwater through structural measures.

The *Integrated land and water management plan* sets out management requirements for water at the regional, local and lot scale, including targets (design objectives) for the management of surface and groundwater quantity and quality and for potable water use. The *Integrated land water management plan* also contains requirements for monitoring, auditing and reporting to support an adaptive management approach.

Links between the *Integrated land and water management plan* and other documents

The *Integrated land and water management plan* presents the Department of Water's guidance for the Western Australian Planning Commission, the City of Gosnells, the City of Armadale, the Water Corporation, land developers and other state agencies with regard to water management issues to help development proceed within the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) area.

The *Integrated land and water management plan* also assists in integrating land and water planning as required by *State planning policy 2.9: water resources* (Western Australian Planning Commission 2004) and outlined in *Better urban water management* (Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts 2008).

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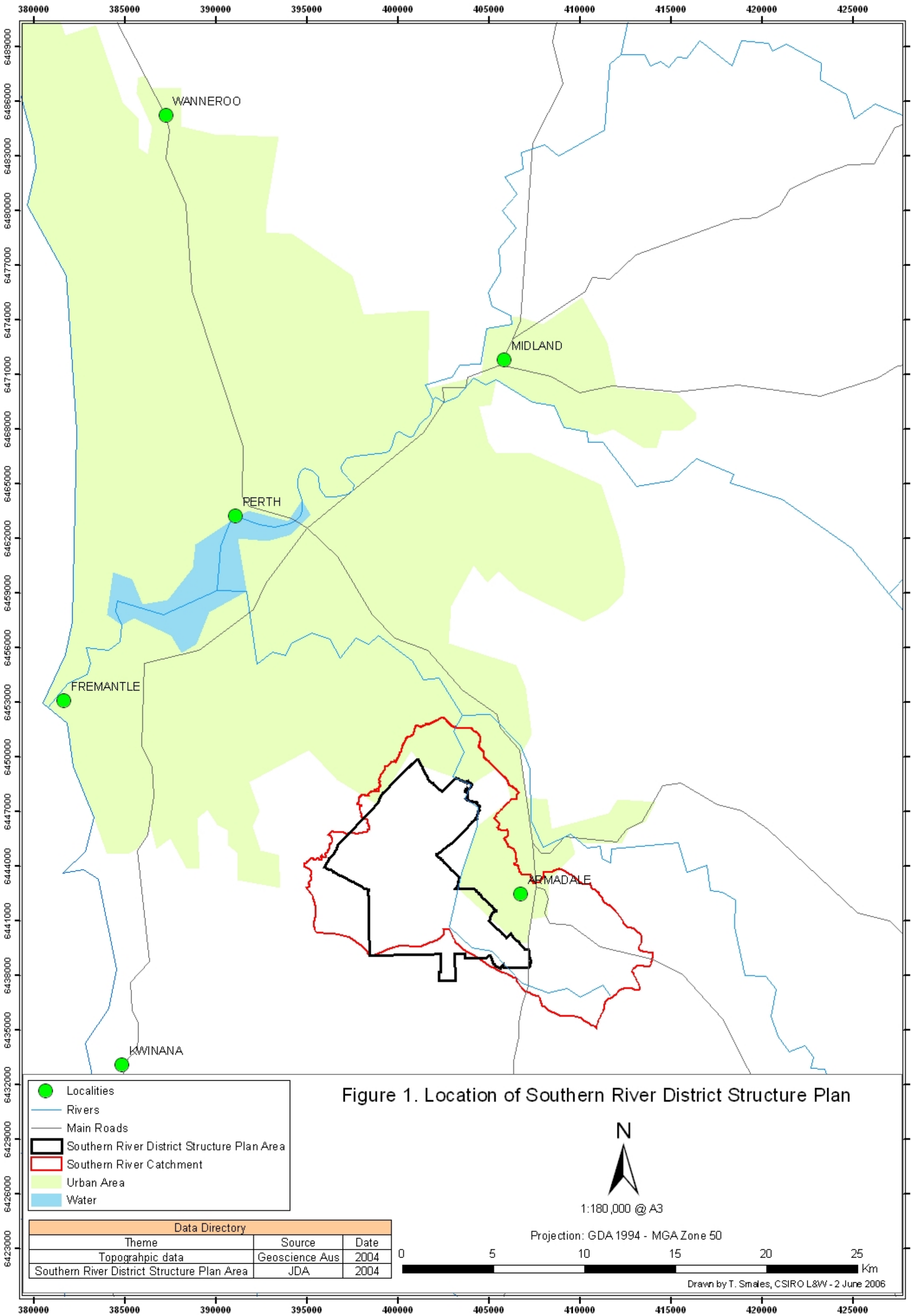
The surface and groundwater management strategies for the catchment area to the east of the Wungong Brook and the Birriga Drain are presented in documents prepared by the Armadale Redevelopment Authority for the *Wungong Urban Water redevelopment scheme 2006* (EPA Assessment No. 1647) in response to Ministerial Statement no. 762, published on 4 March 2008.

The *Integrated land and water management plan* also incorporates information provided in *Groundwater modelling to assess effects of climate variations and planned development* (Rockwater 2005).

These documents should be referred to for further details pertaining to surface and groundwater management and the land use planning process, respectively.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Localities
Rivers
Main Roads
Southern River District Structure Plan Area
Southern River Catchment
Urban Area
Water
Data Directory
Theme | Source | Date
Topograhpic data | Geoscience Aus | 2004
Southern River District Structure Plan Area | JDA | 2004
Figure 1. Location of Southern River District Structure Plan
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Projection: GDA 1994 - MGA Zone 50
0 5 10 15 20 25
Km
Drawn by T. Smales, CSIRO L&W - 2 June 2006

2 Existing environment

2.1 Land use

Existing land use within the structure plan area is generally characterised as sparsely developed, with a predominantly rural nature and large areas of regional open space (

Figure 2).

The northern subarea of Southern River and Forrestdale is represented by several recently developed residential subdivisions including Sanctuary Waters and Forrest Lakes. The remainder of the land is characterised by a range of rural and regional open space facilities, including Sutherlands Park and the City of Gosnells golf course.

The western subarea of Forrestdale is sparsely developed. The majority of the land is used for limited rural pursuits such as the agistment of horses and grazing of cattle. A number of private school uses and institutional activities (including Banksia and Canning Vale detention centres) have been developed in recent years, and a limited area has also been developed for rural-residential or special rural uses.

The south-eastern subarea of Forrestdale and Wungong/Brookdale is characterised by a range of land uses, including Forrestdale townsite, Forrestdale Lake, West Armadale residential area, Armadale golf course, the Armadale rubbish disposal site, and the Brookdale liquid waste treatment facility. The remainder of the land is developed for the keeping of horses and grazing of cattle.

2.2 Geology

The superficial geology of the area includes degraded, low dunes of Bassendean sand with low-lying interdunal areas in the west, and the alluvial Pinjarra plain in the east (Figure 3).

The base of the superficial formation generally slopes downwards to the west, steeply from around 40 metres Australian Height Datum (m AHD) near the Darling fault scarp to 0 m AHD near Southern River, and then more gradually down to about -20 m AHD beneath the centre of the Jandakot mound. The superficial formations generally consist of clayey sediments in the east (‘Guildford clay’), and sandy sediments in the west (a thin layer of ‘Bassendean sand’ overlying ‘Gnangara sand’) (Rockwater 2005).

The Ascot formation, consisting of fossiliferous limestone and calcareous sand with some clay, generally lies at the base of the superficial formations, west of Southern River. There is commonly a ‘coffee rock’ (variably-cemented ferruginous sand) layer

up to 17 m thick below the water table, in the sandy area west of Southern River (Rockwater 2005).

Where intersected, the top of the underlying Leederville formation (cretaceous sediments) generally consists of siltstone or shale. The superficial formations are underlain by the Kardinya shale member of the Osborne formation in the west and north.

Average hydraulic conductivities of the superficial formations have been estimated as ranging from 1.1-8.9 m/d in the area underlain by Gnangara sand (and Ascot formation), and 0.5-5.3 m/d in areas of Guildford clay (Rockwater 2005).

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Kennel Area

Kennel Area

Rural

Rural

Figure 2. Existing Land Uses

Southern River District Structure Plan Area

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1:45,000 @ A3

Projection: GDA 1994 - MGA Zone 50

0 1,000 2,000 3,000 4,000 5,000 Metres

Data Directory		
Theme	Source	Date
Orthophotograph	DLI	2004
Southern River District Structure Plan Area	JDA	2004

Drawn by T. Smales, CSIRO L&W - 2 June 2006

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Surface Geology, Perth Region (DoE)

Geological Code, Description

- Qrw, Swamp and lacustrine deposits - peat, peaty sand and clay
- Qrc, Colluvium, including valley-fill deposits, variably lateritized
- Qpb, Bassendean Sand: quartz sand (dunes)
- Qpg, Guildford Clay: alluvium (clay, loam, sand and gravel)
- Qpr, Yoganup Formation: leached and ferruginised beach sand
- Czl, Laterite over Mesozoic sediments and Precambrian crystalline rocks
- Ag, Undifferentiated Precambrian crystalline rocks
- Water, Water of estuaries, lakes and reservoirs
- Southern River District Structure Plan Area

Figure 3. Regional Geology

Projection: GDA 1994 - MGA Zone 50

0 1,000 2,000 3,000 4,000 5,000 Metres

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Data Directory		
Theme	Source	Date
Surface Geology	DoE	2004
Southern River District Structure Plan Area	JDA	2004

Drawn by T. Smales, CSIRO L&W - 23 May 2006

1:45,000 @ A3

2.3 Hydrogeology and groundwater

The Jandakot groundwater mound is located along the western boundary of the district structure plan area. The mound represents an area of regionally elevated groundwater levels. Groundwater flow through the district structure plan area is therefore predominantly east towards the Canning and Southern rivers.

In the western part of the district structure plan area, hydraulic gradients are steeply downwards to the east and northeast. In the central part of the district structure plan area, where the water table is close to the ground surface, hydraulic gradients are shallow and to the east. There are steep hydraulic gradients downwards to the west (towards the Wungong River) in the south-eastern part of the district structure plan area, close to the Darling Scarp (Rockwater 2005). The regional groundwater level is shown on Figure 4.

Groundwater generally occurs throughout the district structure plan area at a depth of less than 2 m below natural surface (JDA 2002). Levels vary seasonally by approximately 1 to 2 m, with maximum levels in October and minimum levels in April. There are some higher fluctuations of up to 7.5 m in the south-west, in bores in close proximity to Water Corporation Jandakot production bores. There are also fluctuations of 2.0 to 2.5 m near drains and in areas of Guildford clay (Rockwater 2005). Annual maxima and minima vary each year depending on rainfall and temperature, and cumulative effects are evident in long-term monitoring bore records, with the highest and lowest groundwater levels occurring at the end of sustained periods of wet or dry years (JDA 2002).

The groundwater is recharged by the infiltration of rainfall, particularly in areas of sandy soils where the water table is deep, such as on the Jandakot groundwater mound. Early in winter there could also be some recharge from drains and stream flows while surface soils are unsaturated. Groundwater discharges to drains, Southern River, and to the Canning River in the north. There are also evapotranspirative losses from the groundwater in areas of shallow water table. Forrestdale Lake is a groundwater sink, rather than a throughflow lake as is the case for many wetlands in the Perth metropolitan area (Rockwater 2005).

The *Urban water management strategy* provided a summary of the effect of existing drainage systems on groundwater export from the district structure plan area. The length of Water Corporation drainage below modelled pre-development maximum groundwater level (788 mm annual rainfall scenario) in the district structure plan area was approximately 25.5 km, with inverts in the Forrestdale main drain approximately 1.5 m below this modelled pre-development maximum groundwater (788 mm annual rainfall scenario). Local government drainage in the district structure plan area was estimated as 46.5 km in length, with an assumed average invert of 1.0 m below the modelled pre-development maximum groundwater level (788 mm annual rainfall scenario). The Southern River also provides approximately 5.5 km of waterway in the district structure plan area (excluding Wungong River). The maximum monthly

groundwater currently exported from a combination of these systems was estimated as 1.5 GL (Rockwater 2005). The annual export of groundwater from the district structure plan area was estimated as 7.6 GL under average (current climate) rainfall conditions (Rockwater 2005).

Much of the shallow groundwater in the district structure plan area is fresh, with salinity less than 500 mg/L total dissolved solids (TDS). There is some brackish groundwater of up to 3000 mg/L TDS around Forrestdale Lake, as a result of evapotranspiration from the lake and its surrounds; and an area of brackish to saline groundwater (maximum 4500 mg/L TDS) in the northern part of the development area (Huntingdale – Thornlie). There is also brackish groundwater further north along the Canning River (Rockwater 2005). The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has measured groundwater salinity values in the Brookdale area of close to 20 000 mg/L (CSIRO 2006).

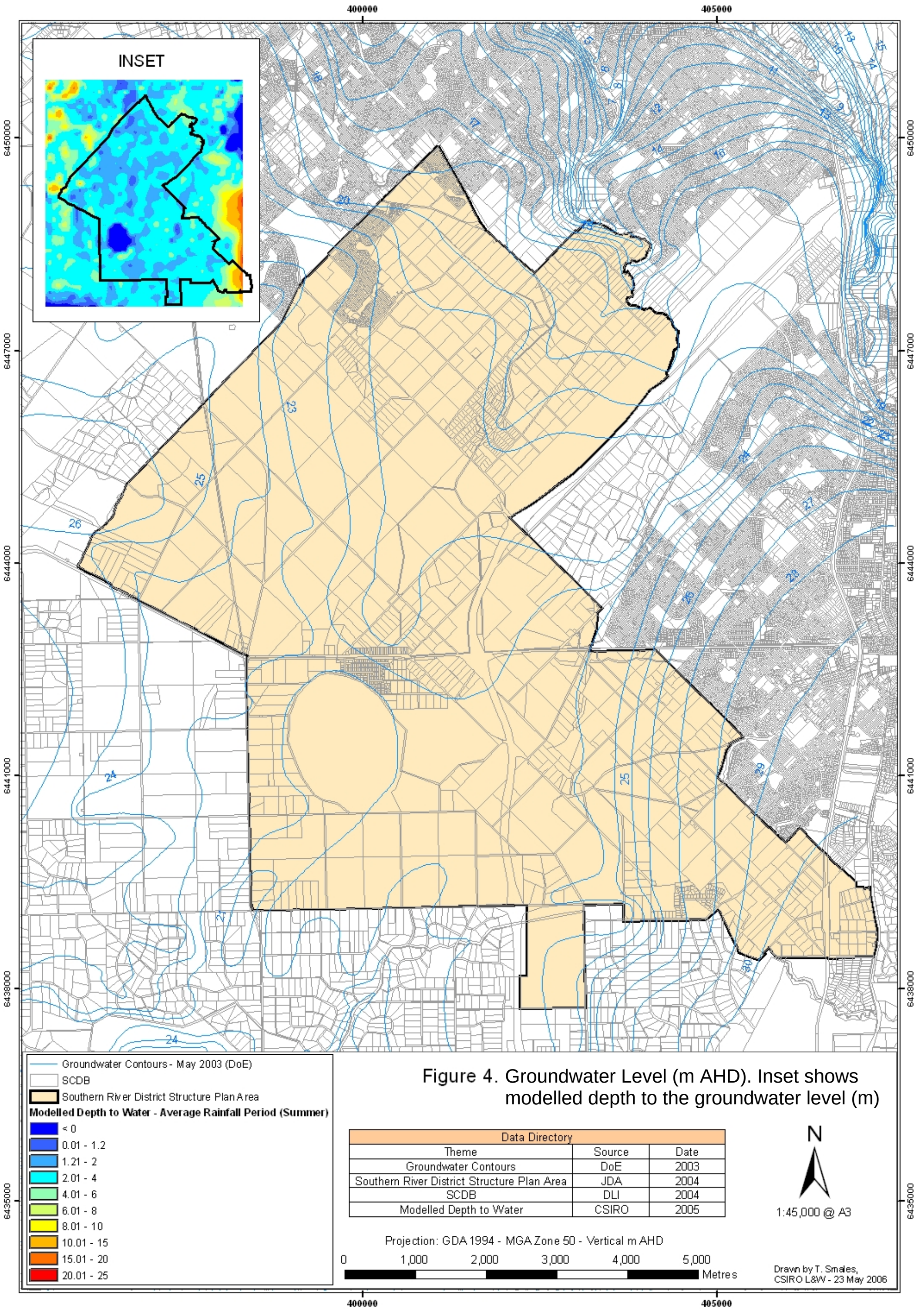

Figure 4. Groundwater Level (m AHD). Inset shows modelled depth to the groundwater level (m)

2.4 Surface water and waterways

The period since 1974 has been the driest on record. Peak seasonal water levels in Forrestdale Lake have decreased from between 23.5 and 24.2 m AHD in wet years prior to 1975, to a maximum level of 22.4 m AHD since 1996. The peak water levels correlate well with long-term and short-term (annual) variations in rainfall. The same probably applies to annual water level minima, but these have not been measured since 1993 (Rockwater 2005).

The district structure plan area falls into two major catchments. The majority of the district structure plan area is situated in the Canning River catchment, which is fed by Southern River. A much smaller southern portion of the district structure plan area drains into the Serpentine River which flows into the Peel Inlet catchment (JDA 2002). Major waterways and drainage lines in the district structure plan area are shown on Figure 5.

The Southern River catchment comprises an area of approximately 150 km^2, located within the local government areas of the City of Gosnells, City of Armadale and Shire of Serpentine-Jarrahdale. The catchment extends from the Water Corporation's Wungong Dam at its upstream end through to the confluence of Southern River and Canning River at its downstream end (JDA 2005).

Wungong River flows from the Wungong Dam, into the district structure plan area south of the City of Armadale and becomes the Southern River at the confluence of the northern branch of Neerigen Brook main drain, adjacent to Armadale Road. The Southern River then flows northwards, separated from the central portion of the district structure plan area by existing development, and forms the eastern boundary of the district structure plan area through the northern portion.

The district structure plan area has an extensive drainage system, which has developed to reduce periods of inundation and waterlogging. Much of this drainage is located below maximum groundwater levels. The Water Corporation currently has a licence to operate and maintain a network of main drains in the district structure plan area, including Forrestdale main drain, Wungong River, Neerigen Brook main drain (north and south courses), Bailey's branch drain, Keane Road branch drain and Birrega main drain.

The existing Forrestdale main drain was designed for the three-year average recurrence interval flow, as was recommended for urban uses in the 1981 Metropolitan Water Board Drainage Manual. Plans to upgrade the Forrestdale main drain to meet development needs are provided in the *Forrestdale main drain arterial drainage strategy* (Department of Water 2009).

Neerigen Brook is a Water Corporation main drain at South Western Highway, where it splits into north and south courses that discharge into Wungong River.

In addition to Water Corporation drainage, the district structure plan area has an extensive network of local authority and private drains, many of which are also located below pre-development maximum groundwater levels. Some of the existing drainage currently runs through or adjacent to conservation category wetlands and *Environmental Protection (Swan Coastal Plain Lakes) policy 1992*.

Details of the proportion of surface water flows in the Southern River that is fed from groundwater base flow can be found in Southern River development area groundwater modelling to assess effects of climatic variations and planned development (Rockwater 2005).

The runoff generated from the escarpment area on an annual basis comprises nearly 50 per cent of the annual Southern River discharge. The estimated total groundwater contribution to flow in Southern River is between 19 per cent and 25 per cent, while the remaining 25-30 per cent is related to stormwater within the low lying area and predominantly associated with urban runoff (CSIRO 2006).

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Southern River Catchment (DoE)

Southern River Hydrography - Basic (DoE)

- Watercourse - minor, perennial
- Drain - major
- Lake - perennial
- Water Reservoir
- Swamp - perennial
- Marsh Area
- Area Subject to Inundation
- 100 Year ARI Floodplain Area (DoE)

Figure 5. Waterways and Major Drainage Lines

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Data Directory		
Theme	Source	Date
Hydrography	DoE	2004
Southern River Catchment	WRC	1997
Floodplain Area	DoE	2004

Projection:
GDA 1994 - MGA Zone 50

Drawn by T. Smales,
CSIRO L&W - 23 May 2006

0 1,000 2,000 3,000 4,000 5,000 Metres

Drain

Main

River

Southern

Bailey's Branch Drain

Forrestdale

Forrestdale Lake

Neerigen Brook Nth

Neerigen Brook

Neerigen Brook Sth

Wungong Brook

Birrega Drain

Large sections of the middle Southern River and local drains are ephemeral, with the flow occurring during only winter and spring. Continuous flow is recorded only in the most northern section of the Southern River and in some years in the Neerigen Brook, suggesting discontinuity in the river flow system (CSIRO 2006).

A monthly water balance indicates that the autumn and early winter increases in rainfall do not cause a significant increase in the river flow. In this period groundwater recharge is expected to contribute to aquifer storage via direct rainfall recharge and recharge from the stream and drain beds to the groundwater system. The variance in monthly water balance from July to September indicates that the groundwater contribution to the river flow becomes significant in the late winter/spring when increases in Southern River flow are proportional to rainfall (CSIRO 2006). In areas of shallow depth to groundwater and predominance of clay (such as in the Brookdale region), the shallow aquifer can become fully saturated as early as June, leading to increased groundwater discharges to waterways.

2.5 Environmental assets

Environmentally sensitive areas in the Southern River catchment are shown in

Figure 6. These areas are declared in *Regulation 6 in Government Gazette No. 115, Environmental Protection (Clearing of Native Vegetation) Regulations 2004*. This dataset is provided to assist landowners and managers in determining the location of environmentally sensitive areas under the *Environmental Protection Act 1986.* It is important to note that areas that are not classified as environmentally sensitive still have the potential to pose an environmental constraint.

The main basin wetlands in the district structure plan area are Forrestdale Lake and Balannup Lake. Forrestdale Lake is one of nine Western Australian wetlands, and one of five in the south west, listed on the Ramsar Convention as a wetland of international significance and is classified as a permanently inundated basin or lake (Hill et al. 1996). Forrestdale Lake is the third most important wetland reserve in southwest Australia for the variety and number of bird species. A total of 71 species of water birds have been recorded at the lake, which regularly supports more than 10 000 water birds (JDA 2002).

Balannup Lake is a conservation category wetland and an *Environmental protection (Swan Coastal Plain lakes) policy* 1992 wetland classified as a seasonally inundated basin or sumpland (Hill et al. 1996). The lake lies across the boundary of the cities of Armadale and Gosnells and is intersected by Ranford Road. The Department of Environment and Conservation monitors water levels monthly via staff gauges at both of these wetlands.

A large proportion of the central part of the district structure plan area is classified as seasonally waterlogged basins or damplands (Hill et al. 1996). Most of the south-east corner of the area identified as Guildford Formation is classified as a flat wetland, being seasonally waterlogged or palusplain (Hill et al. 1996). The very flat upper reaches of the Southern River, which are prone to annual inundation by flooding, are described as floodplain. A long period of settlement and agricultural activity has

substantially altered the natural vegetation and groundwater and surface water drainage of the area so that most of the wetlands are degraded to varying degrees.

Most of the sumpland wetlands (those that contain open water over all or part of the year) have conservation status, with some damplands also included. Wetlands in the district structure plan area designated as environmental protection policy lakes under the *Environmental protection (Swan Coastal Plain lakes) policy* 1992 are shown in

Figure 7. *Environmental protection (Swan Coastal Plain lakes) policy* 1992 lakes were gazetted in December 1992 to protect a selection of Perth's permanently and seasonally inundated wetlands. Wetlands identified in the policy are protected from unauthorised filling, excavation, mining, effluent disposal and alteration to their hydrology.

A total of 13 Bush Forever sites have been identified within the district structure plan area (

Figure 7). A number of these sites correspond with existing nature reserves managed by the Department of Environment and Conservation including Forrestdale Lake, Balannup Lake, and Piara Nature Reserve.

With regard to fauna, the Department of Environment and Conservation has advised that 72 bird species have been recorded, as well as numerous amphibians, mammals, reptiles, and insects. No significant fauna types are characterised within the district structure plan area outside recognised conservation reserves and larger areas of remnant bushland. All but the most common fauna species have been lost from the rural areas because of land clearing and other disturbances.

2.6 Existing water quality

The district structure plan area currently exports nutrients to the Southern River and subsequently the Swan-Canning river system. The link between the existing groundwater nutrient contamination and historical and current land use within the district structure plan area is well documented. The district structure plan area includes a number of known point and diffuse sources of nutrients, predominantly from agricultural use.

High phosphate concentrations in the district structure plan area are thought to be primarily sourced from fertiliser, detergent use and sewerage. The highest phosphate concentration is found in the Bletchley Park subcatchment. This catchment is almost exclusively used for rural purposes. The Baileys branch drain, which serves the partially unsewered Forrestdale townsite, also contributes substantial phosphorous inputs to the Forrestdale main drain. Forrestdale Lake also displays relatively high phosphorous concentrations. However, the only connection to the Forrestdale main drain is via a high level overflow, which operates very rarely and therefore these high nutrient concentrations do not contribute to the water quality of the main drain or the Southern River.

High nitrate concentrations in the district structure plan area are thought to be primarily sourced from septic tank effluent and fertiliser containing animal manure. The highest total nitrogen concentrations are found in Bletchley Park and the Baileys branch drain, with the latter contributing the largest load. Areas of the Forrestdale townsite remain unsewered. Forrestdale Lake displays high total nitrogen concentrations, but its overall load is low and again does not contribute to the water quality in the main drain or the Southern River.

The former Southern River liquid waste disposal facility has resulted in known groundwater contamination. The site has been the subject of detailed investigations

and remediation. The resultant contaminant plume has also led to a consultative environmental review and setting of ministerial conditions. Currently, development proposed within a 1500 m radius of the site is subject to a condition of subdivision requiring a memorial be placed on the title of all lots, restricting the installation and use of private groundwater bores. There is also a potential for subsoil drainage to intersect the contaminant plume and expedite transport of contaminants.

Other historical land uses within the district structure plan area that will constrain development (Western Australian Planning Commission 2001) include:

- poultry and pig farms
- kennel zones
- animal feedlot
- animal processing
- Brookdale wastewater septage disposal area
- Armadale landfill and recycling facility.

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Hydrography (DoE)

Southern River District Structure Plan Area

Environmentally Sensitive Areas (ESA), 08th March 2005 (DoE)

Data Directory		
Theme	Source	Date
Hydrography	DoE	2004
Southern River District Structure Plan Area	JDA	2004
Environmentally Sensitive Areas	DoE	2005

Projection: GDA 1994 - MGA Zone 50 Drawn by T. Smales, CSIRO L&W - 23 May 2006

Figure 6. Environmentally Sensitive Areas in the Southern River Catchment

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Balannup Lake

Forrestdale Lake

Hydrography (DoE)
Southern River District Structure Plan Area
Threatened and Priority Fauna - 5 Oct 2005
Threatened (Declared Rare) Flora - 5 Oct 2005
Threatened Ecological Communities - 30 Sept 2005
Special Control Area No. 1 - Bush Forever Protection Area
Parks and Recreation Reservations
Environmental Protection Policy - Lakes Policy Area - 1992
RAMSAR Sites in Western Australia
CALM Managed Lands and Waters - June 2005

Geomorphic Wetlands

Conservation
Resource Enhancement
Multiple Use

Figure 7. Environmental Constraints to Urban Development

Data Directory		
Theme	Source	Date
Hydrography	DoE	2004
Southern River District Structure Plan Area	JDA	2004
Threatened Fauna, DRF, TEC	CALM	2005
Bush Forever	DPI	2005
Parks and Recreation Reserves	DPI	2005
Lake Policy Area	EPP	2004
RAMSAR	CALM	2005
CALM Tenure	CALM	2005
Geomorphic Wetlands	DoE	2004

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Projection: GDA 1994 - MGA Zone 50

Drawn by T. Smales,
CSIRO L&W - 23 May 2006

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2.7 Acid sulfate soils

Information on the potential risk of acid sulfate soils within the district structure plan area has been taken from map sheet 4: southern metropolitan region scheme acid sulfate soils in *Planning bulletin no. 64: acid sulfate soils* (Western Australian Planning Commission 2003). The map shows that the majority of the district structure plan area falls under the category of 'moderate to low risk of actual acid sulfate soils and potential acid sulfate soils occurring generally at depths of >3 m'.

Substantial portions of the district structure plan area fall under the category of 'high risk of actual acid sulfate soils and potential acid sulfate soils <3 m from surface'. However, it is noted that these areas mostly correspond to wetlands or conservation areas, which are designated as conservation category wetlands or parks and recreation reservation in the district structure plan. Small portions of the district structure plan area, mostly in the Brookdale area, are attributed to 'low to no risk of actual acid sulfate soils and potential acid sulfate soils occurring generally at depths of >3 m'.

It is likely that landowners will need to undertake site-specific acid sulfate soil investigations to determine the risk of actual acid sulfate soils and potential acid sulfate soils on their land, and develop appropriate management strategies if necessary.

3 Potential impacts from development

3.1 Proposed land use

Proposed land uses for the district structure plan area are shown in

Figure 8. The area designated for residential land use has a total potential of 22 650 dwellings, of which 4200 (18.5 per cent) are medium density residential dwellings with allowable housing density of 25 per hectare (R25), and the remainder allowable housing density of 15 per hectare (R15). Key elements of the district structure plan include:

Residential

The district structure plan shows expansion of the existing urban development occurring along Warton and Ranford Roads, along Garden Street, adjoining Forrestdale Lake and in the Brookdale/Wungong area south of Armadale.

Village and neighbourhood centres

Eight village centres are proposed within the urban areas of the district structure plan area. These are located at the corner of Warton Road and Holmes Street in Southern River/Canning Vale, Southern River Road, Garden Street east, corner of Ranford and Wright Roads, Nicholson Road in Forrestdale, Eleventh Road east and west and in Rowley Road.

Industrial

A major light industrial area is to be located alongside Tonkin Highway between the junctions with Ranford Road and Armadale Road.

Rural

Land south of Forrestdale Lake is identified predominantly as either regional open space or rural. The rural area adjoining Rowley Road is identified as a location without development constraints (except for service extensions) and is earmarked for

possible future urban development, as it is not likely to be required for urbanisation for more than 30 years.

Conservation

Land set aside for conservation purposes (conservation category wetlands, Environmental Protection Policy wetlands, Bush Forever sites) will be in addition to the normal 10 per cent public open space requirements for residential land. Three of the Bush Forever sites have been earmarked for reservation as parks and recreation under the *Metropolitan region scheme*.

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Bletchley Park Development

1

North Forrestdale Development

2

POSSIBLE FUTURE URBAN DEVELOPMENT
SUBJECT TO STUDY FOR REFINEMENT
ENVIRONMENTAL MANAGEMENT AREA

3 Forrestdale Development

PROPOSED DIVERSION
OF MAIN DRAIN BY MRWA

Forrestdale
Lake

POSSIBLE FUTURE
URBAN DEVELOPMENT

PROPOSED MAIN DRAIN
EXTENT TO BE AGREED WITH
THE CITY OF ARMADALE

4

Brookdale Development

- Environmental Protection Policy (EPP) Lakes Policy Area
- Community Facilities
- Parks and Recreation Reservatio (existing and proposed)
- Primary Regional Hwy
- Light Industrial
- Mixed Business/Commercial
- Village and Neigbourhood Centres
- Urban (Including balance of P.O.S)
- Private Recreational
- Open Space (including drainage corridors)
- Rural

Figure 8. Proposed District Structure Plan Land Uses

Data Directory		
Theme	Source	Date
Landuse	DPI	2001
Lake Policy Area	EPP	2004

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Projection: GDA 1994 - MGA Zone 50

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Drawn by T. Smales, CSIRO L&W - 23 May 2006

Kennel zones

The Southern River kennel zone fronting Ranford Road has been retained due to the large degree of existing investment and consolidated use of the zone for this purpose. The Forrestdale kennel zone will not be retained.

Environmental management areas

Environmental management areas that define groundwater capture zones for Forrestdale Lake (environmental management area category A: minimum lot size 2 ha rural residential) and Balannup Lake (environmental management area category B: residential and industrial land use change acceptable) are maintained to protect the status of the wetlands.

Drainage and watercourses

Major drainage routes are included in the district structure plan within multiple use corridors (often as linear open space). At a regional scale the indicated corridors reserve sufficient land for surface and groundwater management. The detailed alignment and width of the corridors and areas for surface and groundwater management shall be determined at and incorporated into local structure plans. These local structure plans shall be supported by local water management strategies, consistent with this *Integrated land and water management plan, the Forrestdale main drain arterial drainage strategy* (Department of Water 2009) and the *Wungong urban water master plan district water management strategy (*Armadale Redevelopment Authority in preparation*).*

3.2 Potential impacts on environmental assets

Environmental assets within the district structure plan area include: Bush Forever sites; Ramsar-listed wetlands; threatened ecological communities; threatened and priority fauna; threatened (declared rare) flora; ecosystems of natural heritage; and environmentally-sensitive areas (as shown on Figure 7). These assets have the potential to be impacted by development pressures, including:

- habitat loss (primarily through clearing)
- invasive and exotic species
- access for recreation
- changes to fire and hydrologic regimes
- potential increases in nuisance vectors
- noise
- threats from dogs and cats.

These assets will need to be protected as the district structure plan area is developed. Environmental assets that pose constraints to urban development in the district structure plan area are shown in

Figure 7.

The Department of Water commissioned consultants ENV Australia to undertake an assessment of the tolerance of wetlands and areas of remnant vegetation in the Forrestdale catchment to inundation by stormwater. The outcomes of the study, *Ecological water requirements of selected wetlands – Forrestdale main drain* reported to the Department of Water in a letter dated 2 March 2007, provided a valuable input to the development of the *Forrestdale main drain arterial drainage strategy* (Department of Water 2009).

3.3 Urban water balance

Urban development can lead to a significant change to the water balance within the district structure plan area if not carefully implemented in accordance with current urban water management principles. Changes to the water balance can be due to increases in scheme water demand, wastewater generation and changes to runoff discharges and groundwater recharge rates, as a result of changes in the land form.

Urban development through the district structure plan area will lead to a large increase in water demand. An additional 3.5 GL/yr of drinking water may be required to meet domestic in-house demands and an additional 3.8 GL/yr may be required to meet demand for irrigation of residential gardens and public open space.

Urban development can also result in local increases in surface runoff and decreases in evapotranspiration due to the replacement of existing vegetation with impervious surfaces. Where urban runoff is infiltrated, this can also lead to an increase in recharge.

3.4 Groundwater

The shallow depth to groundwater across much of the district structure plan area and the potential increase in groundwater recharge due to the infiltration of stormwater will require careful management of maximum groundwater levels, via subsoil drainage at a groundwater level approved by the Department of Water. There may also be a requirement for substantial volumes of fill, to provide necessary separation for building foundations from groundwater levels in some areas.

Groundwater modelling (Rockwater 2005) has indicated that following a wet winter the water table would be above the natural ground surface over much of the district

structure plan area. The inundation would last in some parts to the east and north-west of the district structure plan area to the end of the following summer. Rises in peak groundwater levels of up to 0.5 m in the district structure plan area would result in extensive areas of inundation without the installation of subsoil drainage.

Following a dry winter, only small portions of the district structure plan area would be inundated (Rockwater 2005), and these would have mostly disappeared by the end of summer as the water table fell to at least 2 m below natural ground surface in much of the district structure plan area.

Under average rainfall, the low-lying parts of the district structure plan area would be inundated at the end of winter, and by the end of summer the water table would lie at least 2 m below natural ground surface over about half of the district structure plan area (Rockwater 2005).

The modelling scenarios indicate the potential variability in groundwater levels that could arise in the district structure plan area due to climate variations, and highlight the need for appropriate groundwater management as part of urban development.

The most significant changes in summer minimum water levels due to development impacts were indicated to be at the Brookdale wetland, where the water table gradient is relatively steep. Measures to maintain the hydrologic regime at this wetland will therefore need to be carefully considered.

During the development of local structure plans, and associated local water management strategies, it is a requirement to determine the controlled groundwater levels for each development area, to enable the setting of minimum drainage invert levels and to calculate the extent of land filling requirements. The proponent will need to demonstrate, to the satisfaction of the Department of Water and the Department of Environment and Conservation, that there will be no adverse impact upon any affected groundwater dependent ecosystems.

3.5 Surface water

Changes in land use from rural to urban, if not carefully implemented in accordance with current urban water management principles, can lead to increases in peak flows and volumes of runoff due to increases in impervious area. Increases in discharge of peak flows and volumes have the potential to adversely impact on receiving environments by causing erosion and inundation of vegetation. Surface water management will therefore have to ensure that urban development does not increase the peak flows discharging to receiving environments.

It is proposed to maintain as closely as possible the hydrologic regime of wetlands within the district structure plan area. Therefore, wetlands that currently receive runoff during rainfall events that generate catchment surface water runoff are proposed to continue receiving flows as part of the surface water management for urban development. Any proposed change to the hydrologic regime of a receiving

wetland as a result of urban runoff should be quantified and will require approval by the Department of Environment and Conservation and Department of Water as appropriate.

Large storm events also have the potential to damage infrastructure and assets through flooding and inundation. The district structure plan area is particularly prone to impacts from floodwaters due to the shallow depth to groundwater and low-lying topography across much of the area. The Forrestdale main drain currently does not have sufficient capacity to protect urban development from a large storm event.

Development in the district structure plan area will require substantial drainage and fill in order to provide the necessary separation between flood levels and building floor. It has been identified that in order to facilitate land use change within the district structure plan area, the existing drainage system requires major upgrading and extending, particularly the Forrestdale main drain. A conceptual plan for upgrading the drainage system is presented in the *Forrestdale main drain arterial drainage strategy* (Department of Water 2009). A summary of the *Forrestdale main drain arterial drainage strategy* (Department of Water 2009) is provided in Section 4.2.

3.6 Water quality

Available information indicates that nutrient concentrations in surface and groundwater are elevated in a number of subcatchments, most likely as a result of historic land use and associated surface application of nutrients.

Where land use changes from intensive agricultural activities, such as piggeries and horticulture, to residential development, surface water quality discharging from a site could potentially improve if water sensitive urban design practices are employed. Where land use changes from low-intensity agricultural activities, such as grazing, to residential development, water quality could potentially deteriorate, although this may be mitigated through the use of water sensitive urban design practices.

One of the major concerns related to urbanisation in the district structure plan area is that proposed land use changes may increase the mobilisation of the existing nutrient-contaminated groundwater to watercourses as a result of increased groundwater recharge.

Sewerage in new developments will prevent discharge of nutrients emanating from septic tanks, as currently occurs in the Forrestdale townsite.

The salinity present in parts of the district structure plan area has the potential to impact upon development by affecting the water quality of groundwater abstracted for use within the district structure plan area. Hence abstraction bores may need to be strategically placed to avoid the areas of high salinity.

4 Water management strategy

The aim of this *Integrated land and water management plan* is to present a strategy to manage potential impacts of land use change on the hydrology and environmental of the district structure plan area. The strategies developed are presented in the following sections, broadly grouped into those that address:

- the protection of environmental assets
- surface water management
- groundwater management
- water quality
- water conservation.

4.1 Protection of environmental assets

The following strategies have been developed to protect and enhance the value of environmental assets in the district structure plan area.

Minimise changes to hydrology to prevent impacts on watercourses and wetlands

Changes in land use from rural to urban can lead to increases in peak flows and volumes of runoff due to increases in impervious area, if not carefully implemented in accordance with current urban water management principles. Increases in peak flows and volumes have the potential to adversely impact on receiving environments by causing erosion and inundation of vegetation. Surface water management should ensure that urban development does not increase the peak flows discharging to receiving environments. Development should also ensure that watercourses and wetlands do not dry out due to over-abstraction of water resources or lowering of groundwater levels.

Manage and restore watercourses and wetlands

The district structure plan area contains a number of conservation category wetlands, resource enhancement wetlands and the watercourses of Southern River and Wungong River and their tributaries. The Environmental Protection Authority requires all conservation category wetlands to be protected and managed for conservation purposes. The Environmental Protection Authority also recommends the consideration of existing watercourses and inclusion of requirements for restoration, revegetation and reservation of an appropriate corridor width.

Assess and manage impacts on native flora and fauna

The Environmental Protection Authority has noted that the district structure plan area is large (7000 ha) and contains important wetlands, vegetation and native fauna. The Environmental Protection Authority was concerned that recognition and management of native fauna did not receive adequate attention in the draft structure plan. The final district structure plan noted the Environmental Protection Authority's recommendation that detailed fauna assessments be undertaken as part of more detailed levels of planning to ensure that development and subdivision is cognisant of and sensitive to the protection of native fauna.

Protect the designated lake environmental management areas

The final district structure plan recognises the existence of the Forrestdale Lake and Balannup Lake environmental management areas. The Environmental Protection Authority requested that proposed development in these areas be managed to be consistent with the objective for the environmental management areas.

4.2 Surface water management strategy

The following surface water strategies presented below will meet the twin objectives of:

- protecting wetlands and waterways from the impacts of urban runoff
- protecting infrastructure and assets from flooding and inundation.

Minimise changes in hydrology to prevent impacts on receiving environments

Urbanisation results in increased impervious area. Increased rates and volumes of stormwater runoff should be managed to protect infrastructure and assets from flooding and inundation, whilst both water quantity and quality should be managed to protect wetlands and waterways from risk of increased inundation and contaminant loads. Surface water management should ensure that urban development does not increase the peak flows discharging to receiving environments.

Surface water quantity management is not restricted to preventing runoff from increasing due to development but should also manage the maintenance or even restoration of desirable environmental flows and/or hydrological cycles where potential impacts on significant ecosystems such as wetlands are identified.

For the critical one-year average recurrence interval event, the post-development discharge volume and peak flow rates shall be maintained relative to pre-development conditions in all parts of the catchment. Where there are identified impacts on significant ecosystems, desirable environmental flows and/or hydrologic cycles shall be maintain or restored as outlined in this report and detailed further in the *Forrestdale main drain arterial drainage strategy* (Department of Water 2009) and

the *Wungong urban water master plan district water management strategy* (Armadale Redevelopment Authority in preparation).

Manage surface water flows from major events to protect infrastructure and assets

To protect infrastructure and assets from flooding and inundation, the following design objectives should be applied to surface water management:

- manage the catchment runoff for all average recurrence interval events up to and including the 100-year average recurrence interval event within the development area to pre-development peak flow rates
- ensure that water sensitive urban design and best management practices promoting on-site retention of events up to the one-year average recurrence interval form the basis of the surface water quantity management strategy for minor events.

The arterial drainage strategy within the Forrestdale main drain catchment is shown in and described in detail in the report titled *Forrestdale main drain arterial drainage strategy* (Department of Water 2009).

The Forrestdale main drain, in its current trapezoidal configuration, does not have sufficient capacity to protect urban development from large and infrequent rainfall events. It will require conversion to the configuration of a 'natural streamline' within the identified waterway/ multiple use corridors as specified in the *Forrestdale main drain arterial drainage strategy* (Department of Water 2009), as the stages of urban development proceed.

Two options for increasing the capacity of the Forrestdale main drain were considered:

- Option A – continue to use wetland areas for catchment flood management, post development, whilst maintaining their existing hydrological regime
- Option B – prevent all increased floodwater volumes, post development, from wetland areas by storing additional floodwater in constructed basins elsewhere within the catchment.

Option A (using existing wetlands) has the lowest cost and is the adopted strategy on the basis that the environmental impacts are considered acceptable. Changes to the hydrologic regimes of the wetlands due to surface flows during storm events (<0.3 m) are insignificant compared to the seasonal fluctuations in water level due to groundwater (1.0-2.0 m), the annual variability in maximum water levels (0.25 m) and long-term decline in water level due to drying climate (0.2-0.5 m).

Option A also offers the opportunity to manage the hydrology of the wetlands during dry periods by diverting surface flows from the drainage system. In addition, by using existing wetlands to store surface water during infrequent storm events, it minimises

the construction of additional flood storage areas, reducing the land required for drainage purposes.

Within the Wungong redevelopment area the surface and groundwater management strategies for the catchment area to the east of the Wungong River and the Birriga Drain, is presented in documents prepared by the Armadale Redevelopment Authority for the *Wungong urban water redevelopment scheme 2006 (EPA Assessment No. 1647*) in response to Ministerial Statement No. 762, published on 4 March 2008. Where there are inconsistencies between this *Integrated land and water management plan* and the ministerial statement, the formal environmental conditions shall prevail.

4.3 Groundwater management strategy

The key objectives for groundwater management are:

- protection of infrastructure and assets from flooding and inundation by high seasonal groundwater levels, perching and/or soil moisture
- protection of groundwater-dependent ecosystems from the impacts of urban runoff
- management and minimisation of changes in groundwater levels and groundwater quality following development/redevelopment.

Manage groundwater levels to protect infrastructure and assets

The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) area generally contains relatively flat ground with a shallow depth to groundwater and frequent occurrence of shallow clayey soils. The combination of these factors will require management of shallow groundwater to ensure that any rise in groundwater levels due to urbanisation does not impact upon built infrastructure and/or assets.

Groundwater modelling (Rockwater 2005) investigated a range of potential development scenarios. The groundwater model was designed to predict maximum groundwater levels for a range of climate scenarios with the conclusion that filling and/or drainage will be required over substantial areas of the catchment to prevent periodic inundation of the development areas.

The modelling also considered the use of subsoil drains to control groundwater levels within developed areas and the impact of those drains on the lakes and wetlands in the catchment. Subsoil drains are necessary to control peak groundwater levels in substantial areas of the catchment. Without them groundwater levels in the catchment would rise up to 0.2 m higher in winter as a result of urban development, and increase the groundwater flux, thereby impacting on environmentally-sensitive wetlands.

Maintain groundwater regimes for the protection of groundwater-dependent ecosystems

There are a number of significant wetlands and stands of remnant native vegetation within the district structure plan area. Although not all of these have been the subjects of detailed assessments, it is likely that the majority of ecosystems within the district structure plan area are to some extent dependent on shallow groundwater. While it is acknowledged that development in the district structure plan area will require some degree of groundwater management to protect infrastructure and assets, care should be taken to maintain the requirements of groundwater dependent ecosystems.

Manage the shallow aquifer to protect the value of groundwater resources

The district structure plan area is adjacent to, and partially overlaps with, the groundwater protection area of the Jandakot mound, a regionally significant source of water for the integrated water supply system. Groundwater in the region is also used for domestic and commercial purposes and is potentially an important source of water for new development in the area, necessitating ongoing monitoring and maintenance of groundwater availability for abstraction.

4.4 Water quality management strategy

The objective for water quality management in the district structure plan is to prevent adverse impacts from land use changes on wetlands, watercourses and the Swan-Canning river system. With respect to the Swan-Canning river system, the Swan River Trust has agreed that an appropriate target is to ensure development does not lead to any deterioration in water quality in the Southern River.

The Department of Water is currently commissioning research into the performance of water quality structural controls in the context of Western Australia's climate, soils and native vegetation. A review of the performance of 'bio-retention' systems based on research conducted in the eastern states has concluded that sizing of these systems at 2 per cent of the surface area of the connected constructed impervious area is highly likely to achieve the per cent pollutant load reduction targets.

Until further specific research outcomes are published, designs may be based on the above interim sizing and also the methodologies established in the *Stormwater management manual for Western Australia* (Department of Water 2004-2007).

Surface water quality

Targets are to be achieved through adopting a treatment train approach including:

- non-structural measures to reduce applied nutrient loads
- onsite retention of 1-year 1-hour average recurrence interval event

- bioretention structures/systems, (also referred to as rain gardens) are to be sized at 2 per cent of connected constructed impervious areas.

If it is proposed to use a computer stormwater modelling tool to assess a proposed water quality management strategy, the following design targets are recommended:

As compared with a development that does not actively managed water quality, developments should achieve:

- at least 80 per cent reduction of total suspended solids
- at least 60 per cent reduction of total phosphorus
- at least 45 per cent reduction of total nitrogen
- at least 70 per cent reduction of gross pollutants.

Groundwater quality management

The environmental values of groundwater within, and surrounding, the study area should be upheld.

Maintain groundwater quality at pre-development levels (median winter concentrations) and, if possible, improve the quality of water leaving the development area to maintain and restore ecological systems in the (sub)catchment in which the development is located.

Water sensitive urban design and best management practices should not only promote infiltration to aid in prevention of possible local flooding from increased runoff due to urbanisation, but should also treat the water prior to its discharge to waterways, wetlands and to groundwater. This is particularly important given the high variability in phosphorus retention capacity of the soils in the study area and the anticipated increase in nutrient load due to urbanisation.

Where subsoil drainage is installed for groundwater level or soil moisture control, a 'treatment system' (swale/bioretention etc) at each subsoil drain outlet point will be required. The *Stormwater management manual for Western Australia* (Department of Water 2004–2007) contains guidance for the design of subsoil drainage, appropriate to calculated flow rates.

Where appropriate, field investigations should be undertaken to identify acid sulfate soils. Any reduction in groundwater level should not expose acid sulfate soils to the air, as this may cause groundwater contamination. If field investigations identify acid sulfate soils, further advice should be sought from the Department of Environment and Conservation.

Contaminated sites must be managed in accordance with the *Contaminated Sites Act 2003*.

Key design criteria

- The importation of clean fill and/or the provision of subsurface drainage will be required to ensure that adequate separation of building floor slabs from groundwater is achieved. In such instances, the subsurface drainage will need to be placed at or above a groundwater level endorsed by the Department. Guidelines on determining the groundwater drainage level are in preparation by the Department
- The bio-retention system and drainage inverts are to be set at or above the a groundwater level endorsed by the Department, although existing drainage inverts can remain.
- Subsurface drainage should be designed with free-draining outlets.
- Fill imported onto the site is to incorporate a band of material that will reduce phosphorus export via soil leaching, whilst also meeting soil permeability and soil compaction criteria specified by the local government authority.
- Where development is associated with any new or existing waterway or open drain that intersects the shallow water table and may discharge pollutants from the shallow groundwater to receiving environments, the following interim targets will be adopted until such time as appropriate site-specific targets are developed.

As compared with a development that does not actively manage water quality, achieve:

- at least 60 per cent reduction of total phosphorous
- at least 45 per cent reduction of total nitrogen.

Where development is associated with an ecosystem that is dependent on a particular hydrologic regime for survival, the water quality discharged to the groundwater should be in accordance with the requirements of the Department of Environment and Conservation.

Adopt an adaptive management approach to water quality management

It is recognised that there is currently only limited data available on which to base management decisions and that the performance of some best management practices for managing stormwater quality is not yet clearly understood. Two key risks have been identified with the proposed approach of adopting design objectives and not performance targets for the management of water quality:

- the failure of structural and non-structural measures to meet the design objectives
- the mobilisation of legacy nutrients in the groundwater, caused mainly by historical land uses.

To manage these risks it is important to adopt an adaptive management approach, monitoring the effectiveness of the proposed strategies and modifying plans to achieve the required outcomes.

To meet the objective of no deterioration in water quality, water quality will be monitored in the arterial drainage system, particularly the Forrestdale main drain. Should water quality monitoring in the Forrestdale main drain indicate deterioration, the Department of Water will seek to determine the cause and take corrective action, which may include modifying this water quality management strategy.

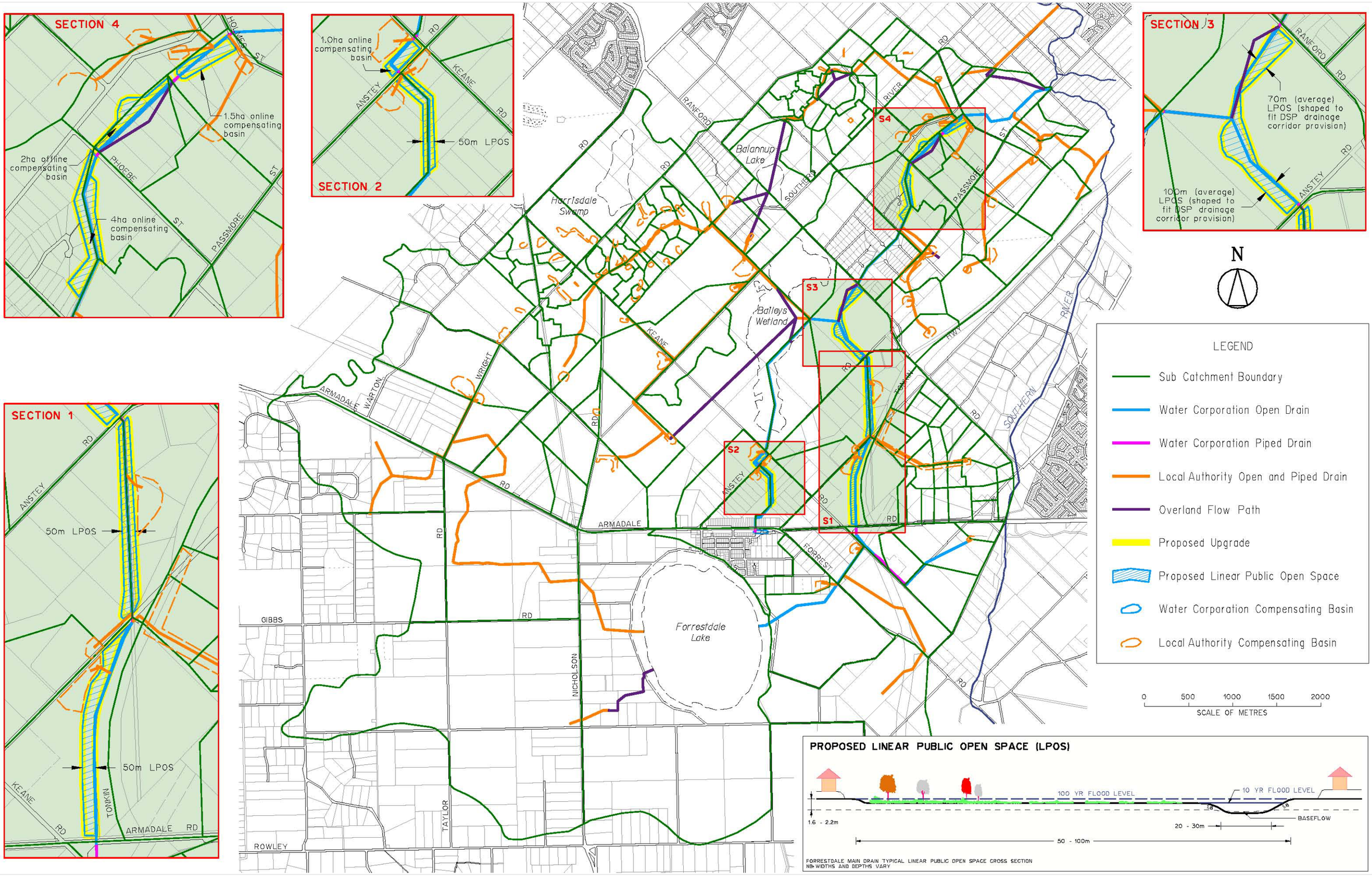

Figure 9. Land required for drainage in the Forrestdale main drain catchment

5 Water use efficiency

Water conservation and efficiency are about reducing water consumption, making it available for higher value purposes and/or achieving greater productivity from the same amount of water.

In new developments, water use efficiency requires the urban form to minimise use and to achieve the highest value use of fit-for-purpose water. This means that water should be of a quality suitable for its intended final use. For example in areas identified as suitable, garden bores provide a fit for purpose alternative to scheme water for garden use.

In the average household, 47 per cent of water is used outside the home. Gardens (private and public) and public open space areas should be waterwise to minimise irrigation requirements. This includes the use of low water requirement plants and minimal turf areas. The use of scheme water for non drinking purposes should be minimised.

Non-scheme water is often used in applications outside buildings, commonly for maintenance of public open space and passive and active recreation areas. Demand has traditionally been met by groundwater resources.

Efficient water use can be achieved through approaches such as raising community awareness, regulation, market mechanisms, and financial incentives or assistance to facilitate change. The State Government has identified demand reduction and efficient use of potable water as a priority (Government of Western Australia 2007).

New developments should aim to achieve a target of:

- less than 100 kilolitres per person per year (kL/person/year) for consumers within Perth

In addition there is an aspirational target of:

- Not more than 40–60 kL/person/yr scheme water

The *State water recycling strategy* (Department of the Premier and Cabinet and Department of Water 2008) further identified the need for new housing developments to consider the use of alternative, fit-for-purpose, water supplies.

5.1 Water efficiency tools

Water efficiency standards and labelling

Products that use water in the home are sold with a star rating similar to that used for energy products. The higher the star rating, the more water efficient the product is.

5 star plus: water use in houses

The Water use in houses code stage one applies to new homes approved for construction after 1 September 2007 (Department of Housing and Works 2007). This provides for:

- limiting water use through efficient 3 or 4 star taps, shower and toilet fittings
- new swimming pools to be fitted with a pool blanket
- reducing energy waste by limiting the distance of taps from a hot water source.

Waterwise rebate

The Waterwise rebate program aims to achieve more efficient water use by promoting water efficient appliances in households. Since being introduced in February 2003 as a state water strategy initiative, the program has been extremely successful in saving water. It has been extended and rebates are now available for swimming pool covers, rain sensors, subsurface irrigation systems, waterwise garden assessments, flow regulators, greywater re-use systems, washing machines, rainwater tanks, garden bores and waterwise irrigation systems.

Waterwise communities toolkit

To integrate and further develop options for household scale water conservation and recycling, an online Waterwise communities toolkit is being developed.

This toolkit will promote water conservation and recycling to local government, developers and other users. It will provide access to information on both recycling and wise water use, including:

- the availability of shallow groundwater
- the availability of sources for recycled water
- key land planning considerations
- alternative water solutions including rainwater tanks, community bores, greywater and landscaping
- streamlined application and approval processes.

The toolkit is currently under development led by the Department of Water, and will be finalised by 2010.

H2Options

H2Options (Water Corporation 2008) is a seven-step guide for developers for considering alternative water supplies, in addition to the existing processes for securing water supply, wastewater and drainage services within a development.

Water conservation/efficiency plans

The *State water strategy* (Government of Western Australia 2003) introduced the concept of water users developing and implementing water conservation/efficiency plans as part of the water licensing process undertaken by the Department of Water and integrating water use efficiency measures into water users' daily operations.

Water conservation/efficiency plans enable licensees to obtain a thorough knowledge of their water use and provide details of a water efficiency implementation program to achieve improved water use efficiency. *Statewide policy no 16 – Policy on water conservation/efficiency plans: Achieving water use efficiency through water licensing state* (Department of Water 2008) further discusses the plans.

In the Perth region, Water conservation plans are required for local governments to:

- develop and implement climate change adaption strategies
- ensure that water use remains within licensed allocations
- demonstrate efficient groundwater use
- address decreasing groundwater availability while maintaining amenity, sport and recreation and biodiversity outcomes
- promote a culture of continuous improvement.

Developers should liaise with the relevant Local Government Authority to ensure that any development will align with the requirements of their Water conservation plan.

Other documents that may also provide guidance are:

- *Interim position statement: constructed lakes* (Department of Water 2007)
- *Interim position statement: third pipe (community bores)* (Department of Water in press)
- *Stormwater management manual for Western Australia* (Department of Water 2004–2007).

The key objectives for urban water use are to:

- ensure the efficient use of all water resources in the newly developing urban form and aim to achieve highest value use of fit for purpose water
- maintain opportunities for future generations by using water more efficiently. This is best achieved by combining several approaches such as raising community awareness, regulation, market mechanisms to facilitate recognition of the true value of water and financial incentives/assistance to facilitate change.

6 Commitment to best management practice

In order to meet the design criteria of reductions in total phosphorus (TP), total nitrogen (TN), total suspended solids (TSS) and gross pollutants as compared to developments in which water treatment is not undertaken, it is necessary to use a combination of best management practice strategies.

In addition, best management practice strategies reduce risks of flooding on housing and infrastructure whilst maximising the potential for stormwater to be treated as a resource.

The hierarchy of best management practice principles is as follows:

- implement controls at or near the source to prevent pollutants entering the system and/or treat stormwater
- install in-transit measures to treat stormwater and mitigate pollutants that have entered the conveyance system
- implement end-of-pipe controls to treat stormwater, addressing any remaining pollutants prior to discharging to receiving environments

Structural and non-structural best management practice strategies should be used in combination to achieve the required stormwater treatment outcomes.


Rainwater Tank, GHD, 2007

Recommended best management practices in increasing order of scale include:

- Residential lot scale:
  - on-site soakage devices, where appropriate, with overflow outlets (detention)
  - water-wise and nutrient-wise landscaping
  - porous pavements
  - amended topsoil
  - rainwater tanks for harvesting, detention and reuse
- Commercial lot scale:
  - on-site detention and/or retention,
  - water-wise and nutrient-wise landscaping
  - maximised permeable surfaces

  - amended topsoils
  - landscaped infiltration structures,
  - hydrocarbon management and sediment traps
  - rainwater tanks for harvesting, detention and re-use
- Street scale:
  - infiltration measures
  - sediment traps
  - porous pavements (car parking)
  - conveyance bioretention systems


Biofiltration Pocket (GHD, 2007)

- Estate scale:
  - retention/detention (including water quality treatment) areas integrated within public open space, in accordance with the objectives and requirements of Elements 4 (public parkland) and 5 (urban water management) of *Liveable neighbourhoods edition 4* (Western Australian Planning Commission 2007)
  - use of imported fill material with a high phosphorous retention capability
  - retention of existing waterways and aim to restore a pre-development ecology and channel morphology in new and existing waterways
  - use of non-structural best management practice such as interpretive signage, garden education programs, publishing a water sensitive urban design web-page for the estate, and inviting residents to engage with existing community catchment groups
- Area scale:
  - non-structural best management practices such as public education campaigns, support of local community catchment groups, installation of interpretive signage and web pages, and the adoption of appropriate planning principles including local laws for on-site detention and retention

The above practices may be limited by several factors, including: local soil and hydrological conditions; the depth and type of fill imported; public safety and public health standards; design life/reliability requirements; maintenance/management costs; legal authority; and streetscape aesthetics. Advice should be sought from the local authority on the practices most appropriate for adoption within the local structure plan area.

7 Implementation

7.1 Requirements for following stages

State planning policy no. 2.9: water resources (Western Australian Planning Commission 2004) requires that planning should contribute to the protection and wise management of water resources through local and regional planning strategies, structure plans, schemes, subdivisions, strata subdivisions and development applications. *Better urban water management* (Department of Planning and Infrastructure, Department of Water, Western Australian Local Government Authority and Department of Environment, Water, Heritage and the Arts 2008) provides guidance on implementation of *State planning policy no. 2.9: water resources* (Western Australian Planning Commission 2004). It identifies the requirements for water management strategies and plans that should be developed to accompany the land use planning and approvals process in the district structure plan area at each stage of the planning process.

In summary, all local structure planning should incorporate a local water management strategy consistent with the strategies and objectives of this *Integrated land and water management plan*. Subsequent subdivision applications should be accompanied by an urban water management plan where required by the Department of Water and the local authority, and/or should be consistent with any approved local water management strategy and with the strategies and objectives of this *Integrated land and water management plan*.

Guidelines for preparing local water management strategies and urban water management plans have been published by the Department of Water and are available on the internet site or from Department of Water offices. Developers are encouraged to contact the Department of Water and the local authority early in the planning process to discuss specific water management requirements for proposals.

Engineering drawings submitted to council for approval should be supported by clear and auditable documentation, providing details of proposed staging and implementation of the surface and groundwater quantity and quality management strategy.

7.2 Review of the *Integrated land and water management plan*

It is intended that the *Integrated land and water management plan* be reviewed within ten years or earlier if deemed necessary until all development has occurred consistent with the *Southern River/ Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001).

The review should be undertaken by the Department of Water, with agreement from the Environmental Protection Authority, Western Australian Planning Commission,

City of Gosnells, City of Armadale, Armadale Redevelopment Authority and the Water Corporation. The review should cover, but not be limited to the following:

- assessment of impacts of development
- design objectives
- requirements for local water management strategies and urban water management plans
- cost recovery mechanisms.

7.3 Monitoring strategy

A groundwater and surface water monitoring program should be designed as part of the local water management strategy to assess the hydrological impacts of the proposed development and to establish a contingency action plan with associated trigger values for specified parameters.

The baseline monitoring programme should be conducted for at least three years prior to development to characterise the sites hydrology and hydrogeology. However, in some cases it may be acceptable to provide 18 months of predevelopment monitoring with a minimum of two winters where the monitored hydrology and hydrogeology are considered suitably reflective of the long-term environment and approval has been given by the Department of Water. The results of the baseline monitoring should be presented in the local water management strategy.

The post-development monitoring program should be tailored to the development, quantifying the developments impact on surfaces water quality, surface water flows, groundwater levels seasonal fluctuation and quality.

The monitoring results can then provide:

- pre-development baseline data
- post-development a comparison to target design objectives and criteria
- a trigger for contingency action, as per the contingency plan
- an interim internal assessment tool of the monitoring program.

All monitoring results should be provided to the Department of Water in an agreed format. A report on these results is not usually required; however, where a trigger for contingency action has been reached it will be necessary to report on the action taken.

Standards

Monitoring sampling should follow *Australian Standards AS/NZ 5667 series of water quality sampling guidance notes* and a National Association of Testing Authorities accredited laboratory is required to perform water quality testing.

Monitoring network

The groundwater monitoring bore network's extent and density should spatially represent the hydrogeology of the local area, to the satisfaction of the local government and the Department of Water.

Surface water monitoring sites should capture the sites' inflows and outflows, detention or retention storages inflow, and water-dependent ecosystems.

Monitoring parameters

Monitoring of groundwater levels should be initially on a monthly basis to establish water level fluctuations. Surface water flows, duration and period are site-specific and should meet the regulatory bodies recommendations.

Samples should be analysed for at least the following water quality parameters:

- in-situ pH, electrical conductivity (EC) and temperature
- heavy metals – arsenic, cadmium, chromium, copper, lead, nickel, zinc, mercury
- total suspended solids (TSS)
- total nitrogen (TN) and total kjeldahl nitrogen (TKN)
- ammonia (NH_4)
- nitrate and nitrite (NO_x)
- total phosphorus (TP)
- orthophosphate (PO_4^{3-})


GHD, 2007

The following additional parameters are recommended in locations where drainage intercepts shallow groundwater systems:

- total titratable acidity and total alkalinity
- major anions (chloride, bromide and sulfate)
- major cations (calcium, magnesium, sodium and potassium)
- iron and aluminium

The effective management of urban stormwater quality typically focuses on the treatment of frequent, low-intensity stormwater events. These small but frequent flows account for the majority of nutrient loads and represent the best opportunity for water quality improvement.

The process of infiltration filters the stormwater and is effective in the removal of particulate nutrients. Dissolved nutrients cannot be filtered and are therefore more difficult to treat. Urban runoff is a combination of dissolved and particulate nutrients.

If the treatment measure is infiltration, then filtered and unfiltered samples of total nutrient concentrations should be measured to quantify the proportion of dissolved and particulate nutrients generated within the development site, and the method recorded.

A summary of an example monitoring program is presented in Table 1 below. The format and frequency of post-development reporting should be proposed within the local water management strategy and approved by the local government and Department of Water. Where a trigger for contingency action, as specified in the local water management strategy, is reached it will be necessary to report on the action taken.

Table 1 Monitoring programme summary

	Sites	Frequency	Parameters
Surface Water	Developments inflow and outflow locations Detention storages inflow and outflow Water bodies	Site specific	-Flows -Water levels
		Monthly grab samples while flowing, to be reviewed after the first year of monitoring	-In-situ pH, electrical conductivity and temperature -Unfiltered sample: pH, electrical conductivity, total nitrogen, filterable reactive phosphorus, total kjeldahl nitrogen, ammonia, total phosphorus, heavy metals -Filtered sample: Nitrate/nitrite and orthophosphate
Groundwater	Network of monitoring bores providing a suitable spatial representation of the study area	Monthly	Water level
		Quarterly (typically January, April, July, October)	-In-situ pH, electrical conductivity and temperature -Unfiltered sample: pH, electrical conductivity, total nitrogen, filterable reactive phosphorus, total kjeldahl nitrogen, ammonia, total phosphorus, heavy metals -Filtered sample: Nitrate/nitrite and orthophosphate

A summary of monitoring requirements and responsibilities is provided in Table 2

Table 2 Assessment requirements of development proposals - monitoring

Responsible Agency	Timing	Monitoring Requirement
Developers	Period of 3 years pre-development (minimum of 18 months with at least 2 winters with approval of the Department of Water)	• Monitor key criteria for maintenance of hydrologic regimes, buffers and ecological corridors/linkages of environmental assets • Monitor local superficial aquifer groundwater levels • Monitor flow and water quality (including nutrients, TSS, and gross pollutants) at regular intervals (monthly) • Monitor peak flows (snapshots) within developments and wetlands
	Period of 3 years post-development, including at least 1 year following completion of the majority (80%) of developments	• Monitor key criteria for maintenance of hydrologic regimes, buffers and ecological corridors/linkages of environmental assets • Monitor local superficial aquifer groundwater levels • Monitor flow and water quality (including nutrients, total suspended solids, and gross pollutants) at regular intervals (monthly) • Monitor peak flows (snapshots) within developments and wetlands • Monitor behavioural patterns with respect to non-structural measures for water quality management • Monitor performance of new drainage systems
Department of Water	Ongoing	• Monitor efficacy of water conservation measures and achievement of water consumption targets • Monitor regional surface water flows and quality • Monitor confined aquifer groundwater levels and regional superficial aquifer groundwater levels and quality • Monitor groundwater abstraction in the district structure plan area • Monitor surface water quality and flows at strategic locations in main drains and waterways • Monitor structural best management practices for efficacy with advice from the research and development for urban water – technical advisory group • Monitor performance of new drainage systems across catchments and property boundaries
Local government – with funding from developer contributions scheme	From 3 years post-development	• Monitor key criteria for maintenance of hydrologic regimes, buffers and ecological corridors/linkages of environmental assets • Monitor local superficial aquifer groundwater levels • Monitor water quality and flows within developments and wetlands • Monitor behavioural patterns with respect to non-structural measures for water quality management
Department of Environment and Conservation	Ongoing	• Evaluate health of significant environmental assets

7.4 Action plan

Table 3 presents the key actions necessary to implement the proposed drainage and water management plan, identifying the responsible agency and proposed time for completion. SJ Shire refers to Serpentine-Jarrahdale Shire.

Table 3 Actions and responsibilities for implementation of the Integrated land and water management plan

Strategy	Action	Lead agency	Timing
Protection of environmental assets			
Minimise changes to hydrology to prevent impacts on watercourses and wetlands	Establish a process for ongoing evaluation of the impacts of development on significant environmental assets and review of the strategy	Department of Environment and Conservation	As part of the planning process
	Identify land required for protection of environmental assets and to allow for the management of their hydrologic regimes	Department of Environment and Conservation	As part of the planning process
	Incorporate environmental assets as a key part of community planning	Department for Planning and Infrastructure and City of Armadale or City of Gosnells	Through assessment of planning proposals
Manage and restore watercourses and wetlands	Develop a management plan for the Wungong River consistent with the post development hydrology	Armadale Redevelopment Authority in conjunction with City of Armadale	Commencing immediately and ongoing
	Review and update management plans for wetlands with management category classifications	Department of Environment and Conservation	Ongoing
Assess and manage impacts on native flora and fauna	Provide appropriate buffers and ecological corridors/ linkages in local structure plans	Western Australian Planning Commission and City of Armadale or City of Gosnells	Through assessment of planning proposals
	Establish responsibilities for ongoing management of natural areas	Department of Environment and Conservation and City of Armadale or City of Gosnells	As part of the planning process
	Undertake more detailed fauna assessments at the local structure plan stage, including details of management measures to deal with issues such as habitat protection, fauna relocation and non-native animal control	Western Australian Planning Commission and City of Armadale or City of Gosnells	Through assessment of planning proposals

Strategy	Action	Lead agency	Timing
Assess and manage impacts on sites of indigenous significance	Undertake more detailed assessments at the local structure plan stage, including details of management measures as required	Developers in consultation with Department of Indigenous Affairs and City of Armadale or City of Gosnells	Through local structure planning
Surface water management			
Minimise changes in hydrology to prevent impacts on receiving environments	Ensure development complies with the stormwater design objectives for flooding and ecological protection	Department of Water	
Manage surface water flows from major events to protect infrastructure and assets	Ensure development in the district structure plan area complies with the stormwater design criteria for flood management in this *Integrated land and water management plan*	City of Armadale or City of Gosnells and Water Corporation	Through assessment of local water management strategy/ urban water management plan
	Secure land that is required for flood protection and drainage requirements.	Western Australian Planning Commission and City of Armadale or City of Gosnells	Through local structure planning
	Design and construct regional flood management infrastructure in accordance with the *Forrestdale main drain arterial drainage strategy* and *Wungong urban water master plan district water management strategy*	Water Corporation	As determined by rate of local structure planning
Apply the principles of water sensitive urban design	Seek opportunities to include environmental and social objectives in planning of stormwater management, such as incorporation of multiple use corridors to provide habitat values and opportunities for recreation	City of Armadale or City of Gosnells	Through assessment of local structure plans
	Retain existing natural waterways and drainage lines in the design of stormwater management systems for urban development	City of Armadale or City of Gosnells and Water Corporation	Through assessment of local structure plans

Strategy	Action	Lead agency	Timing
Adopt nutrient load reduction design objectives for stormwater runoff	Ensure development in the district structure plan area complies with the design objectives for stormwater quality	City of Armadale or City of Gosnells	Through assessment of local water management strategy/ urban water management plan
Groundwater management			
Manage groundwater levels to protect infrastructure and assets	Monitor superficial aquifer groundwater levels pre- and post-development at the local scale	Developers, data to be passed by City of Armadale or City of Gosnells to Department of Water for collation	3 years each pre- and post-development
	Monitor confined aquifer groundwater levels and regional superficial aquifer groundwater levels	Department of Water	Commencing immediately and ongoing
	Investigate potential changes to local water balance and implications for groundwater rise	Department of Water	Through assessment of local water management strategy/ urban water management plan
	Manage groundwater levels within ranges reported in this *Integrated land and water management plan* via a combination of subsoil drainage at local controlled groundwater levels, imported fill and groundwater abstraction as appropriate for management of groundwater rise, and via recharge mechanisms for falling groundwater levels	Developers for 3 years post-development, after that time responsibility of City of Armadale or City of Gosnells	Commencing immediately and ongoing
Maintain groundwater regimes for groundwater dependent ecosystems	Review developers investigations of local groundwater regime to establish local groundwater management criteria near groundwater-dependent ecosystems	Department of Water	Through assessment of local water management strategy/ urban water management plan
Protect the value of groundwater resources	Prepare a groundwater allocation plan for the district structure plan area	Department of Water	Ongoing

Strategy	Action	Lead agency	Timing
Adopt nutrient load reduction design objectives for discharges to groundwater	Ensure development in the district structure plan area complies with the design objectives for groundwater quality	Department of Water	Through assessment of local water management strategy/ urban water management plan
Monitoring and implementation			
Adopt an adaptive management approach	Monitor water quality and flows pre- and post-development, both within developments and at strategic locations in waterways This includes both regular (monthly) sampling for flow and water quality and targeted peak flow during storm events Locations to include key outlets to waterways	At the local scale: developers then City of Armadale or City of Gosnells data to be passed to Department of Water for collation; At the regional scale (sub-catchment outlets): Department of Water and Water Corporation	3 years pre- and post-development, then ongoing
	Collate and analyse monitoring data to establish baseline water quality data throughout the district structure plan area	Developer to pass data to Department of Water, Department of Water to collate and organise data, CSIRO's real-time data collection system to support the data analysis	Commencing immediately and ongoing
	Assess behavioural patterns with respect to non-structural measures and the effectiveness of non-structural measures, using a method such as community-based social marketing	Developer to implement with guidance from local government, local government to take over responsibility 3 years post-development	Ongoing

Strategy	Action	Lead agency	Timing
	Determine efficacy of structural best management practices, provide feedback to developers and allow for alteration of practices if necessary	Department of Water and local government with advice from the research and development for urban water – technical advisory group	Ongoing
	Engage the research community in the process of evaluation and feedback	Research and development for urban water – technical advisory group	Ongoing
Water conservation			
Adopt drinking water consumption target	Ensure that residential development complies with the water conservation design objectives	Department of Water	Through assessment of local water management strategy/ urban water management plan
	Ensure scheme water substitution does not lead to an overall increase in water consumption	Department of Water	Through assessment of local water management strategy/ urban water management plan
Ensure that non-potable water supply systems deliver a net benefit to the community	The impact of a non-potable water supply system on the local water balance should be assessed as part of the local water management strategy	Department of Water	Through assessment of local water management strategy/ urban water management plan
	The design of a non-potable water supply system should be subject to a sustainability assessment as part of the local water management strategy to determine the net benefit or cost of the scheme	Department of Water	Through assessment of local water management strategy/ urban water management plan

Strategy	Action	Lead agency	Timing
Ensure that non-potable water supply systems are designed as part of an integrated water supply	Non-potable water supply systems should be designed in conjunction with potable water supply systems, to ensure that fire-fighting requirements can be met from one or both of the systems and that both systems are designed for efficiency (e.g. minimising pipe sizes and pumping requirements where possible)	Department of Water	Through assessment of local water management strategy/ urban water management plan
	Reach agreement between the developer, local government and licensed service provider (e.g. Water Corporation) on the design, operation and management of any non-potable water supply system, including arrangements for use in public open space and appropriate level of water quality, to ensure that all water demands are met appropriately	Department of Water	Through assessment of local water management strategy/ urban water management plan

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