Forrestdale main drain
arterial drainage strategy

Looking after all our water needs

Department of Water

November 2009
Acknowledgements

This report was prepared by Helen Brookes and associates at GHD for the Department of Water. The Department of Water would like to thank the Environmental Protection Authority, Western Australian Planning Commission, City of Armadale, City of Gosnells, Water Corporation and the Armadale Redevelopment Authority for their contribution to this publication.

The Water Corporation was the project manager for the development of this plan prior to the establishment of the Department of Water.

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

This final Arterial drainage strategy has been prepared by the Water Corporation for the Department of Water. It provides the details of the Arterial drainage strategy for the Forrestdale main drain catchment discussed in the Southern River integrated land and water management plan (Department of Water 2009).

The Arterial drainage strategy presents the Department of Water’s guidance for the Water Corporation, City of Armadale, City of Gosnells, Western Australian Planning Commission, land developers and other state agencies about water management issues to help development proceed within the Forrestdale main drain catchment area.

The Arterial drainage strategy and the Southern River integrated land and water management plan (Department of Water 2009) also assist in integrating land and water planning as required by Statement of 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).

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.

A summary plan and checklist for developers has been developed and included with this document.

A regional scale controlled groundwater level is established and advice for developers and stakeholders for the management of groundwater quantity and quality within the Forrestdale main drain catchment area is given.

Figure 3 shows the strategy, which was developed based on the sustainability approach considering environmental, economic and social issues in the study area.
1 Introduction

The Southern River/Forrestdale/Brookdale/Wungong district structure plan (Figure 1) (Western Australian Planning Commission 2001) provides a guide to the future development and management of key environmental issues for the locality of Southern River in the City of Gosnells and Forrestdale, Brookdale and Wungong in the City of Armadale.

The Southern River/Forrestdale/Brookdale/Wungong district structure plan (Western Australian Planning Commission 2001) describes potential development areas, road networks, major community facilities, conservation and parks and recreation reserves, and a neighbourhood structure. It also provides proposals for the implementation of the plan including zoning mechanisms, staging, and financial and management arrangements.

However, the Southern River/Forrestdale/Brookdale/Wungong district structure plan (Western Australian Planning Commission 2001) did not fully address drainage and environmental issues and in February 2001, the Water and Rivers Commission commissioned JDA consultant hydrologists to undertake the development of the Urban water management strategy (JDA 2002).

In reviewing the Urban water management strategy (JDA 2002) the Environmental Protection Authority advised that it favoured a staged approach to development based on precautionary principles that would allow for monitoring of the impacts of development on water quality and hydrology and subsequent retrofitting of constructed drainage infrastructure if required. Consequently the Environmental Protection Authority sought assurances regarding the implementation of the Urban water management strategy (JDA 2002) and requested that a memorandum of understanding (MOU) be prepared and signed by all agencies involved in the implementation of the Urban water management strategy (JDA 2002). The MOU was signed in October 2003.

Under the MOU, the Water Corporation has undertaken the coordination and project management of the development of the Southern River integrated land and water management plan (Department of Water 2009) in consultation with all parties. In order to provide the surface water management section of this plan, a technical working group was established by the MOU steering committee to develop the recommendations of the Urban water management strategy (JDA 2002) into an Arterial drainage strategy for the Forrestdale main drain catchment.

The scope of the Southern River integrated land and water management plan (Department of Water 2009) covers all aspects of total water cycle management, including:

- protection of significant environmental assets within the structure plan area, including meeting 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 the application of water sensitive urban design principles for 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
- water quality management, which includes source control of pollution inputs by catchment management, acid sulfate soil management, control of contaminated discharges from industrial areas and management of nutrient exports from surface runoff and groundwater through structural measures.

The Southern River integrated land and water management plan (Department of Water 2009) and this Arterial drainage strategy for the Forrestdale main drain catchment form the drainage and water management plan within the state government planning framework, as defined 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) and outlined in Figure 2 below.

Note: The above diagram depicts the optimal process. In situations where there is existing zoning and a lack of guiding information, a flexible approach to implementation may be required. This is at the discretion of the Western Australian Planning Commission on advice of the Department of Water.

Figure 2 Planning framework integrating drainage planning with land planning processes
This document presents the proposed *Arterial drainage strategy* for the Forrestdale main drain catchment in accordance with the responsibilities for drainage planning assigned to the Department of Water by the state government.

### 1.1 Planning background

In addition to *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), the *Arterial drainage strategy* uses the following documents to define its key principles and objectives:

- *State planning policy no. 2.9: water resources* (Western Australian Planning Commission 2004)
- *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001).

### 1.2 Previous studies

A number of key investigations have been undertaken in the Forrestdale locality. It is the aim of this *Arterial drainage strategy* to incorporate information from all of these studies and present design criteria and management strategies.

The *Southern River/Forrestdale/Brookdale/Wungong district structure plan urban water management strategy* was completed in 2002 by JDA consultant hydrologists. It presented stormwater management strategies for the study area and some of the proposed strategies have been incorporated into this study.

Regional-scale groundwater modelling was completed by Rockwater Pty Ltd in 2005 for the Water Corporation to assess any impacts from variations in climate or planned development in the study area.

An evaluation of the impact of water releases from stormwater arterial drainage on Forrestdale wetlands has been completed by GHD (2007) for the Water Corporation.

The study area has been assessed for acid sulfate soil risk, the results of which are presented in *Planning bulletin no. 64: acid sulfate soils* (Western Australian Planning Commission 2003).

Preliminary investigation into the ecological water requirements of selected wetlands on the Forrestdale main drain alignment (ENV 2007) has been undertaken.

Environmental water requirements of groundwater dependent ecosystems have not yet been published for this area.
1.3 Summary plan and checklist

Figure 3 provides an overview of the Forrestdale main drain catchment Arterial drainage strategy addressing stormwater quantity management. A checklist to assist developers in the preparation of local water management strategies has also been developed.

The checklist provides a summary of items to be addressed by developers in the preparation of local water management strategies for assessment by the City of Armadale or the City of Gosnells when an application for a local structure plan is lodged.

The checklist should be completed and signed by a suitably qualified professional and submitted to the local government with the local water management strategy for assessment when an application for a local structure plan is lodged.
Local water management strategy checklist for developers

The checklist provides a summary of items to be addressed by developers in the preparation of local water management strategies for assessment by the City of Armadale or the City of Gosnells when an application for a local structure plan is lodged.

The checklist should be completed and signed by a suitably qualified professional and submitted to council together with the local water management strategy.

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<td>3.7 Indigenous sites identified</td>
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<td>3.8 Existing infrastructure and constraints to design identified (include management strategies for any identified constraints)</td>
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<td>3.9 Site water balance pre-development and post-development identified</td>
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<td>Monitoring/sampling locations</td>
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<td>Water quality parameters to be monitored (refer to Integrated land and water management plan)</td>
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<td>Maintenance schedules</td>
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<td>Roles and responsibilities (for pre-development, during construction and all periods post-development)</td>
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<td>Funding</td>
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<td>Review</td>
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2 Pre-development environment

Documents referred to for background information include:

- *Forrestdale main drain arterial drainage scheme technical report* (Water Corporation 2007)
- *Southern River/Forrestdale/Brookdale/Wungong district structure plan urban water management strategy* (JDA 2002)
- *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001)
- *Planning bulletin no. 64: acid sulfate soils* (Western Australian Planning Commission 2003)
- *Swan coastal geomorphic wetland mapping*
- *Aboriginal Heritage Act 1972 and Register of aboriginal sites* (Department of Indigenous Affairs)

2.1 Study area

The Forrestdale main drain catchment is located 20 km south of Perth, and has an area of approximately 54 km². Approximately 19 km², or one third of the total catchment area forms the Forrestdale Lake subcatchment. The Forrestdale main drain discharges into the Southern River, approximately 6 km upstream of its confluence with the Canning River. The catchment lies within the boundaries of the City of Gosnells and the City of Armadale (Figure 4).

The existing land use of the catchment (Figure 5) is predominantly rural/agricultural with large areas of regional open space. The majority of rural land is used for the agistment of horses and grazing of cattle. There are relatively few residential areas, with Forrestdale townsite and the kennel zone alongside Ranford Road being the most significant of these.

Substantial areas of rural land and regional open space are wetland areas with much of the catchment being subject to periodic inundation from annual groundwater fluctuations. Existing rural residential properties in the catchment have been constructed on pads to prevent flooding.

There are two kennel zones currently situated within the Forrestdale main drain catchment: one at the corner of Ranford Road and Wright Road, which is approximately 0.3 km² in size; and a second, considerably larger area to the east of Ranford Road of approximately 0.9 km², which is bisected by the Forrestdale main drain.

Forrestdale townsite covers approximately 0.6 km² and is mainly situated to the south of Armadale Road on the northern edge of Forrestdale Lake. The town remains partially unsewered and therefore has the potential to adversely affect the water quality of Baileys branch drain and the Forrestdale main drain.
2.2 Geotechnical information

The catchment is located on the Swan Coastal Plain and is predominantly flat with levels varying from 28 m Australian height datum (AHD) in the west sloping gently to the north and east, to around 18 m AHD at the Southern River, which forms the eastern boundary of the catchment (Figure 6).

2.3 Soils

The superficial geology of the area includes degraded, low dunes of Bassendean sand with low-lying interdunal areas.

The base of the superficial formation generally slopes downwards to the west, steeply from around 0 m AHD near Southern River gradually down to about -20 m AHD beneath the centre of the Jandakot mound. The superficial formations generally consist of sandy sediments (a thin layer of Bassendean sand overlying Gnangara sand) with small isolated pockets of clayey sediments (Guildford clay) (Rockwater 2005).

The Ascot formation, consisting of fossiliferous limestone and calcareous sand with some clay, generally lies at the base of the superficial formations. There is commonly a ‘coffee rock’ (variably-cemented ferruginous sand) layer up to 17 m thick below the water table (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).

Acid sulfate soils

The Western Australian Planning Commission’s Planning bulletin no. 64: acid sulfate soils (2003), which is based upon a review of existing geomorphological, geological and hydrological information, indicates that the majority of the Forrestdale main drain catchment has a moderate to low risk of containing actual acid sulfate soils and potential acid sulfate soils (Figure 7). However, some portions of the catchment have a high risk, including some areas where modifications to the Forrestdale main drain and Baileys branch drain are proposed.

Investigations will be needed to identify areas of acid sulfate soils and these areas will require an acid sulfate soil management plan to be prepared in accordance with the strict amelioration standards set out in Planning bulletin no. 64: acid sulfate soils (Western Australian Planning Commission 2003).
2.4 Environmental assets and water-dependent ecosystems

The location of Bush Forever sites and Environmental protection policy (Swan Coastal Plain) 1992 wetlands are identified in Figure 8. These have been considered in developing the proposals for modifications to the Forrestdale main drain and Baileys branch drain. However, these sites do not necessarily represent all occurrences of rare or endangered species within the catchment. A more detailed environmental assessment by a qualified consultant should be undertaken prior to the commencement of vegetation clearance.

Forrestdale Lake is listed under the Ramsar convention as a wetland of international significance, as well as being a conservation category wetland and an Environmental protection policy (Swan Coastal Plain) 1992 lake. The entire lake is contained within Bush Forever site no. 345.

Balannup Lake is a conservation category wetland and an Environmental protection policy (Swan Coastal Plain) 1992 lake, and is contained within Bush Forever site no. 413.

The Forrestdale main drain catchment also contains many other substantial Bush Forever sites and numerous wetlands classified as conservation category wetlands or resource enhancement wetlands including:

- Baileys wetland – conservation category wetland within Bush Forever site no. 342
- Harrisdale swamp – conservation category wetland within Bush Forever site no. 253
- Southern River floodplain wetland – conservation category wetland within Bush Forever site no. 464
- Kennels wetland – conservation category wetland within Bush Forever site no. 465
- Lander Road swamp – conservation category wetland
- Confluence wetland – conservation category wetland within Bush Forever site no. 342
- Nicholson Road wetland – conservation category wetland within Bush Forever site no. 262
- Gerty Way wetland – resource enhancement wetlands adjacent to Bush Forever site no. 340
- Forrestdale Business Park wetland – conservation category wetland
- East Forrestdale palusplain – conservation category wetland within Bush Forever site no. 345.

The Department of Environment and Conservation has recorded the presence of several priority and declared rare flora species within the catchment boundary.
In addition, there are three claypan threatened ecological communities and one Muchea limestone threatened ecological community within the catchment boundary. The locations of these sites are identified in Figure 8 and have been considered in developing the proposals for modifications to the main drainage system.

2.5 Social considerations

The *Aboriginal Heritage Act 1972* was introduced in Western Australia in 1972 to protect aboriginal heritage. The Act recognises Aboriginal peoples' strong relationships to the land, which may go back many thousands of years.

The Act provides automatic protection for all places and objects in Western Australia that are important to Aboriginal people because of connections to their culture. These places and objects are referred to as aboriginal sites.

The Department of Indigenous Affairs maintains a *Register of aboriginal sites* as a record of places and objects of significance to which the Act applies. The presence of an aboriginal site places restrictions on what can be done to the land. Anyone who wants to use land for research, development or any other cause should investigate whether there is an aboriginal heritage site on the land.

The Minister for Indigenous Affairs is responsible for the administration of the Act. Under the Act it is an offence for anyone to excavate, damage, destroy, conceal or in any way alter an aboriginal site without the Minister's permission. The Department of Indigenous Affairs assists the Minister in the administration of the Act. The *Register of aboriginal sites* identifies several sites of indigenous significance in the Forrestdale main drain catchment. These sites are mostly concentrated around the Southern River and its flood plain, but also include Forrestdale Lake and other smaller sites around the catchment.

The locations of these sites are identified in Figure 8 and have been considered in developing the proposals for modifications to the main drainage system. None of the proposals for Water Corporation drains that are described in this report are expected to impact on these sites. However, an assessment should be undertaken by a qualified consultant to determine whether a more thorough aboriginal heritage investigation of the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) area needs to be undertaken for any specific location to identify unregistered sites.

The design of modifications to the main drainage system has considered the potential for public amenity usage of areas within and adjacent to proposed drainage facilities. Flood storage areas have been designed to be kept dry, except during extreme storm events, and will be landscaped to provide the community with public open spaces with multiple potential uses.
2.6 Surface water

The modelled existing drainage system is shown in Figure 9. Approximately one third of the total catchment area forms the Forrestdale Lake subcatchment. Forrestdale Lake is linked to the Forrestdale main drain via a high level overflow on the eastern side of the lake. The top water level of Forrestdale Lake has to reach a level of 23.75 m AHD before overflowing into the main drainage system downstream.

**Forrestdale main drain**

Forrestdale main drain connects Forrestdale Lake to the Southern River. It was constructed as a rural drain in the 1970s to manage the regional groundwater level and prevent the Westfield wastewater treatment site from being flooded.

The Forrestdale main drain has levee banks along much of its length and it passes through or adjacent to a number of Bush Forever sites and conservation category wetlands.

**Baileys branch drain**

Baileys branch drain connects the existing Forrestdale townsite to the Forrestdale main drain upstream of Ranford Road. It was constructed in conjunction with the Forrestdale main drain for the purpose of managing regional groundwater and preventing flooding within the townsite. The drain is also contained in levees for much of its length and passes adjacent to Bush Forever site no 342. The Dumsday Drive compensation basin is located within the townsite at the head of this drain.

**Keane Road branch drain**

The Keane Road branch drain is connected to the Forrestdale main drain south of Armadale Road with the purpose of alleviating flooding of the Westfield wastewater treatment site.

**Local authority drains**

The James drain, which drains the area west of Forrestdale Lake, passes through major wetlands upstream and downstream of Nicholson Road before discharging into Forrestdale Lake.

The Forrestdale Lake south drain is largely undefined and although it is quite substantial at the Nicholson Road crossing, it quickly reduces in size and is replaced by indistinct overland flow to Forrestdale Lake.

Balannup Lake is linked to the Balannup Lake drain via a high level overflow from the north of the lake. The drain overflows to the Lander Road swamp and flows through a very large floodplain upstream of Southern River Road before it joins the Forrestdale main drain just upstream of Holmes Street.

Balannup drain drains the catchment upstream of Nicholson Road and discharges into Baileys branch drain approximately 300 m upstream of its confluence with the Forrestdale main drain via a 600 mm connection pipe. Harrisdale Swamp discharges into Balannup drain which then flows through Bush Forever site no. 342, where its depth becomes very shallow.
The Precinct 4 north and south drains are small and indistinct drains, which disappear before reaching the Southern River or Forrestdale main drain near the Tonkin Highway.

Murphy’s drain is a small drain east of the Tonkin Highway with overflows regularly occurring into adjacent rural land before flowing to the Forrestdale main drain upstream of Allen Road.

**System capacity**

Long section drawings of the main drainage routes within the catchment are presented in Figures 10a to 10j.

Modelling indicates that the main drainage system comprising the Forrestdale main drain, Baileys branch drain and Keane Road branch drain can generally contain the three-year average recurrence interval storm event with approximately 300 mm freeboard to the top of the bank.

The 10-year average recurrence interval storm event can generally be conveyed within the Water Corporation main drainage system, although no freeboard is available. Elsewhere in the catchment, on local authority drains there is significant flooding during the 10-year average recurrence interval storm event.

During the 100-year average recurrence interval storm event the levee banks of the main drainage system are overtopped, contributing to the inundation of extensive areas of rural land, Bush Forever sites, and wetlands.

There is little difference between the 10 and 100-year average recurrence interval storm event discharges from the Forrestdale main drain to the Southern River, due to the large storage volumes that are retained within the catchment during a major storm event in naturally occurring floodplains and wetlands.

High tailwater conditions in the Southern River (levels equivalent to the 25-year flood event has been used for the purposes of this study), when combined with a major storm event, have a large effect on the Forrestdale main drain. Floodwater extends into very large natural floodplains on the Forrestdale main drain downstream of Holmes Street and on the Balannup Lake drain upstream of Southern River Road and at its confluence with the Forrestdale main drain.

**Environmental aspects**

The inundation of wetland areas is caused by a combination of direct runoff from the local catchment area into low-lying land and overland flooding of runoff from a wider catchment area via nearby drains, and also due to elevated groundwater levels.

The Balannup drain and Baileys branch drain contribute to the periodic inundation of Baileys Wetland within Bush Forever site no. 342, in events of greater than three-year average recurrence interval. This inundation occurs mainly due to the throttling influence of the Baileys branch drain connection to the Forrestdale main drain, with water backing up the shallow drains upstream and overflowing into the wetland.
The Forrestdale main drain and Baileys branch drain contribute to the periodic inundation of several other wetlands in events of greater than 10-year average recurrence interval.

Some of the local authority drains in the catchment contribute to wetland inundation in events more frequent than the one-year average recurrence interval.

The contribution of surface runoff to the inundation of wetlands is, however, relatively minor compared with the depth and extent of inundation due to high groundwater levels experienced each year, particularly during wet periods such as shown in Figure 11.

**Conclusions**

The existing drainage system has insufficient capacity to convey the 10-year average recurrence interval event under existing development conditions. The 10-year event is expected to result in significant flooding in the catchment, with overtopping of local authority drains and insufficient freeboard in the Water Corporation main drainage system.

The results of groundwater modelling predict that during wet years (e.g. 1915–1931) the area inundated by shallow groundwater is substantially greater than the area predicted to be inundated by surface runoff resulting from the 10-year or 100-year rainfall event.

**Surface water quality**

The Forrestdale main drain is within the catchment for the Southern River, which the Swan River Trust has identified as a priority catchment in its *Healthy rivers action plan* (Swan River Trust 2008). The Environmental Protection Authority has previously advised that a condition for development in the district structure plan area is the demonstration that development can be managed to meet the environmental objectives and targets for the Southern River catchment, documented in the Swan River Trust’s Healthy Rivers Program.

The Swan River Trust’s Healthy Rivers Program is a key instrument for the implementation of the *Swan and Canning Rivers Management Act 2006* which protects waterways such as the Southern River, as well as the Swan and Canning rivers, for their significance as important ecosystems and valuable recreational waterways. The Swan River Trust has developed short and long-term end-of-catchment water quality targets for nutrient concentrations in tributaries of the Swan-Canning river system.

The long-term targets for nutrient concentrations in the Southern River are 1.0 mg/L total nitrogen and 0.1 mg/L total phosphorus. Typical existing concentrations measured in the Forrestdale main drain are 3.2 mg/L total nitrogen and 0.5 mg/L total phosphorous.

The Swan River Trust has accepted that, although the Healthy Rivers Program targets represent long-term management targets, the agreed condition for development is that there is to be no deterioration in water quality in the Forrestdale main drain or the Southern River.
2.7 Groundwater

Groundwater flows

The Forrestdale main drain catchment is situated in an area of very shallow groundwater immediately to the east of the Jandakot mound. There are extensive areas in the catchment where the groundwater rises to the surface for extended periods.

As well as the obvious implications this has for fill requirements with proposed development, drainage designs will also need to consider likely changes in groundwater and their impact on both capacity and functionality of the main drainage system. Drainage in the catchment is inextricably linked to the groundwater. The Forrestdale main drain and Baileys branch drain were originally constructed to control regional winter groundwater levels with direct and indirect (overland) connections existing between lakes/wetlands in the catchment and the drainage system.

Groundwater modelling

Rockwater Pty Ltd carried out regional groundwater modelling of the Forrestdale main drain catchment in 2005. The modelling study investigated changes to groundwater levels that would result from urban development under three climate scenarios:

- dry rainfall period (post-1975) – 788 mm
- very wet period (1915–1931 rainfall) – approximately 1200 mm
- very dry period (1994–1995) – 690 mm

The report discusses the seasonal variability of groundwater levels in the catchment stating that the average annual groundwater fluctuation in the catchment are generally in the range 1.2 to 2 m, increasing to 2 to 2.5 m near drains and in areas of Guildford clay.

Modelled pre-development maximum groundwater level contours (788 mm annual rainfall scenario) are presented in Figure 11 (Rockwater 2005).

The results of the regional groundwater model have been incorporated into the InfoWorks surface water model by the application of winter peak starting water levels in wetlands and key sections of the drainage system. These starting water levels provide an assessment of the drainage system’s ability to manage significant rainfall events at times of peak groundwater as well as an indication of the base flow within the drain at these times.

The predicted winter peak starting water levels in a selection of key wetlands are presented in Table 1 below for the various pre-development scenarios that were studied.

The environmental impact of groundwater interaction with wetlands and drains is discussed in Section 4.
### Table 1  Groundwater model calculated wetland water levels (m AHD)

<table>
<thead>
<tr>
<th>Location</th>
<th>788 mm rainfall</th>
<th>High (1920s) rainfall</th>
<th>Low rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Summer minimum</td>
<td>Winter peak</td>
<td>Summer minimum</td>
</tr>
<tr>
<td>Forrestdale Lake (Bush Forever site no. 345)</td>
<td>21.5</td>
<td>22.5 21.6</td>
<td>23.2 21.4</td>
</tr>
<tr>
<td>Balannup Lake (Bush Forever site no. 413)</td>
<td>19.9</td>
<td>21.7 20.1</td>
<td>22.5 19.8</td>
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<td>Harrisdale swamp (Bush Forever site no. 253)</td>
<td>24.3</td>
<td>25.2 26.4</td>
<td>26.9 23.7</td>
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<tr>
<td>Baileys wetland (Bush Forever site no. 342)</td>
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<td>21.5 20.0</td>
<td>22.9 19.9</td>
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<td>20.8 19.9</td>
<td>21.7 19.9</td>
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<td>Confluence wetland (Bush Forever site no. 342)</td>
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<td>21.1 20.3</td>
<td>22.3 20.1</td>
</tr>
<tr>
<td>Gerty Way wetland (Adj Bush Forever site no. 340)</td>
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<td>19.9 19.7</td>
<td>21.3 23.3</td>
</tr>
<tr>
<td>Lander swamp</td>
<td>19.0</td>
<td>21.3 19.4</td>
<td>23.5 18.9</td>
</tr>
<tr>
<td>East Forrestdale palusplain (Bush Forever site no. 345)</td>
<td>21.3</td>
<td>22.4 21.4</td>
<td>23.1 21.1</td>
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<tr>
<td>Gibbs Rd swamp (Bush Forever site no. 344)</td>
<td>23.8</td>
<td>25.2 24.7</td>
<td>27.3 23.5</td>
</tr>
</tbody>
</table>
3 Proposed development

3.1 Key elements of the structure plan

The Southern River/Forrestdale/Brookdale/Wungong district structure plan (Western Australian Planning Commission 2001) as shown on Figure 1 designates 16 km² of the Forrestdale main drain catchment for medium density residential development (mainly allowable housing density of 15 per hectare (R15) with approximately 25 per cent allowable housing density of 25 per hectare (R25)), 3 km² for light industrial use, and 2 km² for mixed business/ commercial, community facilities, and village and neighbourhood centres.

The remainder of the Southern River/Forrestdale/Brookdale/Wungong district structure plan (Western Australian Planning Commission 2001) area is to form public open space or remain rural with conservation areas and environmental management areas protected. The kennels zone to the east of Ranford Road will remain unchanged. Some areas have been identified in the Southern River/Forrestdale/Brookdale/Wungong district structure plan (Western Australian Planning Commission 2001) for possible future development, but it is believed unlikely that they will be required for urbanisation within the next 30 years.

The Southern River/Forrestdale/Brookdale/Wungong district structure plan (Western Australian Planning Commission 2001) describes proposed land use change from the existing mainly rural land use to mainly urban land use (Figure 1). This change in land use will result in increased runoff during large (major) rainfall events that will require upgrades to the drainage system.

The drainage upgrade strategy, previously recommended by the Urban water management strategy (JDA 2002) and endorsed by the Environmental Protection Authority, proposed widening the Forrestdale main drain and Baileys branch drain for their entire lengths, to create a meandering ‘living stream’ style drain within a broad multiple use corridor. Whilst this approach may be both aesthetically desirable and hydraulically achievable, there are a number of constraints within the catchment that limit its potential for adoption:

- Several sections of drain pass through or adjacent to Bush Forever sites. Modifications to Bush Forever sites require referral to the Environmental Protection Authority.

- Sections of the Forrestdale main drain (most notably through the kennels zone downstream of Ranford Road) are closely bounded by developed private properties.

In developing this drainage strategy, the locations of these constraints have been identified as well as several other alternative areas where there are more feasible opportunities for increased widening or storage.
4 Protection of environmental assets

The following strategies have been developed to protect and enhance the value of environmental assets in the Southern River/Forrestdale/Brookdale/Wungong district structure plan (Western Australian Planning Commission 2001) area.

Minimise changes to hydrology to prevent impacts on watercourses and wetlands

Changes in land use from rural to urban may lead to local increases in peak flows and volumes of runoff due to increases in impervious area (Figure 12). Large increases in peak flows and volumes have the potential to adversely impact on receiving environments by causing erosion and increasing the period of inundation of vegetation.

Figure 12 Typical pre- and post-development runoff hydrograph comparison.

Surface water management should ensure that urban development does not increase the peak flows discharging to receiving environments, although there may be increases in total runoff volumes (Figure 13). Development should also ensure that watercourses and wetlands do not dry out due to over-abstraction of water resources or lowering of groundwater levels.

Figure 13 Typical pre- and post-development runoff hydrograph comparison, with compensated post-development flows.
Manage and restore watercourses and wetlands

The Southern River/Forrestdale/Brookdale/Wungong district structure plan area includes several significant wetlands and Bush Forever sites that are considered high-value environmental assets that should be protected. Some parts of the existing drainage system are located in or adjacent to these areas and flow over these wetlands during storm events.

To evaluate the environmental impact of any upgrade to the drainage system, it is necessary to determine any changes to the hydrologic regime of these wetlands. The hydrologic regime of a wetland can be characterised by the frequency, depth (or extent) and duration of any inundation.

A separate study of the interaction of surface water runoff and the wetlands of the Forrestdale main drain catchment has been carried out and is presented in Evaluating the impact of water releases from stormwater arterial drainage on Forrestdale wetlands (GHD 2007). The study concluded that the discharge of additional flood flows to Forrestdale wetlands during infrequent (> 10 year average recurrence interval event) storm events will have no significant impact on the hydrology of these wetlands.

This conclusion is based on the following:

- An examination of the available data for Gibbs Road Swamp and Forrestdale Lake supports the conclusion of previous studies (Environmental Resources Management Group 2000) that wetland water levels are largely determined by regional groundwater levels.
- Temporary increases in wetland water level 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 (standard deviation 0.25 m) and long-term decline in water level due to drying climate (0.2-0.5 m).
- Areas temporarily inundated by surface water inflows will usually be inundated by seasonal groundwater rises later in the same year. Only if a major storm event occurs when the wetland is at its annual maximum water level will the additional inflows lead to an increase in the maximum water level that year. The probability of a 100-year average recurrence interval storm event coinciding with the annual maximum wetland water levels is considerably less than one in 100 years.

Regional and local groundwater levels are maintained by the requirement for existing drain inverts to be maintained and not lowered, and for new drain inverts to be located at or above a groundwater level endorsed by the Department of Water. This requirement also includes subsurface drainage, which in all developments will be located at or above a groundwater level endorsed by the Department of Water.

The duration of water level changes due to surface water inflows during infrequent storm events can be managed by hydraulic control structures that can discharge surface water from the wetland to the drainage system after the storm event has passed, as discussed in Section 5.2.
The performance of these structures can be specified in consultation with environmental managers and can include sufficient flexibility to allow future changes, including modification to allow the diversion of surface flows from the drainage system to the wetlands to maintain the hydrologic regime during dry periods.

There are other potentially more significant impacts on wetland water levels than the proposed infrequent discharges from the Forrestdale main drain, including decreasing groundwater levels due to long-term climate change and additional groundwater abstraction. Careful management of drainage discharges to wetlands offers the opportunity to manage the hydrology of the wetlands during dry periods or in times of decreasing groundwater levels by diverting surface flows from the drainage system, protecting those wetland systems.

The short-term impacts of construction of the preferred option will be managed by ensuring that appropriate investigation and mitigation procedures are followed at all times prior to and during construction.

Additional management strategies and design criteria for the protection of environmental assets are presented in the *Southern River integrated land and water management plan* (Department of Water 2009).
5 Stormwater management strategy

The key objectives for surface water management are:

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

5.1 Floodplain management

Mitigate flooding to manage risks to human life and property

Planning measures recommended are:

- New dwellings in proposed and existing residential areas should have their floor levels elevated 500 mm above the 100-year average recurrence interval flood level.
- New industrial or commercial premises should have their floor levels elevated 500 mm above the 100-year average recurrence interval flood level.
- To provide egress for emergency services major arterial roads with immunity to the 100-year average recurrence interval flood level should be identified. Other residential streets should be designed to be serviceable up to the five-year average recurrence interval flood event.
- The design of the new urban areas should incorporate current best practice in water sensitive urban design to mitigate the impacts of urbanisation in the catchments on regional water quantity and quality.
- Waterways within the structure plan area should be constructed to manage the flooding from the 100-year average recurrence interval flood event within their channels and floodplains without allowing flooding from the upstream catchment to enter adjacent residential areas.
- New drainage corridors should be designed with consideration of the current practice in water sensitive urban design by incorporating water quality management controls and riparian vegetation.

5.2 Surface water quantity management

As a result of the identified constraints on widening certain sections of the main drainage system (Section 3.1), it will not be possible to directly convey the entire post-development 100-year average recurrence interval event peak flow. It is therefore necessary to attenuate the peak discharge by providing the equivalent storage to that which currently exists naturally within the catchment. Some storage is provided within the drain, which is hydraulically controlled by existing culverts that restrict downstream flow. However, it is necessary to also provide some additional storage within the system, especially to allow for the potential loss of floodplains identified in the Southern River/Forrestdale/Brookdale/Wungong district structure plan (Western Australian Planning Commission 2001).
Two options were approved by the technical working group for investigation:

**Option A (adopted)**
- widening of Forrestdale main drain and Baileys branch drain in all areas except within environmentally sensitive areas i.e. Bush Forever sites, conservation category wetlands etc
- continued use of wetland areas for storage of floodwaters and allowance for additional floodwater volumes to pass through wetland areas during infrequent storm events.

This option uses existing overland flood routes into wetland areas. In some cases this may involve lowering sections of the levee bank through wetland areas to provide more defined flood routes.

**Option B**
- widening of Forrestdale main drain and Baileys branch drain along some of their length and construction of flood storage areas outside wetlands
- prevention of any additional flooding of wetland areas.

This option with limited wetland inundation provides the additional storage required by increasing storage on the main drainage system in the form of constructed flood storage areas requiring additional land for drainage purposes. Such provision has not been allowed for in the *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001).

**Adopted strategy**

The adopted strategy was endorsed on the basis that the changes to the periodic inundation of the wetlands from drainage overflows during major storm events is insignificant when compared to the impact due to the variability in the annual groundwater regime under existing land development conditions.

The environmental impacts from the adopted strategy were supported ‘in principle’ by the Department of Environment and Conservation. 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).

The adopted strategy 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. Figure 3 shows details of the adopted *Arterial drainage strategy*.

Figures 14a to 14j show the long section of the main drains and some of the precinct drains under the preferred option.

The key assumption in developing the adopted strategy is that existing overland flood paths into wetland areas continue to be used during infrequent events, allowing
increased use of the available storage within these areas. This strategy makes no change to the drains that pass through or adjacent to wetland areas other than to allow more extensive inundation at these points in the system by forming defined (and therefore controllable) flow paths out of the low flow channel. The adopted strategy allows the partial removal or lowering of levee banks and the incorporation of flow control devices.

The use of existing wetlands for storage of drainage flows from infrequent major rainfall events will not significantly affect the hydrologic regime of these wetlands. As described in Section 4, water level changes due to seasonal and annual fluctuations in groundwater are far greater than the water level changes that will result from the diversion of surface flows from infrequent major rainfall events.

Engineered hydraulic control structures will be installed, only where necessary, to regulate flows to and from the drainage system, controlling the depth and duration of inundation of wetlands due to diversion of surface flows. In the case of prolonged dry periods, these structures would allow the diversion of flows from the drainage system to maintain the hydrologic regime of significant wetlands if requested by environmental regulators.

The Forrestdale main drain and Baileys branch drain both require widening as shown on Figure 3. This has been achieved in areas where increasing the size of the drainage reserve has little impact on proposed development and provides opportunities for improving the aesthetics of the immediate surroundings.

Widening of the main drain should be located within linear public open space as shown in the typical cross-sections of Figures 14a-14j. The design includes a main drainage waterway within the linear public open space, incorporating a one-year low flow channel, sized to convey all flows up to and including the critical 10-year average recurrence interval event. More extreme events are then allowed to flow out of this waterway channel and use a broad shallow gradient floodplain area. Because it is infrequently inundated, the flood plain area may be landscaped in keeping with its primary purpose of flood storage and conveyance. This will improve the aesthetic nature of the drain reserve, and provide a valuable area of open space area for public amenity usage.

**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.
Design objectives

- 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 hydrological cycles shall be maintained or restored as outlined in this report and approved by the Department of Water.

- The catchment runoff shall be managed 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. Pre-development critical 10 and 100-year average recurrence interval event peak flow rates are specified in Table 2 of this report.

- Water sensitive urban design and best management practices promoting on-site retention of events up to the one-year average recurrence interval event shall form the basis of the surface water quantity management strategy for minor events.

Increase in the post development peak flow rates from 5- to 100-year average recurrence interval events may be considered, where it can be demonstrated (at district or local water management strategy stage) that the pre-development hydrologic, hydraulic, geomorphic and ecological characteristics of the downstream catchment and receiving environment can be protected and maintained.

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

Hydrologic and hydraulic modelling of the study area using InfoWorks CS has determined indicative subcatchment scale peak discharge flows and volumes, detention volumes required to manage surface water flows from major events, and hydraulic grade lines within the main waterways.

Detention volumes required to meet specified 10 and 100-year average recurrence interval peak flow criteria are also presented in Table 2 of this report.

Figure 3 and Table 2 below present the proposed surface water management strategy for the Forrestdale main drain catchment. Indicative 100-year flood levels, subcatchment delineation (Figure 3), and discharge flows, discharge volumes and detention volumes (Table 2) are provided as a guide to developers. These should be refined and located during local structure planning via the local water management strategy, and finalised during subdivision scale planning via the urban water management plan.

For each subcatchment, the critical 10 and 100-year average recurrence interval event pre-development discharge flow rates are presented in Table 2 along with an indicative post-development storage volume required to maintain that flow rate. It is important to note that the Arterial drainage strategy model assumes that the one-year one-hour average recurrence interval event (from allotments and also from the road network) is retained at source, so this volume is not included in the indicative flood detention volumes provided in Table 2. Flows from the road network in a one-year
average recurrence interval event should be retained (or detained for the duration of
the one-year event) within the road reserve network in a manner that mitigates
pollutant export.

Discharge flow rates quoted in Table 2 are not within main waterways, and do not
include flows generated by upstream subcatchments. Discharge criteria are set for
whole subcatchments at the point at which they connect to main waterways as
indicated by Figure 15 below.

For each modelled node (Figure 15) along the main waterways, the critical 100-year
average recurrence interval event hydraulic grade line with associated peak flow
rates are presented on longitudinal sections (Figures 10a-10j and 14a – 14j).

Figure 15 Schematic presentation of information provided for subcatchments and
main waterways

Where a proposed development forms a part of one or more of the subcatchments
presented in Figure 3, the storage volume to be provided by that development should
be calculated based on the subcatchment surface area as a percentage of the total
subcatchment surface area.

Table 2 Subcatchment drainage planning criteria - ultimate development

<table>
<thead>
<tr>
<th>Subcatchment identification</th>
<th>Catchment area (ha)</th>
<th>Peak discharge flow (m$^3$/s)</th>
<th>Detention volume (m$^3$)</th>
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<tbody>
<tr>
<td>Subdivisinal storage basins</td>
<td>10-year 100-year</td>
<td>10-year 100-year</td>
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</tbody>
</table>
### Forrestdale main drain arterial drainage strategy

A summary of peak flows and levels at critical locations along Forrestdale main drain and associated drains (Figure 3) are presented in Table 3 below.

<table>
<thead>
<tr>
<th>Subcatchment identification</th>
<th>Catchment</th>
<th>Peak discharge flow (m³/s)</th>
<th>Detention volume (m³)</th>
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<td></td>
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<tr>
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</table>
Table 3 Flows and levels at critical locations - ultimate development (see Figure 3)

<table>
<thead>
<tr>
<th>Location Number (Figure 3) and description</th>
<th>Peak flows (m³/s)</th>
<th>Peak levels (m AHD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10-Year ARI</td>
<td>100-Year ARI</td>
</tr>
<tr>
<td>1. Forrestdale main drain at Armadale Rd</td>
<td>1.6</td>
<td>22.3</td>
</tr>
<tr>
<td>2. Forrestdale main drain at Anstey Rd</td>
<td>2.4</td>
<td>22.2</td>
</tr>
<tr>
<td>3. Forrestdale main drain at Ranford Rd</td>
<td>3.8</td>
<td>21.9</td>
</tr>
<tr>
<td>4. Forrestdale main drain at Holmes St</td>
<td>6.4</td>
<td>20.9</td>
</tr>
<tr>
<td>5. Baileys branch drain at Keane Rd</td>
<td>0.7</td>
<td>22.3</td>
</tr>
<tr>
<td>6. Baileys branch drain at discharge to</td>
<td>1.3 1.8</td>
<td>22.0</td>
</tr>
<tr>
<td>Forrestdale main drain</td>
<td></td>
<td>22.3</td>
</tr>
<tr>
<td>7. Keane Rd branch drain at discharge to</td>
<td>0.8 1.1</td>
<td>22.4</td>
</tr>
<tr>
<td>Forrestdale main drain</td>
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<td>23.0</td>
</tr>
<tr>
<td>8. Murphys drain at discharge to Forrestdale main drain</td>
<td>1.9 2.8</td>
<td>22.3 22.9</td>
</tr>
<tr>
<td>9. Balannup drain at Nicholson Rd</td>
<td>0.9 1.0</td>
<td>24.4</td>
</tr>
<tr>
<td>10. Balannup drain at discharge to Baileys branch drain</td>
<td>0.9 0.9</td>
<td>22.2 22.6</td>
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<tr>
<td>11. Balannup Lake drain at Southern River Rd</td>
<td>0.4 0.5</td>
<td>21.1 21.4</td>
</tr>
<tr>
<td>12. Balannup Lake drain at Matison Rd</td>
<td>0.9 0.9</td>
<td>21.1</td>
</tr>
<tr>
<td>13. Precinct 4 north drain at Passmore St</td>
<td>0.4 0.6</td>
<td>19.9</td>
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<tr>
<td>14. Precinct 4 south drain at Passmore St</td>
<td>0.4 0.7</td>
<td>21.7</td>
</tr>
<tr>
<td>15. James drain at Armadale Rd</td>
<td>0.9 1.1</td>
<td>25.4</td>
</tr>
<tr>
<td>16. James drain at discharge to Forrestdale Lake</td>
<td>0.2 0.3</td>
<td>22.9 23.1</td>
</tr>
</tbody>
</table>

Average recurrence interval (ARI)

The following specific main drainage upgrades are proposed by this Arterial drainage strategy:

**Forrestdale townsite**

- Baileys drain requires widening within a linear public open space of approximately 50 m width for a length north of Armadale Road (see Figure 3 section 2).

- The Southern River/Forrestdale/Brookdale/Wungong district structure plan (Western Australian Planning Commission 2001) shows the corridor required for drainage purposes and this is approximately the area required under the Arterial drainage strategy.

- Immediately downstream of Anstey Road there is a short length of drain to Keane Road that runs through land that remains rural but that should be widened.

- To maintain the existing hydrologic regime of the Baileys wetland (Bush Forever site no. 342) it will be necessary to reinstall the 600 mm connection from the Balannup drain into Baileys branch drain which was removed as part of the existing development of the North Forrestdale area.
Adjacent to Tonkin Highway (Armadale Road to Allen Road)

- Forrestdale main drain requires widening within a linear public open space of approximately 50 m width along the length adjacent to Tonkin Highway (see Figure 3, section 1).

- The *Southern River/Forrestdale/Brookdale/Wungong district structure plan* (Western Australian Planning Commission 2001) shows an area required for drainage at the southern end of the required drainage corridor, immediately north of Armadale Road. The area of land required for drainage is similar but now in a different location, although on the same landholding. The widened drain should be located in linear public open space (see linear public open space inserts on Figure 3). Its location adjacent to the Tonkin Highway provides a buffer between that road and the urban area, as well as providing a potential wildlife corridor between areas of remnant bushland.

**Tonkin Highway (at Allen Road) to Anstey Road**

- Forrestdale main drain requires widening within a linear public open space of approximately 50 m width for a length from the Tonkin Highway (at Allen Road) to Anstey Road (see Figure 3, section 1).

- Along this length of drain the land to the west of the drain will remain zoned rural and the land to the east of the drain is shown on the district structure plan as potential light industrial.

- The current district structure plan shows some land required for drainage within this light industrial area and this area is approximately equivalent to the land required for widening the drain under the *Arterial drainage strategy*.

**Anstey Road to Ranford Road**

- Forrestdale main drain requires widening within a linear public open space of approximately 70–100 m width for a length from the Anstey Road to Ranford Road (see Figure 14, section 3). This is regional drainage infrastructure and land acquisition will be required.

- Along this length of drain the land is already zoned light industrial and the district structure plan shows a wide drainage corridor. However, the corridor is bounded to the north-west by conservation category wetlands and to the south-west by a Bush Forever site, which may place significant environmental constraints on any drainage works.

- In order to fully utilise the proposed storage upstream of Ranford Road and provide protection to the existing properties within the kennels zone, it will be necessary to block one 900 mm diameter barrel of the Ranford Road culvert.
Kennels to Phoebe Road

- Forrestdale main drain requires widening within a linear public open space to create online flood storage area between the kennels zone and Phoebe Road (see Figure 3, section 4).
- The current district structure plan shows the corridor required for drainage purposes and this is approximately the area required under the Arterial drainage strategy.

Phoebe Road to Holmes Street

- Forrestdale main drain requires widening within a linear public open space to create online flood storage areas between Phoebe Road and Holmes Street (see Figure 3, section S4).
- The current district structure plan shows the corridor required for drainage purposes and this is approximately the area required under the Arterial drainage strategy.

Precinct 4

- The Southern River/Forrestdale/Brookdale/Wungong district structure plan (Western Australian Planning Commission 2001) currently indicates a drainage corridor running along the eastern boundary of Precinct 4, adjacent to the Tonkin Highway. This Arterial drainage strategy recommends the retention of existing drainage routes, as shown on Figure A3c.

In all locations where a widened drain within linear public open space is proposed, a low flow channel to convey baseflow and minor events (< one-year average recurrence interval) will be incorporated into the base of the main drainage channel. With appropriate planting and treatment, the low flow channel may be modified to improve water quality by providing opportunities for biofiltration as well as provide habitat, provided that the hydraulic capacity is not reduced.

5.3 Surface water quality management

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

Maintaining pre-development discharge rates and volumes from developed catchments is expected to prevent the majority of contaminants from reaching the waterways by ensuring that the majority of flows from high frequency events are detained or infiltrated on site.

Provided that the initial flow of more significant events is subject to the same detention and treatment received by high frequency events, surface runoff that occurs during more significant events represents a lower risk to downstream water quality. This is because nutrients and other contaminants that represent a threat to downstream water quality are typically transported within the ‘first flush’ of an event.
To meet the objective of no deterioration in water quality, the MOU group has developed a water quality management strategy as part of the Southern River integrated land and water management plan (Department of Water 2009).

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.

In addressing any observed deterioration in water quality in the Forrestdale main drain, the Department of Water may recommend that treatment measures be included in the arterial drainage system. Where any treatment systems are installed, they should not reduce the hydraulic capacity of the arterial drainage system and should be compatible with the land uses of any multiple use corridors. It is critical that the design and construction of any treatment systems be undertaken in close collaboration with the drainage asset managers of the service providers (local authority or the Water Corporation).

5.4 Key design criteria

Surface water quantity

- The one-year one-hour average recurrence interval event shall be detained at source for the duration of the event through the use of retention (soakage) or storage devices. Refer to Chapter 9 of the Stormwater management manual for Western Australia (Department of Water 2004-2007) for devices suited to the soil types for this catchment. The Stormwater management manual for Western Australia (Department of Water 2004-2007) contains guidance for the appropriate design of retention and detention systems.

- The post-development critical one-year average recurrence interval peak flow and volume and the 100-year average recurrence interval peak flow shall be consistent with pre-development flows at:
  - the discharge points of all subdivisions into waterways
  - the discharge points from the structure plan area
  - the discharge points of each subcatchment.

- Flows from developed areas should be attenuated, in accordance with Table 2 which protects the regional system, in flood detention/storage areas incorporated into public open space within the subdivision and located outside floodways.

- Post-development flows for all average recurrence interval events should be discharged at flow rates which are consistent with pre-development flow rates for those same events.

- Developments outside the floodway should ensure finished floor levels at a minimum of 0.5 m above the 100-year flood level.

- The existing cross-sectional area of waterways should be maintained. Restoration of waterways is encouraged and in some cases channel realignments and
channel profile modifications may be carried out, provided it is demonstrated that the pre-development cross-sectional area has been preserved.

- Public open space and retention basins should operate as dry basins with a minimum clearance of 0.3 m between the groundwater level endorsed by the Department of Water and the invert of the basin.
- Defined major arterial roads should remain passable in the 100-year average recurrence interval event. The local authority should be contacted to identify roads where this criteria applies.
- Minor roads should remain passable in the five-year average recurrence interval event.
- Emergency evacuation areas should be defined at least 2.0 m above the 100-year average recurrence interval event level.
- Water quality treatment systems and water sensitive urban design structures should be designed in accordance with the *Stormwater management manual for Western Australia* (Department of Water 2004–2007) and *Australian runoff quality* (Institute of Engineers Australia 2006).

### Surface water quality

Designs for infrastructure and management measures to achieve ecological protection and water quality outcomes should be based on the methodologies established in the *Stormwater management manual for Western Australia* (Department of Water 2004–07).

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

- non-structural measures to reduce applied nutrient loads
- on-site retention of the one-year one-hour average recurrence interval event
- bioretention structures/systems, (also referred to as rain gardens) to be sized at two 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

Proponents shall develop and present the strategies for water quantity and quality management in the local water management strategy and urban water management plans to support the planning approvals required for the development to proceed.
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.

It is strongly recommended that consultants meet with the local authority to discuss proposed surface and groundwater management strategies and to gain further guidance on site-specific requirements of the local authority at commencement of any local water management strategy or urban water management plan.

Further details on water quality management strategies appropriate to this catchment are provided in the *Southern River integrated land and water management plan* (Department of Water 2009).
6 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

6.1 Groundwater modelling

Manage groundwater levels to protect infrastructure and 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.

The results of the regional groundwater model have been incorporated into the InfoWorks surface water model by the application of winter peak starting water levels in wetlands and inflows to key sections of the drainage system. These starting water levels and inflows provide an assessment of the drainage systems' ability to manage significant rainfall events at times of peak groundwater, as well as an indication of the base flow within the drain at these times. Subsoil drainage flows predicted by this scenario of the groundwater model have also been incorporated into the InfoWorks surface water model used in this study.

Further information regarding the selection of pre- and post-development model scenarios and the construction and calibration of the groundwater model may be gained by requesting a copy of the Southern River development area groundwater model (Rockwater 2005) report from the Water Corporation.

Figure 11 presents the modelled Rockwater (2005) maximum groundwater level (788 mm annual rainfall scenario) and provides a guide to regional groundwater levels in the study area. However, groundwater levels should be determined in consultation with the Department of Water and presented in local water management strategies.
Further investigations will be required to determine local scale predicted maximum groundwater level for individual developments to determine whether subsurface drainage is required for protection of urban infrastructure. This drainage should always be located at or above a groundwater level endorsed by the Department of Water and presented in the local water management strategy.

Additional groundwater management strategies and design criteria are presented in the Southern River integrated land and water management plan (Department of Water 2009).

6.2 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 they 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 2004-07) 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.

6.3 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 of Water.
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 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 that 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, the following should be achieved:

- 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.

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.

It is strongly recommended that consultants meet with the local authority to discuss proposed surface and groundwater management strategies and to gain further guidance on site-specific requirements of the local authority at commencement of any local water management strategy or urban water management plan.

Further details of groundwater quality management strategies and design criteria are presented in the *Southern River integrated land and water management plan* (Department of Water 2009).
7 Commitment to best management practice

Best management practices suitable for use in the Forrestdale main drain catchment and supported by the Department of Water are presented in the *Southern River integrated land and water management plan* (Department of Water 2009).

In order to meet the design criteria of reductions in total phosphorus, total nitrogen, total suspended solids 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 while maximising the potential for stormwater to be treated as a resource.
8 Implementation

8.1 Requirements for following stages

*State planning policy 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 2.9*. 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 *Southern River integrated land and water management plan* (Department of Water 2009) 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 the *Southern River integrated land and water management plan* (Department of Water 2009) and this *Arterial drainage strategy*. Subsequent subdivision applications should be accompanied by an urban water management plan where required by the Department of Water and the City of Armadale or the City of Gosnells, and/or should be consistent with an approved local water management strategy and with the strategies and objectives of the *Southern River integrated land and water management plan* (Department of Water 2009) and this *Arterial drainage strategy*.

Guidelines for *Developing a local water management strategy* are currently in preparation by the Department of Water.

*Urban water management plans: guidelines for preparing plans and for complying with subdivision conditions* (Department of Water 2008) are available on the Department of Water’s website.

Developers are encouraged to contact the Department of Water (Swan Avon regional office) and the City of Armadale or the City of Gosnells early in the planning process to discuss specific water management requirements for proposals.

8.2 Review of integrated land and water management plan and *Arterial drainage strategy*

It is intended that the *Southern River integrated land and water management plan* (Department of Water 2009) and this *Arterial drainage strategy* be reviewed within ten years or earlier if deemed necessary until 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, the City of Armadale, the City of Gosnells 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.

Monitoring requirements and an implementation action plan for the Forrestdale main drain catchment is presented in the *Southern River integrated land and water management plan* (Department of Water 2009).