SUB-PRECINCT 3A(1)
SOUTHERN RIVER

LOCAL WATER MANAGEMENT STRATEGY

Prepared for:

WRF PROPERTY LTD

Revised version with Second Revised Addendum – July 2009

Job No: 06.024

Report No: RP001

SUB-PRECINCT 3A(1) SOUTHERN RIVER

LOCAL WATER MANAGEMENT STRATEGY

Second revised version with revised Addendum – July 2009

Prepared for:

WRF PROPERTY LTD

Prepared by:

ENV Australia Pty Ltd
Level 7, 182 St George's Terrace
PERTH WA 6000
Phone: (08) 9289 8360
Fax: (08) 9322 4251
Email: env@env.net.au

Prepared by:	*Margaret Dunlop*
Status:	*Final Revised with Addendum- also Revised*
QA Review:	*Karen Lane*
Technical Review:	*Karen Lane*
Content Review:	*Margaret Dunlop*
Date:	*1 July 2009-*

env
Australia

10 July 2009

SUBJECT: REVISED ADDENDUM TO SOUTHERN RIVER SUB-PRECINCT 3A LOCAL WATER MANAGEMENT STRATEGY (JOB NO 06.024, RP001 – JUNE 2009)

This addendum to the LWMS has been prepared to satisfy the City of Gosnells. An addendum has been prepared that has been based on an examination of the matters noted in emails from Markus Botte of the City dated the 5th and 9th March 2009 and 26 June 2006, a phone discussion between Markus and ENV ofn10 July 2009 and the comments/responses/notes made in the project team's response dated the 24th May 2009.

ADDENDUM TO SUB-PRECINCT 3A LOCAL WATER MANAGEMENT STRATEGY	
SECTION IN DOCUMENT	**CHANGE**
Executive Summary	**Page iii under Heading "Stormwater Management"** Bullet Point 2 Replace "Designing basins such that the 1 in 100 year flood levels are 0.5m below residential floor levels;" With:- Providing adequate flood protection by providing appropriate (minimum 300 mm) separation between 1 in 100-year ARI water levels and finished floor levels and ensure that safe overland flood routes are provided through the development to the Southern River or Main Drain outlets. Bullet Point 3, replace "Including swales in the road reserve that store and infiltrate the 1 in 1 year event within the swale; and" With: "Including appropriate contemporary WSUD BMPs in the road reserve that store and infiltrate the 1 in 1 year event; and" **Page iv** – remove second bullet point under Groundwater Management.

<table>
<tr><th colspan="2">ADDENDUM TO SUB-PRECINCT 3A LOCAL WATER MANAGEMENT STRATEGY</th></tr>
<tr><th>SECTION IN DOCUMENT</th><th>CHANGE</th></tr>
<tr><td>1</td><td>Page 1 Paragraph 2 after text “The location of Sub-precinct 3A(1) is shown in Figure 1.” Add text

“It should be noted that the land is Sub-precinct 3A to the south-west of the proposed regional road is excluded from Sub-precinct 3A(1). This is based on discussions with City of Gosnells that indicated that the final location of this road has not been chosen, and as such the planning of this area should be the subject of a separate Outline Development Plan (ODP). Some assumptions have been made about the use of this land, based on discussions with the City, to facilitate drainage planning, where this land is part of the broader Sub-precinct 3A(1) catchment. However, a separate LWMS shall be required to support the ODP for this area.”</td></tr>
<tr><td>1.1</td><td>Page 2. After the last dot point that reads “Add value while minimising development costs - minimise the drainage infrastructure cost of development. (CSIRO, 1999, As reprinted in WAPC, 2004).”

Add a new dot point that reads:-

“Stormwater drainage measures are to be implemented to cause minimal or low nuisance to future residents and achieving high level of usability of open space areas, whilst minimising maintenance requirements.”</td></tr>
<tr><td>2.2.1</td><td>Page 7 At the end of Section 2.2.1 Sediment add a new heading and text as follows:-

Construction Environment Management Plan (CEMP)

A Construction Environmental Management Plan is to be approved before subdivision construction works commence. The plan will consider at least dust and sediment matters as noted in the preceding two sections</td></tr>
<tr><td>4.2</td><td>Page 22 Insert a new paragraph just prior to Section 4.3 under the heading “Site Proposal” to read:-

“Rain gardens and other bioretention structures will be constructed to accommodate and treat the runoff from the 1 in 1 year ARI event. The overall treatment areas will be sized such that their cumulative surface area equates to 2% of the connected impervious area, or their (cumulative) storage capacity is sufficient to contain the 1 yr 1 hr storm event from the connected impervious area - whichever is the greater.”</td></tr>
<tr><td>4.2</td><td>Page 22 Under the heading “Site Proposal” in the first paragraph. replace “up to 1 in 10 year ARI” with:-</td></tr>
</table>

ADDENDUM TO SUB-PRECINCT 3A LOCAL WATER MANAGEMENT STRATEGY

SECTION IN DOCUMENT	CHANGE
	"for each of the 1, 5, 10 and 100-year events". Add new paragraph prior to **Clause 4.3:** The intention is that for stormwater runoff, the pre-development peak flows for each of the critical storm events will be determined and then adopted as a flow event that will not be exceeded by post-development flows.
5.1.5	**Page 33, Section 5.1.5** last paragraph. After last sentence, add sentence "Stormwater harvesting may be considered at the UWMP stage on this basis."
6.1	**Page 39 Paragraph 3, Sentence 1** amend sentence by removing text as follows:- "Flows in Sub-precinct 3A will be managed ~~to the pre-development flow rate for events up to and including the 1 in 100-year ARI event~~ through the use of swales, water garden bioretention systems and detention storages." Add new sentence as follows:- "Critical times of concentration will need to be determined when the UWMP is being prepared. Flows from Sub-precinct 3A are to maintain pre-development flow rates/hydrology in the critical 1 in 1, 5, 10 and 100-year storm events for all catchments, including the future development areas south east of Matison Street that are adjacent to Leslie Street. Multi-stage outlets may be required at detention areas, including the north-eastern POS to manage this." **Prior to heading 6.1.1** add text: **Note:** Drawings, figures and calculations included in this LWMS or detailed in its appendices are conceptual only. The basis of design for all drainage and WSUD facilities should be discussed and agreed with the City prior to the preparation of any UWMP
6.1.1	**Page 41** In Section 6.1.1 in the first paragraph of the text headed "Drainage Philosophy" replace Sentence 1: "The road, lot and POS levels are to be designed to allow a safe flood route and maintain a minimum clearance of 500mm between flood surface water levels and the habitable floor levels and important infrastructure" With: "Flood protection is to be provided by ensuring there is a 300mm freeboard

ADDENDUM TO SUB-PRECINCT 3A LOCAL WATER MANAGEMENT STRATEGY	
SECTION IN DOCUMENT	**CHANGE**
	between the forecast peak flows from the critical 100-year storm event and 500 mm clearance between the forecast 100-year flood level in Southern River (as published by the DoW) and habitable finished floor levels. Suitable emergency access routes are to be nominated to suit the category of the road within the LWMS subject land in accordance with requirements detailed in Figure 60 within Element 5 of the WAPC's Liveable Neighbourhoods. These routes and the areas of inundation within the basins for the 5-year event and the streets and open spaces areas for the 100-year peak storm events will be determined and shown in the UWMP. The maximum basin draining times will be less than 96 hours for the 5-year design event storm. "
6.1.1	**Page 41** After the heading "Drainage Philosophy" insert new first paragraph as follows:- "A fundamental tenet of the WAPC's draft State Planning Policy on water resources is that the drainage design adopted for the development and as detailed in the UWMP should take into account total water cycle management and water-sensitive urban design principles and ensure that development is consistent with current best management practices (BMP) and best planning practices for the sustainable use of water resources, particularly stormwater. For Southern River Cell 3A this means that the developer is to adopt those methods feasibly available at the time of construction which will deliver the best possible outcome in terms of water management. Prior to commencing preparation of the UWMP, the developer should consult with the local authority to discuss and agree on suitable BMP's".
6.1.1	**Page 42 Paragraphs 2 to 5** Remove text from "Swales will be constructed ...(Para 2. Sentence 1)" up to and including "...Swales are proposed to be 500mm to 600mm deep below the edge of road level with 1 in 4 to1 in 6 side slopes. (Para 5. last sentence). Replace with: "Road reserves shall accommodate suitable Best Management Practices (BMPs) as approved by the City where required. Water quality treatment areas to be calculated as such that either the area is equal to 2% of the connected impervious area or sufficient to contain the 1 year 1 hour storm event from the connected impervious area, whichever is the greater. Suitable BMPs as approved by the City should ideally be incorporated within the drainage areas of the POS and their use minimised within the road reserve, wherever this is possible whilst still achieving prescribed water

ADDENDUM TO SUB-PRECINCT 3A LOCAL WATER MANAGEMENT STRATEGY	
SECTION IN DOCUMENT	**CHANGE**
	quality targets. All approved BMPs to have subsoil drainage installed beneath, with inverts at or above the adopted CGL. No swales are to be placed on the active frontage of residential lots.
6.1.1	**Page 43 Prior to heading 6.1.2 add new text** **Lot Drainage** Lot connection pits may need to be installed in areas where there is a likelihood of perched groundwater. This issue will need to be addressed when the UWMP is being prepared and will take into account specific site conditions, the subsoil drains that may be required and the finished lot levels after fill is placed." **Page 44 Delete last paragraph**
6.1.2	**Page 45 Before Clause 6.1.3** add three new dot points as follows:- "The critical times of concentration for the modelled peak storms will be nominated in the UWMP" "Flush kerbing adjacent to swales and open space areas is not a preferred design option and raised kerbs with suitable measures installed to allow only design storms to enter the swales and open space areas shall be adopted and detailed in the UWMP. "Lot drainage measures to be considered during the preparation of the UWMP are to take into account suitable runoff coefficients, soil conditions, the CGL, the depth of fill imported to the site, the impact on any subsoil drains and the density of the development (e.g. higher density sites may require lot drainage connection pits in any event)."
6.1.3	**Page 45** **Replace paragraph 2** with paragraph reading: "Grassed swales, if approved by the City of Gosnells, should be used for road verges throughout the estate. Swales may be approved by the City of Gosnells and could be placed in verges to the side boundary of lots where they will not be interrupted by driveways. Roads will either be designed to be angled towards the swale (Figure 15). Due to the width of the swale, road reserves containing swales will be a minimum of 18m wide." **Paragraph 3, Sentence 1,** replace "will" with "could alternatively"

ADDENDUM TO SUB-PRECINCT 3A LOCAL WATER MANAGEMENT STRATEGY	
SECTION IN DOCUMENT	**CHANGE**
	Remove last paragraph on page 45. **Page 45 Section 6.1.3** after third paragraph add new paragraph as follows:- Note that in each case, Figures 15 and 16 are simply a guide to some of the facilities that can be installed to manage water quality. As noted in Section 6.1.1 and the amendment on page 41, the latest and most suitable BMP's should be considered, discussed with Council and only then adopted for design phases of the UWMP.
6.2	**Page 49** at the end of the text, add new sentence as follows:- "If practical, the storage for Catchment 2 will be separated from any remnant vegetation (located in lots 1515 and 1516 Leslie Street and 1747 and 1748 Bradley Street) that is feasibly retained. It is noted, however, that the remnant vegetation on these lots is not in good condition in any event and simply is the only vegetation that has remained in the Cell 3A area".
7.1	**Page 50 - Section 7.1 Paragraph 1**: remove sentence 2: "Given our current understanding of groundwater levels and the relationship of the site to the Conservation Category Wetland, it is considered that subsoil drainage could be provided at the Annual Average Maximum Groundwater Level (AAMGL) and ensure that a 1.5m separation is provided between the AAMGL and housing." **Page 51** - Before heading of Section 7.2 Add new section as follows:- "7.1.2 Subsoil Drainage. Subsoil drainage will consist of both perpendicular and parallel relief drains, where required. All subsoil drainage must be provided with a free outlet, without any tail water levels affecting the functionality of the subsoil drainage system in up to a 1 in 5 year event. Detailed analysis is required at UWMP stage. The loss of a portion of the evapotranspiration rates on the site due to urban development is likely to result in a rise of the groundwater or perched groundwater levels. This will need to be taken into consideration with the detailed design under the UWMP. The impact of land-use changes and capillary rise to be accounted for in the design of any subsoil drainage system. Clearance requirements from controlled groundwater levels to finished lot levels should also take into account the size and depth of soakwells that may be used when houses are built and these matters will be taken into account

ADDENDUM TO SUB-PRECINCT 3A LOCAL WATER MANAGEMENT STRATEGY	
SECTION IN DOCUMENT	**CHANGE**
	when the UWMP is being prepared. The subsoil drainage system shall be designed to suit soil and groundwater profiles as well as site and road drainage needs and fill provisions. The design shall consider the rise in phreatic surface that may occur under the houses or roads and also take into account capillary effects. Sufficient clearance shall be provided between the bases of footings (usually 1.0 to 1.2 metres), between the bases of soakwells to be used for houses and between the subgrade level of roads and the controlled groundwater level (CGL) in each case. Such clearances shall be demonstrated to comply with current Australian Standards and prior to completion of the UWMP; the developer should consult with the local authority to agree on best practice as it may exist at the time of preparing the UWMP. Where the depth between the CGL and the base of house footings is more than 1.8 metres, subsoil drainage may not be required if lot drainage is not compromised.”
9	**Page 56** After the last dot point that says “detailed area plan addressing the issue of houses with side boundaries facing roads and road swales (UWMP).” Add three new dot points as follows:- “Based on the City of Gosnells’ asset management model and their criteria (and using a pro-forma provided by the City) the developer shall provide details of the potential whole of life cycle costs for the drainage assets including the various BMP’s adopted within the WSUD measures. The extent of information to be provided to the City will be agreed prior to clearances of the subdivision on the basis that the data will be collected during the maintenance and defects liability period and handed over to the City when the landscaped open space areas are finally handed over to the City. Such an agreement will reflect that such information is not yet known in the industry and that the City’s fundamental goal is really to ensure that information is collected and handed over. “A Construction Environmental Management Plan will be prepared before construction works commence. An outline of the Plan will be included in the UWMP”. “A suitable infiltration reduction factor for clogging must be used and justified for all infiltration calculations”.
10	**Page 57** **10.1 end of paragraph** Add text “Comprehensive surface and groundwater monitoring reports are to be submitted by the developer to City of Gosnells

ADDENDUM TO SUB-PRECINCT 3A LOCAL WATER MANAGEMENT STRATEGY

SECTION IN DOCUMENT	**CHANGE**
	on an annual basis for three years following the practical completion of Stage 1, or as otherwise determined by the City." **end of text. Add new section**:- "10.4 Monitoring During Construction Groundwater monitoring requirements during construction will be detailed in the Construction Environmental Management Plan. The Plan will be prepared before construction works commence"
11	**Page 58, Table 1, Rainwater Tank Scheme Development.** Cell should read "Developer to mandate scheme, residents to construct their own systems."
12	**Page 59 Stormwater Management,** Bullet Point 3 Replace "Designing basins such that the 1 in 100 year flood levels are 0.5m below residential floor levels;" With:- Providing adequate flood protection by providing appropriate (minimum 300 mm) separation between 1 in 100-year ARI water levels and finished floor levels and ensure that safe overland flood routes are provided through the development to the Southern River or Main Drain outlets. **Page 59 –** remove second bullet point under Groundwater Management.
Figures 14, 15 and 16	**Figures 14, 15 and 16**: Add text "Concept only, subject to CoG approval at UWMP stage" to title block
Appendix H	**Title**. Add text to title "Guide only, subject to CoG approval at UWMP stage"
Appendix I	**Title**. Add text to title "Guide only, subject to CoG approval at UWMP stage"

Yours sincerely
ENV Australia Pty Ltd

MARGARET DUNLOP
Senior Environmental Engineer

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

STATEMENT OF LIMITATIONS

Scope of Services

This environmental site assessment report ("the report") has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the Client and ENV.Australia Pty Ltd (ENV) ("scope of services"). In some circumstances the scope of services may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

Reliance on Data

In preparing the report, ENV has relied upon data, surveys, analyses, designs, plans and other information provided by the Client and other individuals and organisations, most of which are referred to in the report ("the data"). Except as otherwise stated in the report, ENV has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report ("conclusions") are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. ENV will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to ENV.

Environmental Conclusions

In accordance with the scope of services, ENV has relied upon the data and has conducted environmental field monitoring and/or testing in the preparation of the report. The nature and extent of monitoring and/or testing conducted is described in the report.

On all sites, varying degrees of non-uniformity of the vertical and horizontal soil or groundwater conditions are encountered. Hence no monitoring, common testing or sampling technique can eliminate the possibility that monitoring or testing results/samples are not totally representative of soil and/or groundwater conditions encountered. The conclusions are based upon the data and the environmental field monitoring and/or testing and are therefore merely indicative of the environmental condition of the site at the time of preparing the report, including the presence or otherwise of contaminants or emissions. Also it should be recognised that site conditions, including the extent and concentration of contaminants, can change with time.

Within the limitations imposed by the scope of services, the monitoring, testing, sampling and preparation of this report have been undertaken and performed in a professional manner, in accordance with generally accepted practices and using a degree of skill and care ordinarily exercised by reputable environmental consultants under similar circumstances. No other warranty, expressed or implied, is made.

Report for Benefit of Client

The report has been prepared for the benefit of the Client and no other party. ENV assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of ENV or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

Other Limitations

ENV will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

The scope of services did not include any assessment of the title to or ownership of the properties, buildings and structures referred to in the report nor the application or interpretation of laws in the jurisdiction in which those properties, buildings and structures are located.

EXECUTIVE SUMMARY

This report has been prepared to support the submission of an Outline Development Plan for the land located between Southern River Road, Leslie Street, Matison Street and the proposed realignment of Holmes Road/Garden Street in Southern River (Sub-precinct 3A(1)).

Under the *Southern River Interim Integrated Land and Water Management Plan (*the *IILWMP)* (Water Corporation, 2007), a Local Water Management Strategy (LWMS) is required to support the Local Structure Plan developed to support the application for amendment of the Local Planning Scheme to rezone the land as Urban. The *IILWMP* sets out the requirements for a LWMS within the Integrated Land and Water Management Plan (ILWMP) area, which must be reviewed by the Memorandum of Understanding (MoU) group, including the City of Gosnells, Department of Water, Department of Environment and Conservation and Water Corporation prior to development proceeding.

The objective of this LWMS is to design a development that manages the total water cycle in a sustainable manner. This includes water conservation, stormwater management, groundwater management and wetland management. Sub-precinct 3A(1) aims to manage these issues through the following initiatives.

Water Conservation

- Providing householders with rainwater tanks for toilet flushing and/or washing machines;
- Mandating the use of Waterwise fittings at construction;
- Providing Waterwise landscaping packages that include low water use gardens and soil amendments to minimise water and nutrient loss; and
- Minimising water use in Public Open Space through the use of low water use landscaping treatments and water efficient irrigation systems that are linked to soil moisture characteristics.

Stormwater Management

- Implementing a drainage design that limits the peak outflow from the development to pre-development levels through storage and infiltration on site;
- Providing adequate flood protection by providing appropriate (minimum 300 mm) separation between 1 in 100-year ARI water levels and finished floor levels and ensure that safe overland flood routes are provided through the development to the Southern River or Main Drain outlets.

- Including appropriate contemporary WSUD BMPs in the road reserve that store and infiltrate the 1 in 1 year event; and
- Implementing a stormwater system that the model indicates will meet the ILWMP targets for nitrogen and phosphorus reduction through the use of swales, living streams and bioretention systems.

Groundwater Management

- Allowing the use of controlled groundwater levels only where it can be demonstrated that these will not affect the Conservation Category Wetland to the south of the site; and
- A commitment to further monitoring of groundwater quality on the site to determine whether historical practices have impacted on groundwater quality.

Wetland Management

- Maintaining pre-development levels of flow into the wetland in a 1 in 100 year storm event.

1 INTRODUCTION

This report has been prepared to support the submission of an Outline Development Plan by the contracted purchaser of the below-mentioned lots (WRF Property Ltd) for their lots and the remainder of the land located between Southern River Road, Leslie Street, Matison Street and the proposed realignment of Holmes Road/Garden Street in Southern River (Sub-precinct 3A(1)).

Lots owned by or contracted to WRF Property Ltd:

- Lot 1 Southern River Road;
- Lots 1744, 1745, 1751 Bradley Street;
- Lots 1508, 1509, 1510, 1511, 1512, 1513 and 1514 Leslie Street; and
- Lot 22 and 23 Matison Street.

The location of Sub-precinct 3A(1) is shown in Figure 1.

Under the *Southern River Interim Integrated Land and Water Management Plan (*the *IILWMP)* (Water Corporation, 2007), a Local Water Management Strategy (LWMS) is required to support the Local Structure Plan developed to support the application for amendment of the Local Planning Scheme to rezone the land as Urban. The *IILWMP* sets out the requirements for a LWMS within the Integrated Land and Water Management Planning (ILWMP) area, which must be reviewed by the Memorandum of Understanding (MoU) group, including the City of Gosnells, Department of Water, Department of Environment and Conservation and Water Corporation prior to development proceeding.

1.1 TOTAL WATER MANAGEMENT STRATEGY

The objective of this LWMS is to design a development that manages the total water cycle in a sustainable manner. The objectives of total water cycle management, as described by the Draft Water Resources State Planning Policy (WAPC, 2004) are to:

- Take into account total water cycle management and water-sensitive urban design principles and ensure that development is consistent with current best management practices and best planning practices for the sustainable use of water resources, particularly stormwater.
- Seek to achieve no net difference in water quality and quantity, such that post-development water quality and quantity conditions are equal to or better than pre-development conditions.

- Promote management of the urban water cycle as a single system in which all urban water flows are recognised as a potential resource and where the interconnectedness of water supply, stormwater, wastewater, flooding, water quality, waterways, estuaries and coastal waters is recognised.
- Maximise the opportunities for compliance with best practice stormwater management including retention of stormwater on site/at the source.
- Promote use of water conservation mechanisms that increase the efficiency of the use of water, including stormwater.
- Incorporate the re-use and recycling of water, particularly stormwater and grey water, consistent with state water strategy recycling objectives. Alternative water sources should be considered where appropriate.
- Promote the retention and use of local native vegetation in developments to minimise water use and maximise filtration, particularly where landscaping is proposed.

This is to be done by maintaining the principles of Water Sensitive Urban Design (WSUD), which are:

- **Protect natural systems** - protect and enhance natural water systems within urban developments;
- **Integrate stormwater treatment into the landscape** - use stormwater in the landscape by incorporating multiple use corridors that maximise the visual and recreational amenity of developments;
- **Protect water quality** - protect the water quality draining from urban development;
- **Reduce run-off and peak flows** - reduce peak flows from urban developments by local detention measures and minimising impervious areas; and
- **Add value while minimising development costs** - minimise the drainage infrastructure cost of development. (CSIRO, 1999, As reprinted in WAPC, 2004).

1.2 PLANNING BACKGROUND

1.2.1 Metropolitan Region Scheme

The subject site is currently zoned 'Urban' under the Metropolitan Region Scheme (MRS), as shown in Figure 2. The lifting of urban deferment was achieved in July 2006.

The subject site, Sub-precinct 3A(1), is bordered to the south by the existing MRS 'Other Regional Road' reservation for the future extension of Garden Street (Figure 2). It is understood that the DPI will initiate an amendment to the MRS to realign this reservation to generally reflect the existing Holmes Street reservation, so as to avoid dissecting Bush Forever Site 464 (immediate south of subject site). It is anticipated that upon completion of this realignment planning will be progressed for the balance portion of Sub-Precinct 3A. A LWMS will be required for the balance of the Sub-Precinct in due course. To assist in this, the water balances and MUSIC modelling in this report has been undertaken for the whole Sub-precinct.

The subject site is located on the current development front and the progression of adjoining sites demonstrates this. The land to the north west of Southern River Road (Bletchley Park Estate) is zoned for urban development under both the MRS and Council's Town Planning Scheme, with detailed planning being well progressed for its development. The land north east of the Southern River water course is currently zoned and in the construction phase of subdivision (Chamberlain Street development), highlighting the fact that the study area is situated on the edge of the existing urban area.

1.2.2 City of Gosnells Town Planning Scheme No.6

The subject site is part of Southern River Precinct 3. The site is zoned 'General Rural' but Amendment 70, rezoning the land to 'Residential Development', has been approved by the Minister and is expected to be gazetted in the coming weeks.

1.2.3 Southern River/Forrestdale/Brookdale/Wungong District Structure Plan

This site falls within the area of The Southern River/Forrestdale/Brookdale/ Wungong District Structure Plan (DSP). The DSP was first published for draft comment in October 1999 with the final report being published in January 2001. Final Government endorsement of the DSP has been delayed, however, pending completion of an Urban Water Management Strategy for the district.

An Urban Water Management Strategy was prepared by consultants for the Department of Environment, however, it has never been formally endorsed. More recently, the Water Corporation has completed an *Interim Integrated Land and Water Management Plan* (the *IILWMP*) (Water Corporation, 2007 a). The document *Interim Integrated Land Urban Water Management with Land Use Planning within* *the Southern River Area* (EES, 2006) was used to manage development in the area prior to the completion of the *IILWMP* and has very similar goals and objectives for the area. All three documents recognise water and drainage as one of the key issues for development in the Southern River area. These documents have been used to develop this Local Water Management Strategy.

This enables the DSP to be effectively utilised by Government Planning and Infrastructure agencies as a basis for considering planning proposals at a more detailed level. The DSP is broadly considered to be the most current and relevant strategic planning instrument to guide ongoing development in the district.

1.3 PREVIOUS STUDIES

Previous studies into land and water management in the area include:

- Southern River/ Forrestdale/Brookdale/Wungong Structure Plan: Urban Water Management Strategy (JDA, 2002)
- *Southern River Area: Groundwater modelling to assess effects of climate variation, and proposed development* (Rockwater, 2005)
- Southern River Sub-precinct 3A (1): Request for Urban Zoning (Taylor Burrell Barnett, The Civil Group and ENV Australia (2005))
- Water Corporation (2007 b) *Forrestdale Main Drain Arterial Drainage Strategy (ADS)* (Interim)
- *Precinct 3 Environmental Review* undertaken by ENV for City of Gosnells (not yet available pending Environmental Protection Authority (EPA) review).

1.4 REPORT HISTORY

A previous version of this report was submitted to support the Town Planning Scheme rezoning in 2006. During this process, comments were made on the report by various agencies including the Department of Water, City of Gosnells, Water Corporation and Swan River Trust. Revisions have been made to the report based on these comments and improvements in the understanding of the site. A summary of these revisions can be found in Appendix A.

2 PROPOSED DEVELOPMENT

2.1 DETAILS OF PROPOSED DEVELOPMENT

The development proposal is for a residential development with a range of housing lot sizes. The base residential density will be R20, with medium density developments from R25 to R40 located in areas close to POS, commercial areas and public transport routes (Figure 2).

Two commercial areas are also proposed for the development. An area of 7,600m^2 will be set aside on the corner of Holmes Road and Southern River Road. A further 3,600m^2 of retail area is proposed on the corner of Southern River Road and Leslie Street. In accordance with the City's Draft Commercial Strategy, it proposed that this centre will ultimately accommodate 900m^2 of retail floor space.

Local open space areas have been strategically located to provide for local active and passive recreational facilities, the retention of quality vegetation, and opportunities for natural drainage passage and filtration. Regard has also been given to the site's proximity to Sutherlands Park (opposite on Southern River Road) and the requirements of Council to maximise cash-in-lieu payment to accommodate the compensation requirements for the Wetlands and Buffers within the broader Precinct 3.

A substantial area has been set aside in the north-eastern sector, extending from Matison Street, near Leslie Street; this area is aimed at protecting the main area of relatively undisturbed remnant bushland within the sub-precinct which is associated with an area of classified as a Multiple Use Wetland. This area also incorporates a natural drainage feature.

Other open space has been proposed along Matison Street in the general vicinity of an area mapped as Conservation Category Wetland. This area will be provided as a buffer to the wetland.

2.2 ENVIRONMENTAL ISSUES TO BE ADDRESSED

Environmental issues that have been identified on the site include:

- Acid Sulphate Soils;
- Management of works, including dust and sediment management;
- Potential soil and groundwater contamination, including elevated nutrients, from two former poultry operations;
- High groundwater tables;

- Wetland management issues; and
- The Conservation Category Wetland to the south of the site, part of which is included in Bush Forever Site 464.

These issues are described and addressed by this document to a level that is considered to meet the requirement of the IILWMP at this stage in the planning process. For the majority of identified issues, more detailed assessment and management will be required in subsequent planning phases in accordance with the IILWMP and Department of Environment and Conservation (DEC) policy. However, it is recognised that more detailed work is likely to be required at a later stage to address these issues to the satisfaction of the regulators.

2.2.1 Management of Works

Dust

Dust is generated when there is sufficient wind velocity and frequency to lift fine particles from a surface. The susceptibility of the particles to lift is a function of the size and weight of the particles, the presence of any ground cover, compaction and the moisture content of the ground. The dust management strategy for earthworks on a site should give regard to the surrounding land uses, the closest sensitive receptors and the prevailing wind and climatic condition for the season in which the works are to be conducted.

Dust is considered unlikely to be an issue for the first stages of construction. There are currently no dust sensitive receptors in the area surrounding Sub-precinct 3A(1). When houses are built in the area, the residents of these houses may be affected by the dust from nearby construction. Regardless of this, contractors engaging in civil works should assess their site and develop dust management practices consistent with the guidelines set out on the Department of Environmental Protection (now Department of Environmental and Conservation, DEC) document, Land development sites and impacts on air quality: A guideline for the prevention of dust and smoke pollution from land development sites in Western Australia (DEP,1996). Measures that may be considered during the development phase include the use of shade cloth or hessian wind fencing and wetting down of areas when dust is of concern.

Sediment

Sediment movement is considered unlikely to be an issue during construction. The slopes in the development area are gentle, with the majority of slopes being less than 5%. The sandy soils of the area are considered a low risk of erosion. The steeper areas generally represent ancient sand dunes with high infiltration rates and larger particle sizes. No evidence of erosion has been noted on the site and the risk of significant erosion during works is considered to be low. It is recognised, however, that the stripping of vegetation and movement of soil during works increases the risk of erosion.

The primary concern for sediment management is the risk of sediment entering waterways, such as Southern River. To avoid this, inspection for erosion should be undertaken on a regular basis (at least weekly during winter) during the works, particularly after rain. This inspection should include inspection of stockpiled soils around the site. If erosion is noted on the site, then steps should be undertaken to minimise it through the use of straw bales or temporary sediment fencing.

As specified by the City of Gosnells, street sweeping will be undertaken during housing construction to avoid sand entering the swales and reducing their effectiveness. Street sweeping will be undertaken every two weeks during the winter wet period.

2.2.2 Other Environmental Issues

The other environmental issues identified under Section 2.2 are discussed in greater detail throughout the document and are therefore not addressed in this section.

3 PRE DEVELOPMENT ENVIRONMENT

3.1 GEOLOGY AND SOILS

3.1.1 Geology

The Geological Survey of Western Australia 1:50 000 Environmental Geological Series Armadale Map Sheets 2033 I and 2133 IV describe the geology at the site as being three units:

SP1 – PEATY SAND – grey to black, fine-medium grained, moderately sorted quartz sand, slightly peaty of lacustrine origin.

S8 – SAND – white to pale grey at surface, yellow at depth, fine-medium grained, moderately sorted, subangular and subrounded, minor heavy minerals of Aeolian origin. (Bassendean Sand)

S10 – SAND – as S8 over sandy clay to clayey sand of the Guildford Formation of Aeolian origin, (Bassendean Sand over Guildford Formation) (Figure 3).

Bores drilled on the site indicate that the site is generally S10 - Bassendean Sand over Guildford Formation. Some iron cementation and material with a higher organic content was found in the Leslie Street Wetland area (MW4), while coffee rock has also been found in some areas (Appendix B).

3.1.2 Soils

The soils of the Southern River site are generally expressed as a grey or white Bassendean sand that grades to Guildford Formation material at a depth of less than 6m BGL (generally about 3-5m BGL) (Appendix B). The Guildford Formation material ranges from silty sand material through to sandy clays. Coffee rock has been found on the edge of the CCW to the South of the site (MW6) and also in one bore near the Egg Farm on Southern River Road (MWA). This indicates that patches of coffee rock may be present in other lower lying areas of the site (Figure 4).

3.1.3 Soil Contamination

A preliminary assessment of the potential for soil contamination was undertaken through a review of historical aerial photographs and a site walkover to identify areas of concern. A desk top study conducted as part of this investigation identified several areas with a low risk of potential contamination. These include general farming activities and the presence of two poultry farms. The potential contaminants identified from these land uses are mainly hydrocarbons, metals and pesticides associated with farming activities and concentrated nutrients from poultry farming activities.

ENV is currently undertaking Preliminary Site Investigations (PSIs) on the two poultry farms in expectation of a condition of subdivision requiring the investigation and potentially remediation of the sites to the satisfaction of the DEC. The work will be undertaken in line with the *Contaminated Sites Act* (2005) and DEC's standards.

3.1.4 Acid Sulphate Soils Assessment

Desktop Investigation

A desktop study conducted for the site identified one area as high risk for PASS and ASS at depths <3.0m located in the north eastern area of the site (WAPC, 2004). The rest of the site is classified as moderate to low risk of PASS and ASS at depth >3.0m. Figure 5 provides the mapped areas of ASS risk.

Field Testing for Acid Sulphate Soils

Four holes, MW2 to MW5, were drilled at various locations across the site to an approximate depth of 6.0m in 2005 (Appendix B). MW4 and MW5 targeted the high risk area. Soil sampling occurred approximately every 250mm. Field testing conducted on the samples indicates the presence of Potential Actual Acid Sulphate (PASS) soils in MW3, MW4 and MW5. Positive acid sulphate soils tests were generally found at depths of greater than 2.5m below ground level however PASS was detected at 1.5m in MW5 (Appendix B).

Testing for Actual Acid Sulphate Soils (AASS) was also conducted on samples and did not indicate the presence of AASS in any of the samples. Laboratory testing was conducted on the samples to confirm the presence of PASS, indicated in the field testing.

Based on the likely presence of acid sulphate soils in three of the four locations drilled, further acid sulphate testing will be conducted at the site, including additional drilling, sampling and analytical work. This additional work will also better delineate the vertical extent of the presence of PASS.

ASS Results

Field testing for ASS has indicated the presence of Potential Actual Acid Sulphate (PASS) soils in MW3, MW4 and MW5 at depth. Positive ASS soils were generally found at depths of 1.5 – 6.0m below ground level. Field tests indicate that no Actual Acid Sulphate Soils (AASS) is present on site. Laboratory testing was conducted on the samples to confirm the presence of PASS, as indicated in the field testing. Soil logs for the holes are shown in Appendix B.

Initial investigations have indicated that Acid Sulphate Soils on site are of most concern in areas that will be dewatered due to drainage or for installation of services such as sewers.

Although the site is surrounded by a number of sensitive receptors, the potential sources identified in this investigation are not considered to be of high risk. It is therefore considered that effective management of the potential risks and any identified contamination will be possible.

Management Strategy

The current mapping and preliminary field work indicates that ASS is a concern on the site for sewer construction only. Therefore further assessment is required prior to the submission of a dewatering licence so sewer construction can take place. Acid Sulphate Soils are best assessed at a subdivision stage, when the depths of excavation and dewatering required for sewers are known. Undertaking ASS assessment before sewer design is undertaken often results in sampling being undertaken over insufficient depths or in the wrong location. The work must then be redone when the sewer layout is known.

Acid Sulphate Soils Investigation will therefore be carried out as required by the sewer and other servicing requirements of the individual developments. Investigation will be carried out to the DEC guidelines on the advice of the Land and Water Quality Branch.

If the investigations reveal that ASS are present, then an ASS Management Plan will be developed that addresses the specific constraints and issues raised. This management plan will address the issues of the temporary lowering of groundwater to install sewers and the disposal of dewatering management. It is not clear at this stage whether lowering of groundwater will be required for sewer installation. If this is the case, it is expected that the dewatering water will be able to be disposed of by infiltration on site. If ASS is considered to be a significant issue based on DEC/DoW advice, the pH of the dewatering water will be monitored and the water limed to increase the pH if required.

The ASS Management Plan will be reviewed by the DEC and DoW prior to implementation during the construction phase. Without the approval of these agencies, dewatering and sewer installation cannot commence. The regulator approved monitoring will then be carried out during the construction phase and a post-construction monitoring report, including at least six months' groundwater monitoring, will be prepared for the DEC/DoW's approval. The process will conform to the DoE's ASS guideline: *Draft Identification and Investigation of Acid Sulphate Soils* (May 2006) and/or other guidelines that are relevant at the time.

3.2 GROUNDWATER

3.2.1 Groundwater Work by Others

Groundwater monitoring and contouring for the Southern River area was initially undertaken by JDA (2002) and then updated by Rockwater (2005). The Rockwater report only provides 5m contours for the area, which makes it difficult to interpolate the results at a site level. Requests were made to the relevant authorities for more detailed contouring but advice was given that the JDA contours should be used instead (J. Wegner, personal communication). The JDA contours indicate that groundwater flow on the site is in a generally east to north-easterly direction, towards Southern River (Figure 6) with Average Annual Maximum Groundwater Levels (AAMGLs) varying between 20.0m AHD in the west and 17.5m AHD in the east. The JDA study did not include any bores on this site. These contours are considered more accurate than the *Perth Groundwater Atlas* (DoE, 2005) in this area.

3.2.2 Site Hydrology

The surface and groundwater conditions of Sub-precinct 3A(1) are governed by the relatively low permeability of the underlying clayey soils and flat nature of the site. When rain falls on the site, it may pond at the surface and move towards low points on the site, such as the Leslie Street wetland and the corner of Southern River Road and Leslie Street. These points may also represent places where groundwater comes to the surface of the site. The clayey layers close to the surface maintain an effectively perched groundwater system over much of the site. The groundwater levels on the site are controlled by the Matison Street Drain on the site, Southern River to the east and the Forrestdale Main Drain to the south.

Results of bore pumping records indicate that the unconfined aquifer is perched in places. In August 2005, (a wet period), of four bores placed on the site, only two, one at the Leslie Street wetland and one at the Chicken Farm, were able to produce the 20 L volume required for a full purge. The other three bores became dry before this volume could be produced indicating shallow perched lenses of groundwater or a tight aquifer with low porosity, or possibly elements of both.

3.2.3 On Site Groundwater Levels

Groundwater levels were measured between August 2005 and November 2007 (Appendix C). Groundwater levels on the site were initially monitored at four locations on three successive occasions:

- MW2: Adjacent to a former broiler farm in the south-west of the site (near Matison Street). The area is currently used for horse agistment;
- MW3: The current poultry egg farm on Southern River Road;

- MW4: Paddock adjacent to the Leslie Street wetland; and
- MW5: Paddock in the north-east corner of the site.

These locations are shown on Figure 4.

In May and June 2006, four further bores were constructed to investigate groundwater levels and quality near the CCW and potential impacts from the former broiler hen farm and current poultry egg farm on the site. These bores were:

- MW6: Adjacent to the CCW on Matison Street;
- MWA: Down gradient of the of the former poultry egg farm;
- MWB: Up gradient of the current poultry egg farm on the corner of Southern River Road and Bradley Street.
- MWC: Down hydraulic gradient of the former broiler farm.

These locations are shown on Figure 4. The first of these, MW6, was constructed and monitored in May 2006 along with MW4 to MW6. All eight bores were monitored between July 2006 and November 2007. Results of the monitoring are given in Appendix C.

Groundwater levels were lowest in March 2007 and highest in October 2007. Water levels in two local Department of Water bores, known as T75 and 8285 were also measured. The groundwater levels on the site varied between 13.3 m AHD (MB5 in March 2007) and 19.5 m AHD (MBB in October 2007). In all cases, groundwater flows were in a generally easterly direction, towards Southern River. This is line with the groundwater work undertaken by JDA (2002).

3.2.4 Average Annual Lowest Groundwater Levels

July 2006 groundwater levels varied from 18.76m AHD at MW2 in the south-west of the site to 14.97m AHD at MW5 in the north-eastern corner. This area represents a low point where the Guildford Formation is close to the ground surface. Groundwater levels were also measured at the nearest DoE monitoring bore, T75[1] to obtain an Average Annual Lowest Groundwater Level (AALGL) (Figure 7). This date was chosen because the new bores had been installed and groundwater levels in the area were still very low due to the lack of rain in the previous months. The AALGL calculations and a graph of the bore record for T75 are shown in Appendix B. AALGLs for the site varied between 14.06m AHD in the north-eastern corner of the site and 17.85m AHD in the south-western corner. Average Annual Maximum Groundwater calculations will be undertaken following peak groundwater

---

[1] The location of T75 is shown in Figure 6.

levels this spring. The four extra bores developed in 2006 will allow for more accurate determination of groundwater levels than would be possible with the previous data.

3.2.5 Average Annual Maximum Groundwater Levels

The first version of the LWMS did not include a calculation of Average Annual Maximum Groundwater Levels (AAMGLs) because the very low rainfall in winter 2006 meant that water levels in that year were not considered representative of an average winter. While the 2007 Perth total rainfall of 703mm was lower than the average 855mm, it was significantly greater than the 2006 total of 467mm. The total rainfall in 2005 was 875mm. In Sub-precinct 3A(1), this meant that surface water that was observed in Spring 2005 and 2007 was not observed in 2006. Therefore, the groundwater levels encountered in 2005 and 2007 could be considered more representative of an average winter than the groundwater levels in 2006 and were therefore used to calculate the AAMGL (Figure 8).

The Department of Water Bore T75 (WIN ID 4880) was used to calculate the AAMGL. This bore is located approximately 1km north-east of the site (Figure 6). Readings from 11 October 2007 and 28 August 2005 were used, depending on which represented the peak water level at that particular monitoring bore.

The Average Annual Maximum Groundwater Levels for the site varied between 20.2 and 17.3m AHD, as shown in Figure 9. Depth to AAMGL varied from greater than 3m in the west of the site to approximately zero along the 18m contour in the south-east of the site, which represents a drain (Figure 8). The AAMGL calculated for the site is similar to the groundwater levels calculated for the area under an average rainfall scenario (Rockwater, 2005) and slightly higher than the levels calculated by JDA (2002). The Rockwater report indicates an 18m contour near Leslie Street, rising to greater than 20m AHD near Holmes Street. Under this scenario, only a small area near the Leslie Street Drain was expected to be inundated (Rockwater, 2005). This is consistent with observations on the site.

3.2.6 Superficial Groundwater Quality

Guidelines

No formal guidelines exist for nutrient levels in groundwater in the Swan Coastal Plain and therefore the Swan Canning Catchment Clean Up Criteria developed by the Swan River Trust have been used as a guide (Table 1). Guidelines exist where water is proposed to be used for irrigation or drinking water or for near pristine wetland systems (ANZECC, 2000) but these are not considered appropriate in this case. The SRT levels have been used as indicator levels for groundwater quality.

Table 1: Swan-Canning Cleanup Program targets for median total nitrogen and total phosphorus concentration in tributaries of the Swan-Canning Rivers (SRT, 1999) and median concentrations from Southern River (SRT, not dated**)**

	Nitrogen (mg/L)	**Phosphorus (mg/L)**
SRT Short-Term Target	2.0	0.2
SRT Long-Term Target	1.0	0.1
Southern River Median Concentration (2001)	0.87	0.15

Sampling

Tables 2 and 3: Total Nitrogen and total phosphorus results

Total Nitrogen

Date	MB2	MB3	MB4	MB5	MB6	MBA	MBB	MBC
16/08/2005	5.6	7.8	22.4	14.9	#	#	#	#
7/03/2006	3.0	dry	14.0	17.0	#	#	#	#
4/07/2006	1.1	dry	3.0	1.9	5.0	2.4	10.4	5.6
10/08/2006	2.4	3.3	2.6	2.1	4.9	4.9	7.5	4.8
13/09/2006	2.9	3.9	3.6	8.2	3.5	8.0	2.8	9.1
21/03/2007	dry	dry	2.2	5.9	3.6	2.9	dry	dry

Total Phosphorus

Date	MB2	MB3	MB4	MB5	MB6	MBA	MBB	MBC
16/08/2005	1.72	8.56	2.71	1.14	#	#	#	#
7/03/2006	0.6	dry	0.35	1.2	#	#	#	#
4/07/2006	0.19	dry	0.08	0.2	0.09	0.12	0.44	11.2
10/08/2006	0.25	5.7	<0.05	<0.05	<0.05	0.1	0.25	<0.05
13/09/2006	0.14	5.9	<0.01	0.29	0.06	0.05	0.14	15
21/03/2007	dry	dry	0.05	1.1	0.14	0.11	dry	dry

All values in mg/L.
(a) Sampling was attempted on 24/5/06 but all wells purged dry before sample could be taken.
bores constructed in 2006

⬜	Meets long term SRT guideline (1 mg/L TN and 0.1 mg/L TP)
▨	Meets short term SRT guideline (2 mg/L TN and 0.2 mg/L TP)
🟨	Does not meet either guideline

Groundwater sampling was undertaken on:

- 16 August 2005;
- 7 March, 4 April, 10 August and 9 September 2006; and
- 21 March 2007.

Groundwater sampling was also attempted on 25 May 2006. On this date, the wells purged dry almost immediately. This is considered to be due to the water table having retreated into the clay layer, which has a very low hydraulic conductivity. Because the wells purged dry so rapidly, no water sampling was undertaken. It was therefore proposed to change to methods that were more suitable for low volumes. Using these methods, groundwater sampling was successfully undertaken on 4 July 2006. All groundwater sampling results are shown in Appendix E.

Nitrogen

The total nitrogen levels on site varied from 1.1 to 22.4mg/L, with an average of 8.2mg/L and a median of 5.6mg/L (Table 2). Groundwater nitrogen levels appeared to decrease over the study period. These results are similar to those recorded at Bletchley Park, to the east of the site (GHD, 2005a). Bletchley Park has historically been used as pasture and is not considered to have been subject to any contaminating land uses (GHD, 2005a).

The elevated nitrogen levels appear to be across the entire area with no distinct high or low points. The bores located downstream of the poultry farms (MB3 and MBC) did not appear to have significantly different nitrogen levels from the rest of the bores. Only two of the samples met the SRT short term guideline of 2mg/L total nitrogen. None met the SRT long term guidelines. Where a break down of nitrogen into different chemical forms was taken, this is shown in Appendix E. Kjeldahl nitrogen (nitrogen in organic forms) was the dominant form of nitrogen in most bores.

Phosphorus

The total phosphorus levels varied between less than 0.05mg/L to 15mg/L (Table 3). The total phosphorus results from August 2006 are significantly lower than the rest of the results. These results are questionable and the difference may be due to laboratory error. As no triplicate samples were taken, it is not possible to determine if this is the cause.

Total phosphorus levels were generally above the Swan River Trust Long Term guideline of 0.1mg/L. The total phosphorus concentrations at the bores down hydraulic gradient of the former poultry farms, MBC and MB3 were higher than the results for the other bores. Ignoring the August 2006 round, total phosphorus levels for MBC and MB3 ranged between 5.7 and 15mg/L, which is higher than the less than 0.05mg/L to 2.7mg/L recorded at the other bores. It is therefore likely that the use of these sites as poultry farms has impacted upon the groundwater phosphorus concentrations in the area.

3.3 SURFACE WATER HYDROLOGY

Drainage

The site has two ephemeral surface water drains (Figure 9). The longest of these drains transects the site in a roughly south-easterly direction from Southern River Road to Matison Street and will be referred to as the Matison Street Drain. The drain both receives surface water intercepts seasonal groundwater and forms a seasonally inundated area in the north-eastern corner of the site (Figure 9). Surface water levels at this location have been recorded at 0.5m deep after winter rains (Table 4). On leaving the site, the Matison Street Drain heads south-east along Leslie Street and into Southern River.

Table 4: Recorded Surface Water Levels

Date	Date	16/08/2005
Rain *	Rain *	21.8 / 29
Recorded Level		
SW1	-	0.68
SW2	-	0.57
Dm	-	-
Level (AHD)		
SW1	-	18.07
SW2	-	20.80
Dm	-	-
Water Depth		
SW1	-	0.31
SW2	-	0.49
Dm	-	-

The second drain starts near the corner of Southern River Road and Leslie Street and heads from the site in a north-easterly direction towards Southern River. This corner is waterlogged after rain but does not flood due to the flat nature of the site. This area feeds the ephemeral drain, known as the Southern River Rd Drain.

Based on information from the Department of Water, the site is not affected by the 1 in 100 year flood plain of Southern River or the Forrestdale Main Drain (Figure 10).

Catchment Boundaries

Five catchments have been identified within Sub-precinct 3A (Figure 11). As the boundaries of these catchments lie outside Sub-precinct 3A(1) and the drainage design has been undertaken for the whole of Sub-precinct 3A, the catchments are described for the whole of Sub-precinct 3(A).

The first catchment is located on the corner of Southern River Road and Leslie Street and forms the start of the Southern River Road Drain. Catchment 1 drains in a north-easterly direction towards a drain on the corner of these roads. The estimated area of this catchment is 3ha. This catchment forms part of the JDA catchment SR14. The remainder of this catchment lies to the east of Leslie Street.

The second catchment is the largest and runs between Southern River Road and Matison Street. This catchment slopes in an easterly direction. Catchment 2 accepts a very small volume of drainage from the road junction to the north, which drains onto the site at the poultry egg farm. This road drainage may include some runoff from the Sutherland Park ovals. The water then drains into the Leslie Street wetland and out to Matison Street via a drain. This is the main catchment of the site, with an approximate area of 24ha. This catchment and Catchment 3 forms the JDA catchment SR12.

Catchment 3 runs parallel to Catchment 2, although it is bounded by a small ridge to the north. This catchment does not appear to have any wetland characteristics or a defined drain. This catchment is in general slightly higher than Catchment 2 and has an approximate area of 8ha. Much of the catchment will be redirected to be included in Catchment 2, with the balance to Catchment 4 following proposed earthworks.

Catchment 4 also runs parallel to Catchment 2. It is bounded by the ridge to the north and the sand quarry to the south. The area of this catchment is approximately 11ha, including the sand quarry. This catchment and Catchment 5 forms the JDA catchment SR14.

Catchment 5 is a small catchment that currently drains in a westerly direction, under Holmes Road and through Precinct 2. In the *Forrestdale Arterial Drainage Strategy (Interim)* (Water Corporation, 2007 b), the Water Corporation advises that the drainage connection through Precinct 2 will be closed. Under this scenario Catchment 5 will be required to drain south through Catchment 3. Catchment 5 has a total area of 7ha.

3.3.1 Surface Water Quantity

Surface water flows can be quantified either through stream flow monitoring or by undertaking of streamflow calculations as prescribed by *Australian Rainfall and Runoff* (Institution of Engineers Australia, 1986). Because of the small size of the streams on site and the difficulties associated with installing and maintaining pluviometers, it was considered that calculations were the best way to determine flows from the site. This approach was supported by the regulatory authorities for this site. Based on the methods of described in *Australian Rainfall and Runoff* and the base assumptions of JDA (2002) for the Southern River area, the following peak flows were determined for each catchment:

Table 5: Modelled Peak Outflows for Each Drain Under Storm Events With Different Average Return Intervals (Aris) for the Whole of Sub-precinct 3A. All values are in m^3/s. (a) figures supplied from JDA (2002)

	1 in 10 year ARI	**1 in 100 year ARI**
Western Catchment (SR9)	0.043 [a]	0.134 [a]
Matison Street Drain (SR12)	0.083 [a]	0.134 [a]
Southern River Road Drain (part SR14)	0.01	0.026

As discussed in Section 3.3, a section of paddock around the Matison Street Drain becomes inundated in winter. This area is generally referred to as the Leslie Street Wetland. This area is shown in Figure 9.

3.3.2 Surface Water Quality

Preliminary surface water quality sampling was undertaken on 16 and 23 August, 2005. Sampling was also attempted on 7 March, 25 May and 4 July 2006 and 21 March 2007 but no surface water was present on the property at this stage. Samples were taken from the drain entering the site on Southern River Road (Dc) upstream of the former poultry farm, in the Leslie Street wetland (SW2) and where the drain exits the site near the corner of Leslie Street and Matison Street (Dm) (Figure 9). On the 23 of August, a sample was also taken immediately downstream of the poultry egg farm (Dds). The results of this sampling are shown in Table 3. One filtered and one unfiltered sample were taken at each location.

Table 6: Surface Water Quality

16 August 2005		Dc	Dm	SW2
Suspended Solids (SS)	mg/L	7	6	4
Dissolved Nutrients				
Total Nitrogen as N	mg/L	2.6	4.5	1.4
Total Phosphorus as P	mg/L	0.35	0.76	0.04
Total Nutrients				
Total Nitrogen as N	mg/L	2.9	4.7	1.6
Total Phosphorus as P	mg/L	0.4	0.88	0.07

23 August 2005		Dc	Dds	Dm	SW2
Suspended Solids (SS)	mg/L	7	<5	<5	8
Dissolved Nutrients					
Total Nitrogen as N	mg/L	4.8	6.3	5.2	4.8
Total Phosphorus as P	mg/L	0.5	0.3	0.55	0.2
Total Nutrients					
Total Nitrogen as N	mg/L	4.3	5.9	4.8	4.8
Total Phosphorus as P	mg/L	0.2	0.3	0.55	0.25

Note: No surface water observed during 2006.

☐	Meets long term SRT guideline (1 mg/L TN and 0.1 mg/L TP)
▨	Meets short term SRT guideline (2 mg/L TN and 0.2 mg/L TP)
🟨	Does not meet either guideline

The surface water flows currently present on the site have low total suspended solids and most of the nutrients are present in a dissolved, rather than particulate, form. The nitrogen levels on the site are above the long-term guidelines for tributaries to the Swan and Canning Rivers and are well above the 2001 median concentrations for Southern River (Table 3). The sample from the wetland (SW2) met the short-term guidelines for nitrogen.

Only one of the samples meets the short-term guidelines for phosphorus on the Swan Coastal Plain of 0.2mg/L (Table 6). The results are all above the 2001 median concentration for phosphorus in Southern River of 0.18mg/L (Table 6). These elevated levels of nitrogen and phosphorus indicate that nutrient issues are already a concern on the site.

The results from sampling of the Matison Street Drain immediately downstream of the poultry egg farm are not different from those of other sampling locations and are comparable to water quality as it enters the site to the north of the poultry egg farm. The poultry egg farm initially appears to have no or little effect on the surface water quality of the site. However, further surface water monitoring is proposed to refine the water quality data. This monitoring will include early winter, mid-winter and end of winter events.

3.4 ENVIRONMENTAL ASSETS AND WATER DEPENDANT ECOSYSTEMS

3.4.1 Wetlands

The Southern River site contains three Multiple Use Category wetlands (Figure 10). A Conservation Category Wetland is located to the south of the site, across Matison Street.

The status and condition of the wetlands on site was assessed in 2005 as part of a Vegetation Survey undertaken by the City of Gosnells. This report has recently been released by City of Gosnells (ENV, 2006). This report indicated that based on vegetation quality, ecological and human value, the Multiple Use wetlands present in the area are of insufficient conservation significance and should therefore be considered available for development purposes.

3.4.2 Vegetation

The site has been largely cleared and limited vegetation is present on the site. The vegetation on the site was assessed in 2005 as part of a Vegetation Survey undertaken by the City of Gosnells. The study identified that most of the vegetation in Sub-precinct 3A(1) was completely degraded, with small areas of vegetation in a degraded or good condition (Figure 12), (ENV, 2006).

The vegetation identified in good to degraded condition in the eastern part of the site is a Low Open Woodland of *Banksia menziesii*, *Melaleuca preissiana*, *Corymbia calophylla* and *Eucalyptus todtiana* over *Kunzea glabrescens*, *Regelia ciliata* ,*Xanthorrhoea preissii* , *Phlebocarya ciliata* and *Dasypogon bromeliifolius* (ENV, 2006). The vegetation in good condition in the western part of the site is a Low Open Woodland of *Eucalyptus todtiana*, *Banksia ilicifolia*, *Banksia attenuata*, *Banksia menziesii* and *Nuytsia floribunda* over *Adenanthos cygnorum*, *Eremaea pauciflora* var. *pauciflora*, *Hibbertia hypericoides*, *Allocasuarina humilis*, *Xanthorrhoea preissii* and *Lyginia imberbis* (ENV, 2006). Neither of these communities are considered to be Threatened Ecological Communities (ENV, 2006).

4 DESIGN CRITERIA

4.1 WATER CONSERVATION

Principle

The use of potable water should be minimised where drinking water quality is not essential, particularly outside the house

Design Objectives

A consumption target for potable water of 40-60kL/person/year for the residential sector has been set for the Southern River area (Water Corporation, 2007 a). This is well below the 155kL/person/year water use targeted by the State Water Strategy (Government of Western Australia, 2003). This target is therefore ambitious.

Assuming an occupancy rate of 2.4 residents per house (based on the 2001 census (Australian Bureau of Statistics website, accessed 17/10/2006)), the target set for Southern River gives a potable water goal of 96 – 144kL/house per year. Rockwater (2004) indicates that the total annual water use expected for a Waterwise house is 149kL/house/yr internally and a further 155kL/house/yr externally, giving a total of 304kL/house/yr annual water use without water restrictions. This compares to the current potable water use average of 274kL/house/yr (J. Brennan, Water Corporation, personal communication). These total water uses are well above the Southern River target and hence significant effort is required to meet this goal. This issue is discussed further in Section 5.

Site Proposal

The main opportunities for reducing potable water use involve reducing water use in the garden and encouraging residents to be water wise. Alternative water sources in the area include groundwater, rainwater collected from rooves and greywater. These options are further discussed in Section 5.

4.2 STORMWATER QUANTITY

Principle

Post development peak flows and event discharge volume be maintained relative to pre-development conditions, unless otherwise established through determination of Ecological Water Requirements for sensitive environments (Water Corporation, 2007 a).

Design Objectives

For Ecological Protection: For the critical 1 year Average Recurrence Interval (ARI) 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, maintain or restore desirable environmental flows and/or hydrological cycles as specified by the Department of Water.

For Flood Management: Manage the catchment runoff for up to the 1 in 100 year ARI event within the development area to predevelopment peak flows.

Site Proposal

Stormwater peak flows will be maintained through the use of compensation and retention structures such as swales and basins. These structures will be designed to maintain the discharge peaks of events up to the 1 in 10 yr ARI. Retention and peak flow mitigation for events greater than this may be limited due to area constraints on the site.

Flows in the 1 in 100 year events will be discharged generally through their current flow lines. For catchments where the 1 in 100 year flow line goes through the Conservation Category Wetland to the south of the site, this flow line will be maintained, as shown in the Water Corporation’s *Forrestdale Arterial Drainage Strategy* (2007b).

4.3 STORMWATER NUTRIENT MANAGEMENT

Principle

Reduction in the average annual loads of stormwater pollutants discharged by the development into the surface water and groundwater systems if it used traditional, directly connected stormwater drainage design (Water Corporation, 2007a).

Design Objectives

As compared to a development that does not actively manage water quality:

- At least 80% reduction in the average annual load of total suspended solids.
- At least 60% reduction in the average annual load of total phosphorus.
- At least 45% reduction in the average annual load of total nitrogen.
- At least 70% reduction in the average annual load of gross pollutants.

Site Proposal

Stormwater will be treated through a system of swales and vegetated retention basins to reduce nutrient loads leaving the site. This system has been modelled with MUSIC. MUSIC modelling results show the development meeting the design objectives. Results of this modelling are given in Section 6.

4.4 GROUNDWATER QUANTITY

Principle

Minimise change in peak winter levels at groundwater dependent wetlands due to change in groundwater flux associated with urbanisation (Water Corporation, 2007a).

Design Objectives

Post development end of winter operating levels at wetlands to be maintained at pre-development levels, unless otherwise established through determination of Ecological Water Requirements for sensitive environments.

Site Proposal

The current development is associated with a drain that intercepts the winter water table in the form of the Matison Street Drain. This drain will be heavily altered during development to become a swale with a base at or above AAMGL. Where the drain intercepts shallow groundwater, the proponent will minimise the discharge of pollutants from the shallow groundwater to the intersecting waterway or drain.

The current development has a limited hydrological association with the Conservation Category Wetland to the south of the site. As groundwater flow on the site is in a generally easterly direction, only water from the extreme south-west corner is likely to impact on the wetland. The main groundwater impact of development could be due to potential changes in the water balance in this area.

It is proposed that in the 1 in 100 year storm, some stormwater from the development would also enter the wetland via overland flow. The volume of this inflow would be limited. This is further discussed in Section 8.

4.5 GROUNDWATER QUALITY

4.5.1 Where Development is Associated with a Waterway or Open Drain that Intersects the Shallow Water Table

Principle

Minimise the discharge of pollutants from the shallow groundwater to the intersecting waterway or drain.

Design Objectives

Where drains intercept the groundwater, compared to a development that does not actively manage water quality, the development will show an:

- at least 60% reduction in the average annual load of total phosphorus; and
- at least 45% reduction in the average annual load of total nitrogen.

Site Proposal

Nutrient inputs to groundwater may occur directly from water infiltrated on site or indirectly through stormwater runoff being infiltrated on site. Quantifying nutrient inputs to groundwater is difficult and ENV is not aware of a model that can do this with any degree of reliability. It is therefore proposed to use best management practice to reduce nutrient inputs from the development.

The site is associated with an existing drain which intercepts shallow groundwater during the winter months. The reduction of the nutrient loads from this drain will occur through the use of vegetation to uptake nutrients swales and other drainage related infrastructure as described in Section 6.

The former poultry farms are being assessed as contaminated sites in line with the DEC guidelines. Management practices to prevent groundwater contamination from these sites include remediation in line with the *Contaminated Sites Act* (2003) and the removal of the top 300 mm of soil, which is considered to contain most of the nutrients.

Best management practices such as high PRI soil amendments and not fertilising POS will be incorporated during landscaping to reduce nutrient movement into groundwater.

4.5.2 Where the Development is Associated an Ecosystem that is Dependent Upon a Particular Hydrological Regime for Survival

Principle

a Minimise the discharge of pollutants from the development into the shallow groundwater.

b Minimise the discharge of pollutant from the groundwater to the receiving water.

c Maintain or restore desirable environmental flows and/or hydro-periods, water quality and habitat in specified water sensitive environments.

d Develop alternative habitats if feasible and desirable.

Site Proposal

The relationship between the development and the Conservation Category Wetland to the south is limited, as described in Section 4.4. Groundwater flow on the site is in an easterly direction and it is therefore considered that the hydrological links between the areas are limited. However, the potential impact will be minimised by limiting the use of subsoil drainage in the area. Any proposal for subsoil drainage within 100m of the CCW will be required to demonstrate that the impact on the wetland is not unacceptable.

The wetland will only receive surface water from the site during extreme events (1 in 100 year storm or greater) in line with the Water Corporation's *Forrestdale Main Drain Arterial Drainage Scheme* (2007 b). Complete water quality management in such extreme events is not feasible due to the size of the retaining structures involved and the rarity with which the structures would be fully utilised.

The impact of the development on the wetland will therefore be limited to changes in groundwater level due to alternative uses of groundwater and inputs from storms.

4.6 COMMITMENT TO BEST MANAGEMENT PRACTICE

The developer is committed to:

- decreasing potable water use on the site in ways that are environmentally sensitive and economically feasible for a development of this size.
- maintaining the stormwater outflows to pre-development levels for events up to and including the 1 in 100 year ARI storm event.
- Implementing best management practice for stormwater nutrient management within the normal percentages of land set aside for road reserve, drainage and

Public Open Space. The systems will also be designed to manage nutrients in groundwater where this is intercepted by the drains.

- Managing the hydrological impacts of development on the Conservation Category Wetland to the south of the site.

5 WATER CONSERVATION STRATEGY

5.1 OPTIONS UNDER CONSIDERATION

The small scale of the Sub-precinct 3A(1) development means that large scale water conservation strategies such as large scale aquifer storage and recovery (ASR) or wastewater recycling projects of a third pipe nature are constrained by infrastructure costs and the associated impact on the ultimate affordability of the housing.

These options were considered, however, the systems involved are complex and must be operated by a Licensed Service Provider (LSP) that has been licensed by the Economic Regulation Authority. The only LSP currently operating in the Metropolitan area is Water Corporation. Water Corporation has indicated that they are only interested in becoming involved in a small number of trial projects for alternative water supplies in the Metropolitan region that are economically viable in their own right or could lead to larger, economically viable schemes (Water Corporation, 2006).

An alternative option would involve another body (such as the City of Gosnells) becoming a LSP to operate such a scheme. Becoming a LSP is an intensive and expensive process and has limited benefits for isolated LSP providers, particularly if the long-term economic benefits of the associated scheme are limited.

The options considered feasible for this development are therefore limited to:

- domestic use of rainwater tanks for gardens, toilets and washing machine cold water inlets;
- use of greywater, roof water or groundwater for residential gardens;
- use of shallow groundwater for residential gardens as well as Public Open Space; and
- Waterwise practices in the house, garden and within the development.

Large scale projects are considered unlikely to be feasible in this area. Lot based options, where householders reduce their water use through the use of rainwater tanks, and other options are therefore preferred in Sub-precinct 3A(1). The four options listed above are described in detail below.

Previous versions of the LWMS discussed the potential for a shared bore scheme. The shared bore proposal was discussed with Landgate, who indicated that the management of such a strata scheme would not be feasible. If the equipment broke down, there would be no legal way of ensuring that the individual householders paid their share of the electricity and repair costs. If the system broke down, it would be difficult to ensure that it was repaired and that repairs were paid for fairly. Such a system would also require a complex central control system similar to the system used at Brighton. Such complex control systems would be expensive for householders to fix. This system is therefore considered not to be feasible, therefore the alternative rainwater tanks and low water use garden system will be implemented. As the proposal was determined to be unfeasible, groundwater modelling of the bore system was not undertaken.

5.1.1 Areas for Potential Domestic Potable Water Use Reduction

The average potable water use for a Perth house is 274kL/house/yr based on Water Corporation statistics undertaken during water restrictions (J. Brennan, Water Corporation, personal communication). Water consumption prior to restrictions was estimated at 459kL/house/yr for a single residential house and 280kL/house/yr for multi-residential dwellings (Coghlan and Loh, 2003). Both the pre- and post- restriction water usages are much higher than the Southern River target of 96 – 144kL/house/yr in the Southern River area. This goal requires a reduction in potable water use from current levels in the order of 47 to 65%.

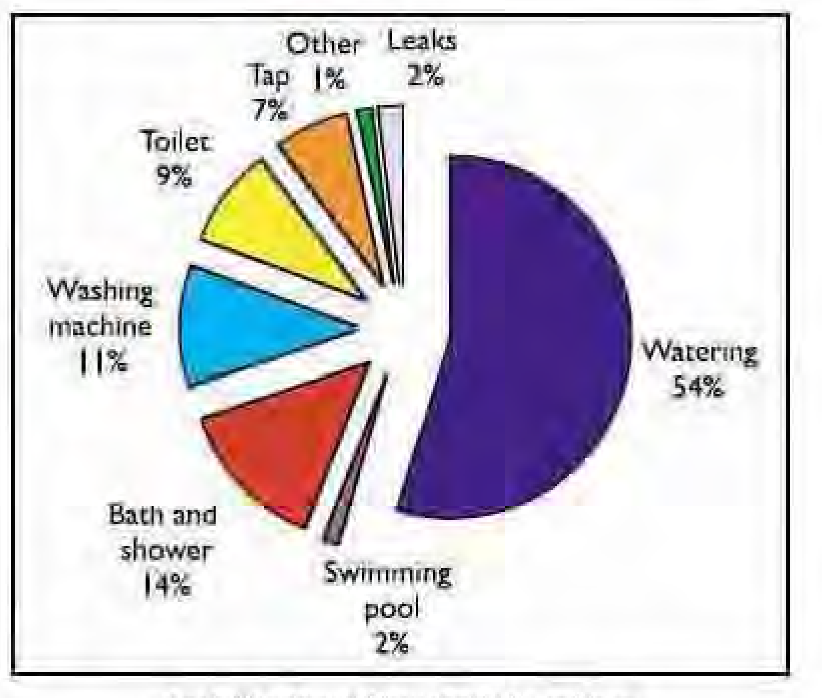


Figure 13: Single Residential House Water Usage prior to water restrictions (From Coghlan and Loh, 2003). Detailed post-restriction breakdowns are not available, but most of the reduction has been due to reductions in irrigation (J. Brennan, Water Corporation, personal communication).

Prior to water restrictions, garden watering accounted for 54% of potable water use in single residential dwellings in Perth (Coghlan and Loh, 2003) (Figure 13). After restrictions, this has dropped to an estimated 47% or 127kL/house/yr (J. Brennan, personal communication). This use can be substituted by non-potable water sources including bore water, rainwater and greywater. Internal water use after restrictions is estimated at 145kL/house/yr (J. Brennan, personal communication). Other uses of potable water that can be substituted with non-potable water sources include toilets (approximately 9% of water usage) and washing machines (approximately 11% of water usage).

Hot water may also be substituted with roof water if this can be managed and treated to reach a potable standard, but obtaining and maintaining this standard is likely to require disinfection at a household level (GHD, 2005b). The risks associated with the failure to reach an appropriate water quality standard in a hot water system that provides water for showers, baths and dishwashing is higher than for alternative uses associated with toilets or washing machine.

An alternative to in-house potable water use substitution is the use of Waterwise fixtures such as showerheads, taps, toilets and washing machines to reduce water use. Rockwater (2005) indicates that the installation of all Waterwise fittings, including washing machines, could reduce internal potable water use to 149kL/house/yr.

Based on current potable water use, achieving the target water use reduction of 47 to 65% will require the substitution of all garden watering and either installation of all Waterwise fittings or substitution of potable water with another source for either toilet flushing and/or washing machine cold inlets. Without being able to substitute for garden watering, the Southern River targets are not achievable as this accounts for approximately 47% of current domestic potable water use.

Rainwater flushing for toilets and washing machine cold water and the use of groundwater for irrigation are currently supported by Water Corporation as some of the easier ways of reducing potable water use (Table 7: Water Corporation, 2006). Current legislative conditions, mainly health considerations, in Western Australia make a number of the other options difficult to implement (GHD, 2005b).

Table 7: Ease of implementing non-drinking water sources based on current legislation (Water Corporation, 2006)

Water uses → / Water sources ↓	Toilet Flushing	Washing Machine Inlet	Domestic Irrigation	Public Open Space Irrigation	Aquifer Recharge
Rainwater	Easy to implement	Easy to implement	More effort to implement	More effort to implement	Easy to implement
Shallow groundwater	More effort to implement	More effort to implement	Easy to implement	Easy to implement	N/A
Greywater	Difficult to implement	Difficult to implement	Significant effort to implement	Significant effort to implement	More effort to implement
Stormwater	Difficult to implement	Difficult to implement	Difficult to implement	Difficult to implement	Easy to implement
Treated wastewater	Difficult to implement	Difficult to implement	Significant effort to implement	More effort to implement	Significant effort to implement

5.1.2 Residential Garden Watering

Residential garden watering may be reduced through the use of Waterwise gardening but separating gardens completely from potable water use will require substitution by another source such as roof water, domestic greywater or shallow groundwater.

Roof Water

Rainfall in Perth is concentrated over the winter months with most irrigation occurring over the hot, dry summer months. Because of this, roof water is not available for irrigation over summer without very large storages (i.e. one or more 100m^3 tanks per house[2]). This would effectively involve building rain water tanks under part or the whole of the house. This is not considered feasible (GHD, 2005b).

Domestic Greywater

Domestic greywater reuse can be undertaken on a lot scale with householders being responsible for their own greywater treatment systems. Greywater systems require maintenance and householder education on how to use the system. There is currently no regulation for the use and maintenance of greywater systems by householders. Such systems may be suitable for responsible householders who

---

[2] 1m^3 is equivalent to 1 kL or 1,000 L.

wish to have them but the irresponsible use of greywater may lead to health and environmental harm.

Greywater reuse requires householders to use special detergents, not irrigate edible plants and meet requirements for setbacks from fences, footpaths and buildings (Department of Health, 2005). Reuse is also not allowed less than 100m from wetlands where the PRI of the soil is less than 5 (Department of Health, 2005). These constraints mean that greywater reuse is not likely to be feasible on parts of the development close to the Conservation Category Wetland and on small lots where use will be constrained by setback distances.

In conclusion, while greywater reuse may be feasible for some householders in some areas of the development, it is not a broad scale solution to water use in the area.

Shallow Groundwater

Shallow groundwater bores are commonly used in Perth for domestic watering, with approximately one third of households having a bore (Coghlan and Loh, 2003). It is possible for developers to require households to have a bore or to provide shared bores for domestic use. Household bores are currently subsidised under the State Government’s Waterwise rebate program.

While domestic bores do not have to be licensed where the lot is less than 2,000m^2, bores for larger properties, Public Open Space (POS), commercial and industrial uses must be licensed by DoW. The Department of Water considers the City of Gosnells to be fully allocated with respect to these larger bores. The use of domestic bores will add pressure to the limited water resources available in the area.

Urbanisation of rural areas increases the percentage of the area covered by hard surfaces. This increases the amount of stormwater runoff because less water is intercepted by vegetation and surface losses. This additional runoff generated by urbanisation will be infiltrated on site where possible and become part of the groundwater system. The groundwater may stay in the site or move into local wetlands and waterways. Where the groundwater stays in site, it can then become available for use by bores. This difference can be calculated by undertaking a water balance for the site, which calculates the amount of water entering and leaving the site.

Waterwise Landscaping

Waterwise landscaping involves reducing the amount of water used for irrigation through the use of low water use plants, soil amendments, reduced areas of lawn and water efficient irrigation systems. Waterwise landscaping will require some irrigation, particularly if lawns are included. Native vegetation may require irrigation for establishment and then possibly limited irrigation during the hotter months. The level of water use reduction will depend on the householder and how they manage and water their garden. Any landscaping packages provided to householders within Sub-precinct 3A(1) should be Waterwise in order to minimise water use.

5.1.3 Waterwise Fittings

An alternative to in-house potable water use substitution is the use of Waterwise fixtures such as showerheads, taps, toilets and washing machines to reduce water use. Rockwater (2005) indicates that the installation of all Waterwise fittings, including washing machines, could reduce internal potable water use by 12% compared to a house with conventional fittings. Rockwater projected the internal water use for such a house was 167kL/yr, which is above the current estimated internal water use of 145kL/yr. The drop in internal water use following water restrictions is thought to be mainly due to improved efficiencies in showers, with the remainder due to the rebates on water efficient fixtures and appliances. However, as not all houses in Perth have water efficient fixtures and appliances, there is clearly room for reductions in in-house water use.

While it is possible for developers to set conditions requiring the use of Waterwise fitted fixtures such as toilets and taps in a house, the mandating of washing machine type would be difficult as these are not fixed to the house. Water efficient washing machines are covered by the Waterwise Rebate scheme, which subsidises these items.

Assuming that all fixed items in the house are Waterwise and that a conventional washing machine is used, average in-house water use would be less than 145kL/yr, which is within the Southern River guidelines. Clearly, garden water use would still pose a challenge.

5.1.4 In-house Water Substitution

In-house water substitution involves the substitution of potable water with either rain water or grey water. The options considered most feasible by Water Corporation are the use of roof water for toilet flushing and washing machine cold water. This is preferable to the use of roof water for garden watering because these uses occur during winter as well as summer and hence require significantly smaller storages (in the order of 3m^3 as compared to 200m^3). Through the use of a 3.5m^3 tank, an average house with a 210m^2 roof can supply 36kL or approximately 87% of the water required for toilet flushing each year and provide additional water for a washing machine over winter (Appendix F). Tanks of this size can be provided in designs that fit under the eaves or between the house and side fence of even small lots.

The use of roof water for substitution could affect the local water balance by reducing groundwater recharge. This option will therefore be investigated through the use of a water balance. This water balance is shown in Section 5.2 below.

A State Government Rebate of $600 or up to 50% of the cost of the rainwater tank is available for rainwater tanks greater than 2kL in size connected to toilets and washing machines. These systems may require special plumbing in the form of reflux valves to stop backflow of roof water into the potable water supply system and associated potential water quality problems. Before systems are mandated by the developer, the developer will require that any systems installed comply to Department of Health (DoH) guidelines. It is understood that guidelines for such systems are currently being developed by the DoH (N. McGuiness, Department of Health, personal communication).

5.1.5 Water Use in Public Open Space

Water use in Public Open Space (POS) is a separate issue from household water use but requires discussion.

Water efficient irrigation systems will be installed in POS. This will include irrigation systems that are controlled by soil moisture meters and only provide plants with the amount of water required for growth. Where landscaping is to be undertaken, Waterwise (preferably local) species will be used and irrigated in a way that minimises water use. The area of lawn should also be minimised to reduce water requirements. Non-invasive species will be used in areas adjacent to native bushland. Given that the final location of POS is not determined yet, a species list will be developed to support the Subdivision stage which is the point at which species can be matched to the areas of interest. Details of landscaping and groundwater allocations for Public Open Space should be provided at the Urban Water Management Plan.

The groundwater allocation for Gosnells has recently been fully allocated. The Department of Water has recently reassessed the groundwater allocation for Gosnells is being reassessed and will increase the allocation (J. Connolly, personal communication). WRF is therefore lodging an application for a groundwater license for the whole Sub-precinct 3A(1) area to ensure that water is made available for the Public Open Space.

5.2 WATER BALANCE MODELLING

Water balance modelling is one way to investigate the hydraulic impact of development upon the catchment. Water balance modelling determines the net flows of water from potable, rainwater and groundwater sources to systems such as surface water and groundwater. This allows the investigation of fluxes of water between these systems and comparison to pre-development situations. Changes in the systems due to urbanisation can therefore be determined. The modelling allows investigation of the potential changes associated with the use of shallow groundwater and collection of rain falling on rooves as alternative water sources for gardens and in-house use.

The aim of water balance modelling should be to ensure that the post development water balance is similar to the pre-development water balance with respect to the discharge of groundwater to surface and groundwater. This represents an environmentally sustainable solution.

In no circumstances should the post-development water balance for the site result in a negative discharge to these systems. A negative discharge implies that the amount of water taken up from the site in groundwater is greater than the discharge to surface water and groundwater. This situation implies mining of groundwater sources and leads to falling water tables and drying out of wetland areas.

5.2.1 Pre-development Water Balance

Originally, the Southern River site would have been bushland. It is estimated that evapotranspiration in the area would have accounted for 75% of the rainfall on the site (Rockwater, 2005). Assuming interception losses are minimal, approximately 25% of the rainfall on the site would have recharged the surface and groundwater systems. Assuming an annual rainfall of 730mm/yr [3] and a total site area of 55ha, the total annual rainfall volume for the site would be 401ML/yr. The total volume recharging the surface and groundwater systems would be in the order of 100ML/yr.

5.2.2 Post-development Water Balances

The post-development water balance for the site will depend on how the water is used on the site. This water balance is more complex than the pre-development case as it must take into account the importation of potable water from off-site, the interception and runoff characteristics from man-made surfaces including roads and rooves.

Assumptions for the water balances are given in Appendix G**.** These assumptions are based on information from the Perth Domestic Water Use Study (Coghlan and Loh, 2003), conversations with members of Water Corporation's Water Cycle Project team (J. Brennan and M. Loh, personal communications), Rockwater (2001), Bureau of Meteorology rainfall and evaporation data and the proposed subdivision design provided by Taylor Burrell Barnett.

---

[3] Rainfall based on the average annual rainfall for Perth Airport over the period 1995 to 2005

The assumptions used here are based on post-water restriction potable water use statistics with an average ex-house water use of 424.7L/house/day (J. Brennan, Water Corporation, personal communication). These statistics were used because it appears unlikely that the restrictions will be lifted in the short to medium term (i.e. next five years), during which time the development will take place. Ex-house water use in the development is also likely to be relatively low because of the small average lot size (404m^2), which will lead to smaller gardens and the expectation that all landscaping packages provided will be of a low water use variety.

Scenario 1 – Conventional Development

The first scenario run was a conventional scenario, which represents a typical development on the site. This scenario assumes that development on the site is not Waterwise. A third of the households are considered to use bore water for irrigation (based on P. Coghlan, Water Corporation, pers. Comm.) and all the public open space is irrigated using bore water. Under this scenario, 260ML/yr of water is discharged to groundwater and surface water systems. 55ML/yr of groundwater is abstracted for irrigation. This gives net recharge to ground and surface water systems of 206ML/yr, which is 206% of the pre-development recharge rate. This increase in recharge rate is due to increased areas of hard surfaces that have high runoff coefficients and the addition of potable water to gardens.

Scenario 2 – Waterwise Development with Rainwater for Toilet Flushing

The use of rainwater for the flushing of toilets has been suggested as a relatively easy way to reduce potable water use (GHD, 2005 b). In the average single residential dwelling, an average of 43kL/yr of potable water is used for toilet flushing.

By taking up this rainwater for toilet use in addition to shared bores, recharge to groundwater and surface water is reduced by 29ML/yr over the estate, and potable use decreased by the same amount. This is a reduction in potable water use of approximately 36kL/house/yr. Assuming that only a third of the households have bores, this results in a net recharge of approximately 122ML/yr, 122% of the pre-development recharge of groundwater and surface water. This indicates that there is the potential to use rainwater for toilet use on the site.

The model is a simple spreadsheet model and as such cannot distinguish between infiltration to groundwater and runoff that leaves the catchment. Results from the MUSIC model indicate that the average volume of surface water leaving the site is in the order of 5.5 to 8.5ML/yr, or less than 5% of rainfall. However, this does not take into account groundwater removed from the site through subsurface drainage, if this is chosen as a management option.

5.2.3 Discussion

Results of the surveys undertaken indicate that the additional volume of recharge due to hard surfaces and infiltration on site is more than adequate to allow bores to be used on site. The geology of the site encourages caution in the use of bores in the area.

The geology of the site indicates that there is generally less than 6m of sand present on the site above a clayey sand to sandy clay layer that forms the top of the Guildford formation and considerably less in many places. The Guildford Formation consists of lenses of material varying between sands and clays. Extraction bores in the Southern River area are generally drilled into sandy lenses within the Guildford Formation that can support adequate flow rates.

The potable water targets required for the ILWMP area can only be achieved through substituting ex-house potable water use with non-potable water and the use of either all Waterwise fittings in the house or plumbing rainwater tanks into toilets and possibly washing machines. The ex-house potable water use target can be achieved by either greywater systems or bores. Greywater systems are not feasible in areas of the site close to wetlands. The additional nitrogen and phosphorus added to the groundwater through greywater reuse may also make meeting groundwater quality targets in the area difficult.

An economic and legislative assessment of the shared bore option will also be undertaken. The shared bore proposal was discussed with Landgate, who indicated that the management of such a strata scheme would not be feasible. If the equipment broke down, there would be no legal way of ensuring that the individual householders paid their share of the electricity and repair costs. If the system broke down, it would be difficult to ensure that it was repaired and that repairs were paid for fairly. Such a system would also require a complex central control system similar to the system used at Brighton. Such complex control systems would be expensive for householders to fix. This system is therefore considered not to be feasible, therefore the alternative rainwater tanks and low water use garden system will be implemented. As the proposal was determined to be unfeasible, groundwater modelling of the bore system was not undertaken.

5.3 FIT FOR PURPOSE WATER CONSERVATION STRATEGY

Water management in the Southern River area requires the development of a “fit for purpose” water strategy that minimises the use of potable water and production wastewater within the subdivision. Based on the work discussed above, the fit for purpose water strategy for Sub-precinct 3A(1) will be based on a core platform of:

- mandatory Waterwise fittings for all houses;

- houses to be provided with landscaping packages that include a limited amount of lawn to be underlain by soil amendments to retain moisture and nutrients. All landscaping packages provided will be of a low water use variety; and

- Public Open Space treatments will be low water use. Irrigation of the POS will be controlled by moisture sensors to minimise water use. A minimal turf approach including areas of local native plantings will be developed in consultation with the City of Gosnells when the POS is designed (Figure 15).

- provision of free rainwater tanks to households, with design covenants requiring them to be plumbed into toilets and/or laundries.

The second stage of the Department of Housing and Works' Five Star Plus scheme is expected to be mandated in late 2008. This will require that all new houses are plumbed in a manner that makes it easy for householders to install rainwater tanks and other alternative water supplies. The basic implementation of the rainwater tank scheme is therefore expected to be:

- Households will be provided with a top-up rebate to cover the cost of a rainwater tank, up to a maximum of 5kL, by the developer. This rebate will top up the current government rebate for rainwater tanks. The top-up rebate plus the government rebate will cover 100% of the cost of the rainwater tank.

- Plumbing the tank into the toilet and/or laundries will be mandated through the use of design covenants on the housing. Information will be provided on how to plumb the tanks into household toilets and/or laundries. The standards for this will be based on the guidelines alternative water supplies provided by the Department of Health.

5.4 WATER INFRASTRUCTURE

5.4.1 Potable Water Infrastructure

A standard condition of subdivision will require all lots to be serviced by a water reticulation system to be taken over and operated by the Water Corporation.

The Water Corporation has advised that the site can be serviced for water reticulation by an extension from the existing 400mm diameter water distribution main at Chamberlain Street, along Southern River Rd to the entry of the proposed development. The extension of the DN400 distribution main is to be prefunded by the developer and these costs are refunded by the Water Corporation as per a Prefunding Agreement.

The Civil Group advise that standard water reticulation mains are to be extended from the distribution main.

5.4.2 Wastewater Infrastructure

A standard condition of subdivision will require all lots to be serviced by a sewer reticulation system to be taken over and operated by the Water Corporation.

The Water Corporation advises that the sewer planning for this sewer catchment has been completed. This development is to be served by a reticulated gravity system draining to a permanent sewer pump station called Ballanup Wastewater Pump Station C. This is proposed to pump to a number of proposed permanent pump stations which eventually pump to the major wastewater transfer station at Waterworks Road, Brookdale.

5.5 WORK REQUIRED

Further work required at the Urban Water Management Plan (UWMP) stage will demonstrate how the chosen water conservation strategy will be implemented.

6 STORMWATER MANAGEMENT STRATEGY

6.1 FLOW AND FLOOD MANAGEMENT

Stormwater flow and flood management in Sub-precinct 3A has been undertaken through a series of swales and living streams that eventually discharge into Southern River. The site is separate from the Forrestdale Main Drain. The current 1 in 100 year flood plain for the Forrestdale MD does not enter the site but lies directly to the south of the site, along the southern boundary of Matison Street (Figure 10). The Forrestdale MD is currently being investigated by Water Corporation and GHD as part of the Southern River Arterial Drainage Scheme (ADS) (Water Corporation, 2007b). Water Corporation advises that the Scheme does not propose to upgrade the Forrestdale MD downstream of Holmes Street and therefore the existing floodplain and hydrologic regime of the area should remain unchanged (Water Corporation, 2007b). Based on this advice, surface water flows into the wetland to the south of Matison Street will be maintained at pre-development levels.

Drainage design has been undertaken for the whole of Sub-Precinct 3A, as the flow paths for the catchment areas outside Sub-Precinct 3A(1) will flow through the 3A(1) area, in line with the *Interim Forrestdale Main Drain Arterial Drainage Scheme* (Water Corporation, 2007b).

Flows in Sub-precinct 3A will be managed to the pre-development flow rate for events up to and including the 1 in 100 year ARI event through the use of swales, water garden bioretention systems and detention storages.

6.1.1 Post Development Flow Management

Storage Volumes

The 100-year peak flow volumes calculated by The Civil Group represent the estimated pre-development 1 in 100 year flow rates. By limiting post-development 1 in 100 year flood outflows to less than these flow rates, the development will meet the requirements of Water Corporation and Department of Water with respect to post-development flow rates. To cope with this, the Actual Storage Volumes provided within the preliminary plan are provided in Table 8:

Table 8: Required Flood Volumes for the Catchments in the Site

	C1	**C2**	**C3 & C5 (joined catchment)**	**C4**
Rural 100 year				
Peak Flow	0.557	2.283	1.626	1.203
Urban 100 year				
Peak Flow Out	1.564	0.289	0.184	0.176
Stored Volume	300	11883	8884	4919
Rural 5 year				
Peak Flow	0.143	0.786	0.563	0.42
Urban 5 year				
Peak Flow In	0.276	1.357	0.872	0.686
Peak Flow Out	0.054	0.086	0.084	0.069
Stored Volume	237	2379	1233	922

The drainage system on the site proposes to manage the drainage through a mixture of swales, bioretention systems and drainage basins in the Public Open Space. A combination of the swales and roadways are to be used to convey major stormwater events to the POS areas. Storage will be provided in both the POS and swales within the road reserves. As per standard design we have also allowed for some additional minor storage of the 1 in 100 year event in the low points of the local streets to provide additional storage. Where this occurs the habitable floor levels are to be 0.5m above the ponding level. The total storage volumes and swales are shown in Table 9.

Table 9: Volumes of Storage Provided in the Plan

	C1	**C2**	**C3**	**C4**	**C5**
Length of swale (m)	220	1600	320	460	360
Swale storage (m^3)	184	1344	269	386	302
Water garden storage (m^3)	0	63	63	63	63
POS storage (m^3)	0	10071	1891	5000	5000
Additional Storage in the Road Reserves Surrounding the POS -100Year		1812	1200	0	793
Total Storage (m^3)	184	11478	2223	5449	5365

These volumes conform to the above requirements, except for Catchment C1. In the case of this catchment, only a very small area of the total natural catchment is located on site. This area has been identified in planning as a future commercial area. The commercial area is proposed to be located on the corner of Southern

River Road and Leslie Street, which is the lowest part of the catchment on site and therefore the best location for on-site storage. Locating storage in this area would involve moving the commercial area back from the corner. Moving the commercial area back from the corner would reduce its' functionality and appeal.

Where possible, for Catchment C1 the 1 in 1 year, 1 hour event is provided within the site but compensation for the 1 in 100 year event is likely to be located off site where it cannot be included further up in the catchment. Some storage is expected to be available within the road reserve of Southern River Road. Southern River Road is currently a two lane road that will be upgraded to four lanes by the council in future. An alignment for the road is yet to be determined in this area. When the alignment is determined, the potential for additional compensation in the road reserve will be reviewed. Discussions with the City of Gosnells indicate that they are amenable to this approach.

Further details of pipe, swale and basin sizes and flow rates are provided in Appendix H. The drainage design is shown in Figure 14.

Drainage Philosophy

The road, lot and POS levels are to be designed to allow a safe flood route and maintain a minimum clearance of 500mm between flood surface water levels and the habitable floor levels and important infrastructure. As part of the JDA UWMS report for this district (JDA, 2002) storage volumes have been modelled for each sub-catchment. The storage in the network of basins is designed so that discharge from the development does not exceed the capacity of the downstream drainage systems. Flows are compensated back to the pre-development rates at each point of outflow where possible. This is difficult in some locations because City of Gosnells' regulations require a minimum 300mm diameter pipe for drainage pipes leaving the site. The minimum flow rate for a 300mm pipe at a 1 in 300 grade is 55L/s, which is well above the predevelopment flow in some catchments. City of Gosnells has indicated that they are willing to consider a mixture of smaller inlet orifices combined with overflow baffles to control flows. The smaller orifices will control of flows to less than 55L/s, while the baffles allow for overflow to occur, preventing flooding should the orifice become blocked.

Street drainage is proposed to be directed to swales within the verge and water gardens within the POS for the storage and soakage of the 1 in 1 year event. It is proposed, via a planned grid pattern of streets, to allow road stormwater to flow down street gutters for up to 100m distance and discharge at the end of a street grid to a grassed swale that runs alongside the side verge of a connecting street. To avoid problems of crossovers over the swale, the street and lot pattern has been arranged so that side boundary fences, rather than front fences, abut the swales, except where blocks are rear loaded. On rear loaded blocks, swales will be allowed on the front of the house blocks provided that pedestrian access is provided to the front of the houses.

Swales will be constructed on roads with a minimum of 18m width except where one side of the road is Public Open Space and the swale forms part of the POS. If developers wish to use swales in narrower roads where POS is not present, consultation with the City of Gosnells will be required and Detailed Area Plans will be necessary. Indicative swale concept drawings are shown in Appendix J.

The only piped drainage proposed in the swale system is possible subsoil drainage beneath the swales, Side Entry Pits at the street corners with connecting pipes to the swales and pipes to cross over intersections for the swales. This system meets the criterion that all stormwater from the roads is to pass over a vegetated surface (ref. *Decision Process for Stormwater Management in WA*, Dept of Environment, 2005).

In roads with swales, non-drainage services will generally be laid on the side of the road opposite the swale. In the existing, 20m wide road reserves, services may be laid on both sides of the street. In the case of rear-loaded lots abutting the swale, the services may be placed in the laneway rather than the road containing the swale.

Lots are generally planned to front the opposite side of the street to the swales. By rotating the grid pattern to suit existing roads and features the streetscape can be planned to provide traffic calming, a pleasant outlook and reduce the length of streetscape with the swales and side boundary fences on one side. The swales' length and capacity are to be sized to allow storage and soakage of a 1 in 1 year event with overflow into the POS areas once the 1 in 1 year recurrence interval design has been exceeded. The catchment for each swale and the size of the swales are sized to suit the 1 in 1 year event for soakage (i.e. contained locally) within the swale. Where the layout means that volumes cannot be stored in the swale, storage has been provided through water garden bioretention systems in the POS.

The swales in the road reserve will generally have a nominal 600mm between the base or invert of the swale and the AAMGL. There are some situations where it will be greater than this. Swales are proposed to be 500mm to 600mm deep below the edge of road level with 1 in 4 to1 in 6 side slopes.

Dry detention basins will be used in the public open space. These will be effectively grassed or vegetated structures that will remain dry except following significant rainfall events (generally greater than 1 in 6 month ARI storms). . The basins will have their base above the AAMGL while maximising the capacity to accommodate extreme events within the space available. This design will allow the basins to dry out before summer to prevent midge and mosquito breeding. 1 in 5 year inundation levels for the basins are shown as hatched areas in the drainage design (Appendix J).

6.1.2 Response to Regulator Comments on Drainage Design

The drainage philosophy and infrastructure locations were discussed with of Department of Water and Water Corporation on 11 July 2006 and City of Gosnells on 14 July 2006. The Swan River Trust also commented on the Local Water Management Strategy and these comments were included in the minutes of the City of Gosnells meeting of 28 August 2007. There was general agreement on the drainage philosophy. The following issues were raised:

- Questions were raised about the impacts of overflow of the 1 in 100 year event from Catchments 4 and 5 into the Conservation Category Wetland and Forrestdale Main Drain (Water Corporation and Department of Water). This would be the current flow path for water from these catchments in extreme events. As the Water Corporation has indicated that flows in the Forrestdale Main Drain during extreme events will not change following development, it will be required that the flows into the wetland from Sub-precinct 3A are also unchanged. The *Forrestdale Arterial Drainage Strategy* (*Interim)* (Water Corporation, 2007b) also shows an overflow path from the western section of Sub-precinct 3A into the wetland in both options. The currently proposed flow lines for the 1 in 100 year event reflect this and are shown in the drainage design (Appendix J).

- Issues were raised by the City of Gosnells regarding with houses with side boundaries facing roads and road swales. The Council raised issues regarding the safety and aesthetics of this approach, where one side of the road will effectively be fenced. Proposed strategies to enhance security and aesthetics, such as requiring lots to overlook the swales, will be addressed by a Detailed Area Plan in the Urban Water Management Plan and Subdivision Application Stage.

- Both the City of Gosnells and Department of Water raised the question of whether the off-site section of drain along Leslie Street between Matison Street and Southern River should be piped or remain as a drain. This section of drain receives water from Catchment 2. The section is currently a narrow, steep-sided farm drain and would present a safety hazard in an urban environment. Making the drain safe would involve either piping the drain or purchasing land from landowners outside this sub-precinct to turn the drain into a living stream. Modelling has indicated that the water in the drain from Sub-precinct 3A will meet the required water quality standard and therefore it is considered that a living stream is not required in this area for this development. It is therefore proposed at this stage that this drain should ultimately be piped, but this may require negotiation between the council and DoW because the land is outside the area of influence of this development. The developers of Sub-precinct 3A(1) will contribute to the redevelopment of the drain whether it is changed to a pipe or living stream.

- Comments from the Swan River Trust include comments on the use of MUSIC and nutrients in groundwater. These comments are addressed in Sections 6.1.2 and 7.2.

A letter summarising the response to these issues can be found in Appendix A.

Drainage Structure Design and Maintenance

The design and maintenance of drainage structures was discussed in a meeting with City of Gosnells (CoG) on 26 February 2008. The following points were agreed on in that meeting:

- Road swales would be grassed and irrigated and managed by the City of Gosnells to avoid landowners fertilising and/or filling in the swales. The City prefers grass to mulched vegetation because of concerns regarding mulch and silt building up in the swales and blocking swales and drains.
- A Special Area Rate should be considered for be Sub-precinct 3A(1) for the maintenance of swales.
- Swales are not expected to need as much irrigation as the parks as they will concentrate rainfall from the roads. The swale irrigation should therefore be on a separate irrigation program.
- Path access shall be provided for lots fronting onto swales.
- Areas of POS that will be inundated in the 1 in 1 year event shall be planted with reeds and rushes. Subsoil drainage shall be provided in these areas to avoid water lying in parks.
- CoG has a preference for useable Public Open Space. Areas that will be inundated in events between the 1 in 1 and 1 in 10 year ARI should be grassed with trees to minimise maintenance issues and ensure that active POS is provided. Verges and areas that are not subject to inundation may be mulched with natives, grassed or paved as appropriate. Paving should be where appropriate (eg near playgrounds, picnic tables gazebos) and not used indiscriminately.
- CoG indicated that vehicles accessing swales and parks is an issue where ‘kerbless’ roads are used. CoG’s preference is to avoid bollards as they are seen as causing mowing and other maintenance issues. Instead, it was agreed that kerbed roads with flush points every 5 meters to allow water into the parks would be used on the edges of POS.

- Consideration should be given to providing measures to prevent sand entering the swales during the construction period.

6.1.3 Post Development Water Quality Management

Proposed Best Management Practices (BMPs)

Best management practices proposed for the site include swales, bioretention systems and dry detention basins. These are some of the commonly used BMPs in the Metropolitan Area and are detailed in Chapter 9 of the DoW's *Stormwater Manual for Western Australia.* Gross pollutant traps may also be used in areas that are expected to have high gross pollutant loads, such as car parks. While the area is not proposed for heavy industry, specific systems such as grease arrestors may be required for petrol stations or other land uses with high pollutant loads.

Grassed swales will be used for road verges throughout the estate. Swales will be placed in verges to the side boundary of lots where they will not be interrupted by driveways. Roads will either be designed to be angled towards the swale (Figure 15). Due to the width of the swale, road reserves containing swales will be a minimum of 18m wide. Where possible, road verges with swales should be managed and irrigated by the council to prevent householders considering them as part of their land and filling in or applying fertiliser to the swales.

Water gardens are a form of bioretention system and will be used in the POS to retain the 1 in 1 year flow where swales are unsuitable due to road design constraints. Bioretention systems consist of a swale like structure with a trench filled with high permeability, sandy soil located underneath. This sandy layer contains a geofabric coated porous underdrain (Figure 16). This structure allows rainwater to filter through the sand and gravel layer into the underdrain. This process removes nutrients and sediments from stormwater. There is the potential for enhanced infiltration of water from the bioretention system into the soil, or for the underdrain to act as the subsurface drain to control groundwater levels. Bioretention systems can be used with a range of vegetation, including trees, grass and native vegetation. It is proposed to use native sedges and rushes in the rain gardens. Water gardens have been used successfully in Brookland Grove and Ascot.

The swales and bioretention systems in the road reserve will generally have nominally 500mm between the base or invert of the swale and the AAMGL, although this is likely to be greater where depths to groundwater are greater. There are some situations where it will be greater than this. Swales are proposed to be approximately 300mm deep below the edge of road level, 1m base width and 1 in 4 to 1 in 6 side slopes. The vegetated detention basins in the POS are expected to have bases on or in the AAMGL.

Dry detention basins consist of normally dry basins that are used to retain stormwater. As well as a nutrient stripping function, they are designed to reduce flow rates out of the catchment in larger storm events. In this area, basins will generally be designed as relatively flat areas that are useful as public open space as well as providing for retention of stormwater.

Results of MUSIC Modelling

MUSIC modelling was undertaken to assess whether the proposed BMPs could meet the water quality targets outlined in Section 4.3. The development was modelled as five catchments, as per the current drainage design. Modelling assumptions are given in Appendix K. Modelling for the site was undertaken in discussion with Christian Zammitt of the Department of Water who developed the MUSIC model for the Southern River area. The model was undertaken in line with guidelines for MUSIC modelling developed by GHD for the Water Corporation (GHD, 2007) and with the advice of Christian Zammitt.

Because the detailed design of the area has not yet been undertaken, the work was based on the preliminary design developed by The Civil Group.

The designed system was modelled with as bioretention systems for the swales and water gardens, as this allows for the use of an under drain. The detention systems were modelled as ephemeral ponds.

Table 10: Results of the MUSIC Modelling Runs Undertaken. Earlier runs were undertaken prior to these guidelines being produced and thus did not take them into account

Run Name	Assumed Infiltration Rate (mm/hr)	% TSS reduction	% TP reduction	% TN reduction	% Gross Pollutant reduction
ILWMP Criteria	**N/A**	**80**	**60**	**45**	**70**
April 08 V2	0.36	97	83	72	100

An infiltration rate of 0.36mm/hr was chosen as a worst case scenario to reflect the potential effects of high groundwater levels on infiltration. This is a worst case scenario for nutrient reduction in surface water discharge because a low infiltration rate means less water (and hence nutrients) infiltrating and hence more leaving the site as surface water. This infiltration rate is equivalent to a system with a medium to heavy clay base, or low infiltration rates due to high groundwater levels. It is likely that the base of the swales will be in materials ranging between sandy clay and sand, which would have an infiltration rate of 3.6 to 360mm/hr, according to MUSIC. The results of the MUSIC modelling are shown in Table 12.

The results show that even with a very limited infiltration rate of 0.36mm/hr, indicates that the modelled water quality complies with the requirements of the ILWMP while using the BMP performance factors supplied by GHD (2006) (Table 12). Further details of the MUSIC modelling, including a summary of the model, are shown in Appendix K.

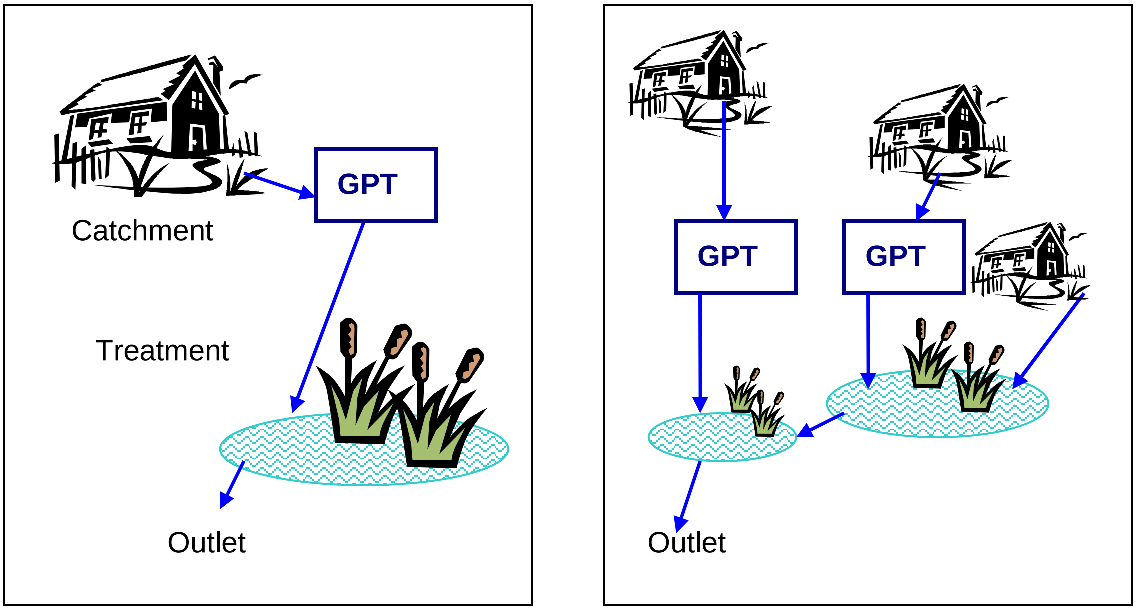


Figure 17: The Difference Between a 'Lumped' Model (left) and a 'Network' Model (right). In both cases, the catchment area and total size of the treatment structures is the same.

Modelling was initially undertaken with a lumped catchment model, as opposed to a network model. A lumped model is a model that contains all of the elements of the water treatment process lumped together and is thus easier to run (Figure 17). So all the basins in the catchment are considered as one basin, and all the swales as one swale. In a network model, the model would be broken down so that the individual swales and basins had their own catchments that reflect the structure of the catchment.

To determine whether the lumped model was accurate, a network model was developed for Catchment 4. The results from the detailed network model were then compared to the lumped model for that catchment. Results from the network model of Catchment 4 were within 0.5% of the results from the lumped model of the same catchment. This indicates that the lumped model is sufficiently accurate for this stage of work.

It is understood from the Swan River Trust's response to the Town Planning Scheme amendment that the Trust is concerned that MUSIC has not been calibrated for Swan Coastal Plain conditions in that it does not model the interactions between surface water and groundwater and has not been fully calibrated for the Swan Coastal Plain.

MUSIC was used for this LWMS based on advice from the Department of Water and was used in compliance with their criteria and the criteria developed by Water Corporation for the use of MUSIC, including the way that the BMPs are modelled. The DoW at the time agreed that they had calibrated MUSIC for the Southern River area and the project team used the DoW's calibration methods in the model. We agree that there is limited data on which to base the model on, but this is due to a limit on the data that has been gathered regarding BMP performance on the Swan Coastal Plain (SCP). This is an acknowledged constraint for all stormwater models and all developments on the SCP. MUSIC was used it is the only commercially available model that will model whether the development meets the Southern River Design Criteria for Water Quality Management.

The BMPs used by the development comply with the DoW's Stormwater Management Manual for Western Australia and as such can be considered as 'Best Practice'. The system used for the site was first designed without using MUSIC, before checking whether it would meet the Water Quality Management criteria. MUSIC indicated that the stormwater system would comply with the guidelines. The use of MUSIC therefore did not alter the design of the stormwater system for the site.

6.2 IMPACT ON WATER DEPENDANT ECOSYSTEMS

The main water dependant ecosystem in the area is the conservation category wetland to the south of Matison Street. Inspection of the site indicates that it is unlikely that surface water from the site enters the Matison Street wetland, except during extreme rainfall events. The surface soils in the area are sandy and would not support surface runoff except during extreme events. In addition, Matison Street is slightly raised, which would further prevent surface water runoff. This wetland is therefore not generally directly surface water dependant but may receive direct surface water from the site in extreme rainfall events. The wetland will receive groundwater from the site.

It is not proposed to directly drain water across Matison Street and into the wetland. Some overflow of water will occur from C3 and C4 during the 1 in 100 year flood event. These flow volumes will be limited to the pre-development 1 in 100 year flood peak flow rate, as developed by JDA (2002).

Water levels in the Matison Street wetland will be more impacted by the Forrestdale Main Drain (MD) and backflow from Southern River than by water from this site during the 1 in 100 year event (Helen Brookes, GHD, pers. comm.). This is due to backflow from Southern River into the wetland. An assessment of the impact of urbanisation on floods in the Forrestdale MD is currently being undertaken by GHD.

An assessment of the environmental impact of changes to water levels in the drain and associated flooding on the wetlands is also being undertaken. Once these studies and the CoG vegetation report are finalised, the net hydrological and botanical impact of the 1 in 100 year event flow on the wetland will be assessed.

7 GROUNDWATER MANAGEMENT STRATEGY

7.1 CONTROLLED GROUNDWATER LEVELS AND FILL

In appreciation of the shallow depth to groundwater in parts of the site, the use of controlled groundwater levels and/or fill is considered likely in some areas of the site. Given our current understanding of groundwater levels and the relationship of the site to the Conservation Category Wetland, it is considered that subsoil drainage could be provided at the Annual Average Maximum Groundwater Level (AAMGL) and ensure that a 1.5m separation is provided between the AAMGL and housing. Preliminary planning for this concept has been undertaken through the use of AAMGLs developed by JDA (2002).

It is recognised that fill is also required over much of the north of the site, and the area around the conservation category wetland. Some of this material may be able to be provided from cut material from other parts of the site.

7.1.1 Groundwater Impact on Water Dependent Ecosystems

The impact of the development on the groundwater dependant ecosystems to the south of the site will depend on two factors:

- the change in groundwater levels (both maxima and minima) associated with the development; and
- the vegetation associated with those wetlands and the tolerance of the vegetation to groundwater level changes.

Groundwater levels may:

- decrease due to increased abstraction of groundwater for irrigation in summer;
- decrease due to the control of groundwater levels through subsurface drainage in winter; and
- increase due to infiltration of increased volumes of stormwater to groundwater.

This development proposes to minimise the impacts of development on groundwater levels by:

- only allowing the use of shallow groundwater for residential and POS irrigation if modelling can show that sufficient water is available and that this will not have a negative impact on the CCW;
- subsoil drains will not be laid below AAMGL unless modelling can show that this will not have a negative impact on the CCW; and

- infiltrating water as high in the catchment as possible to minimise impacts on the hydrology of the CCW.

7.2 GROUNDWATER QUALITY

7.2.1 Former Poultry Farms

The nutrient levels found in groundwater around the site are generally above the Swan Canning Catchment Clean Up Criteria. Elevated nutrient levels are not uncommon in areas of Bassendean sand where agriculture has occurred. The only evidence of potential contamination from a chicken farm is the elevated phosphorus concentration in MWC, down-gradient of the former broiler farm (Section 3.4.2). This bore is located in a paddock used for relatively intensive horse agistment and the elevated result could be due to horse excretions instead of the historical use as chicken farm. While this indicates that there is some potential for nutrient transport off the site, further work is required to identify whether this is a single value or indicative of contamination.

The poultry farms are currently the subject of Preliminary Site Investigations that will address the potential for contamination (including nutrients) on the site in expectation of a condition of subdivision requiring the investigation of the site, as is the common process for potentially contaminated sites. The process includes an assessment of the risk of contaminants being mobilised and leaving the site will be undertaken. Remediation will be undertaken if required by the DEC and the auditor. The process is and will be undertaken in line with the requirements of the DEC and the *Contaminated Sites Act* (2003). As part of the remediation of these sites, the top 300mm of soil, which is considered likely to contain most of the stored nutrients and contaminants, will be removed.

7.2.2 Best Management Practices for Groundwater Quality

The best way to manage groundwater quality is to avoid nutrients entering groundwater from fertilisers, via either direct infiltration or through stormwater. The stormwater aspect is managed through the use of nutrient stripping vegetation in swales and basins.

The direct infiltration issue is best resolved through minimising fertiliser use. This will be undertaken by not fertilising Public Open Space and swales managed by the Shire and through the landscaping packages provided to residents. As part of the development, landscaping packages will be provided and these should attempt to minimise fertiliser use. These landscaping packages will be required to include:

- a high Phosphorus Retention Index soil amendment to bind phosphorus to the soil and prevent leaching;

- a minimal area of lawn, with the aim of minimising water and fertiliser use; and
- information about low fertiliser use gardening.

The compliance of the landscaping package with these guidelines should be assessed as part of the UWMP.

8 WETLANDS AND ENVIRONMENTAL WATER REQUIREMENTS

The predominant wetland of concern that may be affected by the site is the Conservation Category Wetland (CCW) to the south of the site. While much of the site is classified as Multiple Use wetland, the area has been cleared and used for farming for decades. The DEC generally considers that Multiple Use wetlands can be utilised for development objectives. The degraded nature of this wetland means that development is likely to be acceptable.

The CCW extends along the Forrestdale Main Drain. The wetland is currently in private ownership. Parts of the wetland lie within the current 1 in 100 year flood plain of the Main Drain. The Main Drain itself is currently subject to a study investigating the impact of urbanisation of the Southern River/Brookdale/Forrestdale/Wungong area on flood areas and vegetation. While the final report of this study is not available, most of the work has been undertaken and Water Corporation has provided advice on the outcomes (E. Sahouryeh and J. Wegner, personal communications). Based on this advice, surface water flows into the wetland to the south of Matison Street will be maintained at pre-development levels.

8.1 DETERMINATION OF ENVIRONMENTAL WATER REQUIREMENTS

Determination of Environmental Water Requirements (EWRs) for wetlands requires an understanding of the vegetation of the wetland and its' preferred hydrological conditions as well as the current and future hydrological regimes. The vegetation of the CCW has been documented in the City of Gosnells' environmental report for Precinct 3. The water dependence of this vegetation has been assessed as part of the Forrestdale Main Drain Arterial Drainage Study (the ADS) at the request of the Department of Water. ENV has undertaken the botanical component of this study, however, the findings are yet to be released.

As discussed in Sections 6.2 and 7.1.1, the hydrological impact of the development of Sub-precinct 3A(1) on the adjacent CCW is considered to be manageable in terms of surface water and groundwater. The drainage design maintains the current flood volumes up to the 1 in 100 year event.

8.2 ECOLOGICAL HEALTH MONITORING

The impact of development on the CCW to the south of the site needs to be considered in the context of other potential impacts to the site, including the impacts of the proposed ADS and associated developments upstream of the wetland and within Sub-precinct 3C, which contains the wetland. The potential impacts of the development of Sub-precinct 3A(1) on the wetland are considered small when compared to the potential impacts of the proposed drainage scheme and the development of the wider catchment.

A co-ordinated effort will be required to monitor the ecological health of the wetland. While this could be achieved through the ADS project, the author understands that this project will not be referred to the EPA and thus monitoring will not be set as a condition by the EPA. It is therefore suggested that the MoU group consider the issue of, and responsibilities for, monitoring of the CCW. It is accepted that such a program may require a pro-rata contribution from local developers. This is supported in principle provided that contributions are equitable.

8.3 REGIONAL WATER MANAGEMENT STRATEGY

A Regional Water Management Strategy (RWMS) has not yet been developed for Precinct 3. However, development on the site should be undertaken in line with the RWMS when this is produced. If the developer wishes to deviate from the RWMS, the reasons for this should be argued at the Urban Water Management Plan (UWMP) stage.

8.4 BUFFERS

The current boundary of the CCW to the south of the site is Matison Street itself. Where possible a 50m buffer has been provided by way of POS adjacent to Matison Street. Lot 20 currently has a house located within this buffer so the buffer at this stage does not continue into this area.

City of Gosnells has proposed a 100m buffer be provided to this wetland. The City's proposed buffer is informed by ENV's assessment of the wetland which confirmed its current classification as a CCW wetland and indicated that the wetland has high conservation value. It is understood that the 100m buffer proposed by the City was also based on advice provided by the Department of Environment and Conservation (City of Gosnells, 2006). The requirement for a 100m buffer to CCW wetlands is presented in the WAPC draft document, Guideline for the Determination of Wetland Buffer Requirements. Recent discussions regarding this document between ENV and the wetlands section of the Department of Environment and Conservation (DEC) have indicated that the buffer suggestions in the WAPC document are not representative of policy or practice and that a 50m buffer is the standard requirement by the DEC. Furthermore, in seeking clarification form the DEC on of the impact of cadastre boundaries and existing infrastructure such as roads on buffer requirements, the DEC has provided verbal advice that buffers are generally still required, however, in the circumstance of existing roads, a case by case consideration would be undertaken on whether the road's impact on important hydrological and ecological functions is such that the positive management benefit of a 50m buffer is effectively negated. In these circumstances consideration would be given to reducing the buffer requirement.

In the specific circumstance of Matison Street itself, whilst it currently represents a barrier to surface water movement, except in high rainfall events, it has been determined that the hydrological and ecological health of the wetland would be benefited by the provision of a 50m buffer, in which intensive land uses are not permitted. The buffer has been designed to maintain the pre development hydrological regime.

In considering the ultimate buffer distance, it should be remembered that, except in the circumstance where clearing of native vegetation is required, the prescription of wetland buffer distances is a function of State Government policy. DEC advice on buffer distances is simply that, advice, with the ultimate decision on final buffer distances resting with Local Governments.

9 MATTERS TO BE ADDRESSED IN THE UWMP

It is recognised that some of the work required for a study of this type was not available at the time of development. Because of this, additional work will be required at the Urban Water Management Plan stage. The work identified for the UWMP stage includes:

- more detailed surveys for acid sulphate soils where required;
- completion of soil and groundwater testing in line with the Contaminated Sites guidelines for the poultry farms (ongoing work);
- developing ecological water requirements for the CCW based on groundwater monitoring and modelling and work done on the Forrestdale Main Drain by Water Corporation with this development, including floodplains, 1 in 100 year flows and potential of development to mitigate impact of the Main Drain on the CCW (UWMP, when Forrestdale Main Drain and CSIRO Precinct Level model becomes available);
- additional work on wetland monitoring requirements and buffer definition for the Conservation Category Wetland to the south (UWMP);
- developing a system to ensure that all houses have rainwater tanks for toilet flushing and providing details of the landscaping package (UWMP);
- review potential for stormwater storage in the Southern River Road reserve (UWMP)
- a detailed post-development monitoring plan; and
- detailed area plan addressing the issue of houses with side boundaries facing roads and road swales (UWMP).

Other items needing to be addressed will be identified in consultation with the regulators following their preliminary review of this document.

10 FUTURE MONITORING AND MODELLING REQUIREMENTS

10.1 SURFACE WATER MONITORING AND MODELLING

Post-development surface water monitoring for a given subdivisional area will commence at practical completion of Stage 1 (i.e. completion of engineering lot construction) of the area covered by a specific UWMP. Monitoring will continue for three years on a similar basis to the pre-development monitoring. A post-development monitoring plan shall be provided in the Urban Water Management Plan. This will include identifying any opportunities for monitoring performance of the stormwater system in conjunction with CSIRO.

10.2 GROUNDWATER MONITORING AND MODELLING

Post-development groundwater monitoring for a given subdivisional area will commence at practical completion of Stage 1 (i.e. completion of engineering lot construction) of the area covered by a specific UWMP. Monitoring will continue for three years on a similar basis to the pre-development monitoring. A post-development monitoring plan shall be provided in the Urban Water Management Plan. This will include identifying any opportunities for monitoring performance of the stormwater system.

10.3 WETLAND MONITORING

The primary wetland of concern is the Conservation Category Wetland to the south of this site. Currently, groundwater level and quality monitoring is being undertaken from a bore within the road reserve adjacent to the wetland. As a minimum, this will be continued as part of the pre- and post-development groundwater monitoring program.

As indicated in Section 8.2, it is recommended that a coordinate monitoring effort is conducted over this wetland. A commitment is provided to contribute to this monitoring program.

11 IMPLEMENTATION

To be addressed following the preliminary regulator review of this document.

Table 11: Table of Responsibilities

Item	**Scheme Development**	**Interim Maintenance (First two years)**	**Long-term Maintenance**
Rainwater Tanks	Developer (residents to construct their own systems)	Residents	Residents
Landscaping Packages	Developer	Residents	Residents
Waterwise fittings	Developer (residents to construct their own systems)	Residents	Residents
Swales and drainage system	Developer	Developer	Council
Monitoring of the development	Developer	Developer for three years following practical completion of Stage 1.	Council
Monitoring of CCW to the south of the site	To be resolved through the MoU group with possible contributions from the developers of Sub-precinct 3A(1).		

12 SUMMARY

The objective of this LWMS is to design a development that manages the total water cycle in a sustainable manner. This includes water conservation, stormwater management, groundwater management and wetland management. Sub-precinct 3A(1) aims to manage these issues through the following initiatives.

Water Conservation

- Providing householders with rainwater tanks for toilet flushing and/or washing machines;
- Mandating the use of Waterwise fittings at construction;
- Providing Waterwise landscaping packages that include low water use gardens and soil amendments to minimise water and nutrient loss; and
- Minimising water use in Public Open Space through the use of low water use landscaping treatments and water efficient irrigation systems that are linked to soil moisture characteristics.

Stormwater Management

- Implementing a drainage design that limits the peak outflow from the development to pre-development levels through storage and infiltration on site;
- Designing basins such that the 1 in 100 year flood levels are 0.5m below residential floor levels**;**
- Including swales in the road reserve that store and infiltrate the 1 in 1 year event within the swale; and
- Implementing a stormwater system that the model indicates will meet the ILWMP targets for nitrogen and phosphorus reduction through the use of swales, living streams and bioretention systems.

Groundwater Management

- Allowing the use of controlled groundwater levels only where it can be demonstrated that these will not affect the Conservation Category Wetland to the south of the site;
- Filling and controlling groundwater levels at or above average annual maximum groundwater levels so that at least 1.5 m clearance is maintained between AAMGL and surface level on residential and commercial lots; and

- A commitment to further monitoring of groundwater quality on the site to determine whether historical practices have impacted on groundwater quality.

Wetland Management

Maintaining pre-development levels of flow into the wetland in 1 in 10 year storm event and limiting runoff in the 1 in 100 year storm to pre-development levels.

This Local Water Management Strategy demonstrates that the land can be developed without significant constraints. We are confident that the outstanding issues can be resolved at the Urban Water Management Plan stage to create a development that meets the goals and ideals of the Integrated Land and Water Management Planning process.

13 REFERENCES

Australian and New Zealand Environment and Conservation Council (2000) *National Water Quality Management Strategy: Australian and New Zealand guidelines for fresh and marine water quality.*

Coghlan, P. and Loh, M. (2003) *Domestic Water Use Study*

CSIRO (1999) *Urban Stormwater: Best Practice Environmental Guidelines* Prepared for the Stormwater Committee

Department of Environmental Protection (1996) *Land development sites and impacts on air quality: A guideline for the prevention of dust and smoke pollution from land development sites in Western Australia*.

Department of Health (2005) *Code of Practice for Reuse of Greywater in Western Australia*

ENV (2006) *Southern River Precinct 3: Environmental review*

Essential Environmental Services (2006) *Interim Approach for Integrating Urban Water Management with Land Use Planning within the Southern River Area*

Essential Environmental Services (18 September 2006) *Meeting Notes: Southern River Sub-Precinct 3A(1) Local Water Management Strategy*

Geological Survey of Western Australia (1986) *Armadale Part Sheets 2033 I and 2133 IV, Perth Metropolitan Region* 1:50 000 Environmental Geology Sheets.

GHD (2005 a) *Bletchley Park Local Water Management Strategy*

GHD (2005 b) *Non-potable Water Use: Guidelines for developers and their consultants* (draft)

GHD (2007) *MUSIC Guidelines for Perth*

Government of Western Australia (2003) *State Water Strategy*

Institution of Engineers, Australia (1987) *Australian Rainfall and Runoff*

JDA (2002) *Southern River/Forrestdale/Brookdale/Wungong Structure Plan: Urban Water Management Strategy*

JDA (2006) *Brookdale Redevelopment Master Plan: District Water Management Strategy*

Rockwater (2005) *Southern River Development Area: Groundwater modelling to assess effects of climatic variations and planned developments.*

Swan River Trust (undated) *Southern River*

Swan River Trust (1999) *Swan-Canning Cleanup Program: An Action Plan to clean up the Swan-Canning Rivers and Estuary. Water and Rivers Commission*

Water Authority of Western Australia (1987) *Perth Urban Water Balance Study*

Water Corporation (2006) *Nondrinking Water Factsheets Series*

Water Corporation (2007 a) *Southern River Interim Integrated Land and Water Management Plan*

Water Corporation (2007 b) *Forrestdale Main Drain Arterial Drainage Scheme (Interim)*

West Australian Planning Commission (2004) *Draft Water Resources Statement of Planning Policy*

West Australian Planning Commission (2003) *Planning Bulletin 64: Acid Sulphate Soils*

FIGURES

FIGURE 1 – Site Location

CLIENT: WRF Property Ltd

JOB NUMBER: 06.024

SCALE: NTS

DRAWN BY:JS

CHECKED BY: MD

DATE: 25/8/05

FIGURE 2: Subdivision Concept Plan

CLIENT: WRF Property Ltd

JOB NUMBER: 06.024

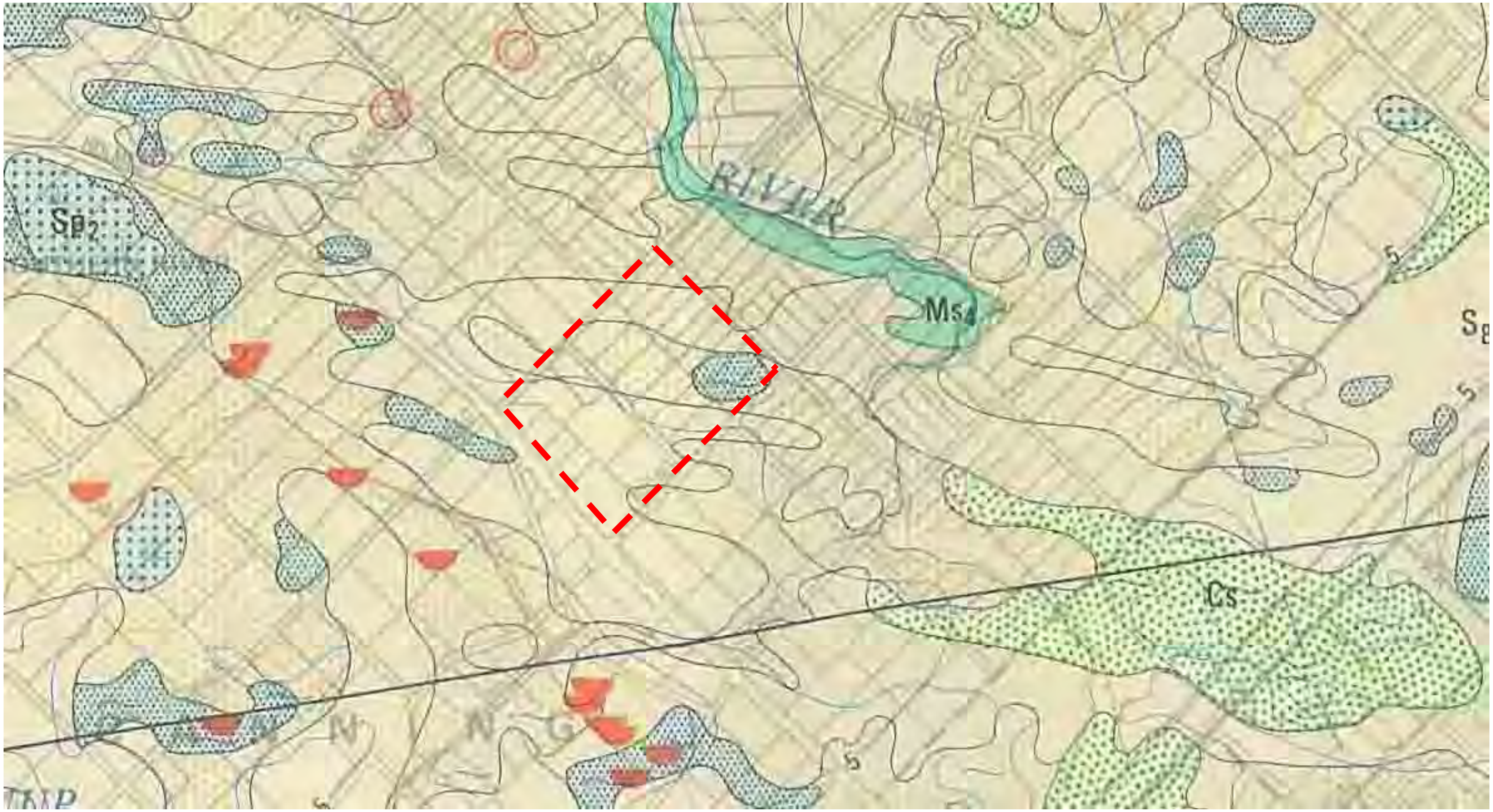
DATE: 20/3/08

DRAWN BY: MD

CHECKED BY: DN

SCALE: NTS

env Australia



Key

🟨 S8 – Bassendean Sand
▨ S10 – Bassendean Sand over Guildford Formation
🟦 SP1 – Peaty Sand

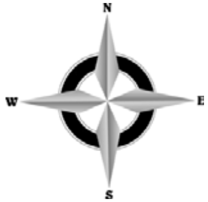


FIGURE 3: Geology

CLIENT: WRF Property Ltd	JOB NUMBER: 06.024	DRAWN BY: MD
DATE: 4/8/06		CHECKED BY:

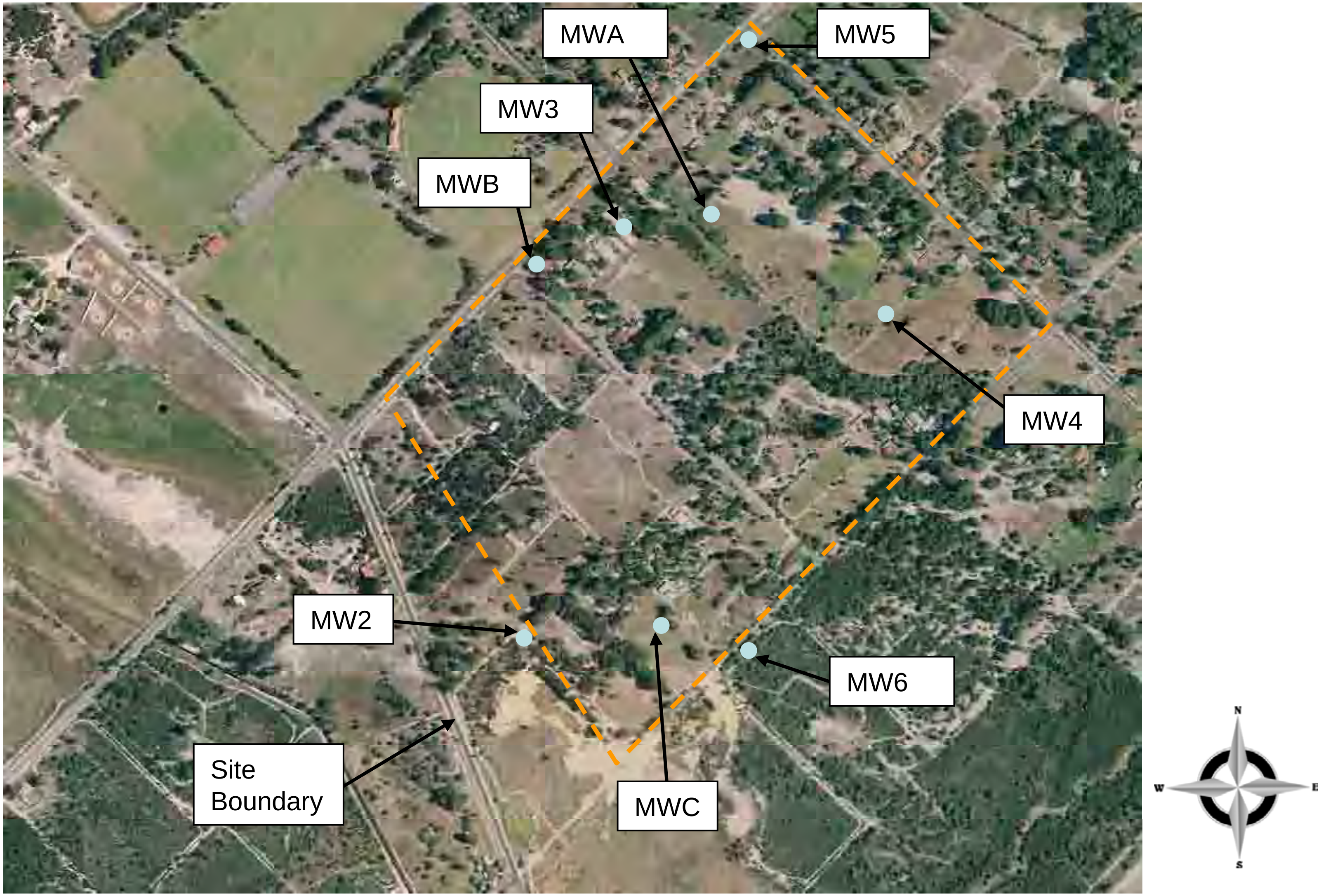


Figure 4: Monitoring Bore Locations

CLIENT: WRF Property Ltd	JOB NUMBER: 06.024	DRAWN BY: MD
DATE: 31/3/2008		CHECKED BY: DN

env Australia

Figure 5: Acid Sulphate Soils

CLIENT: WRF Property Ltd	JOB NUMBER: 06.024	DRAWN BY: DN
DATE: 31/3/2008		CHECKED BY: MD

Figure 6:Annual Average Maximum Groundwater Levels (AAMGLs) *From:* Southern River/Forrestdale/Brookdale/Wungong Structure Plan UWMS (JDA, 2002)

CLIENT: WRF Property Ltd

JOB NUMBER: 06.024

DRAWN BY: MD

DATE: 4/8/2006

CHECKED BY: DN

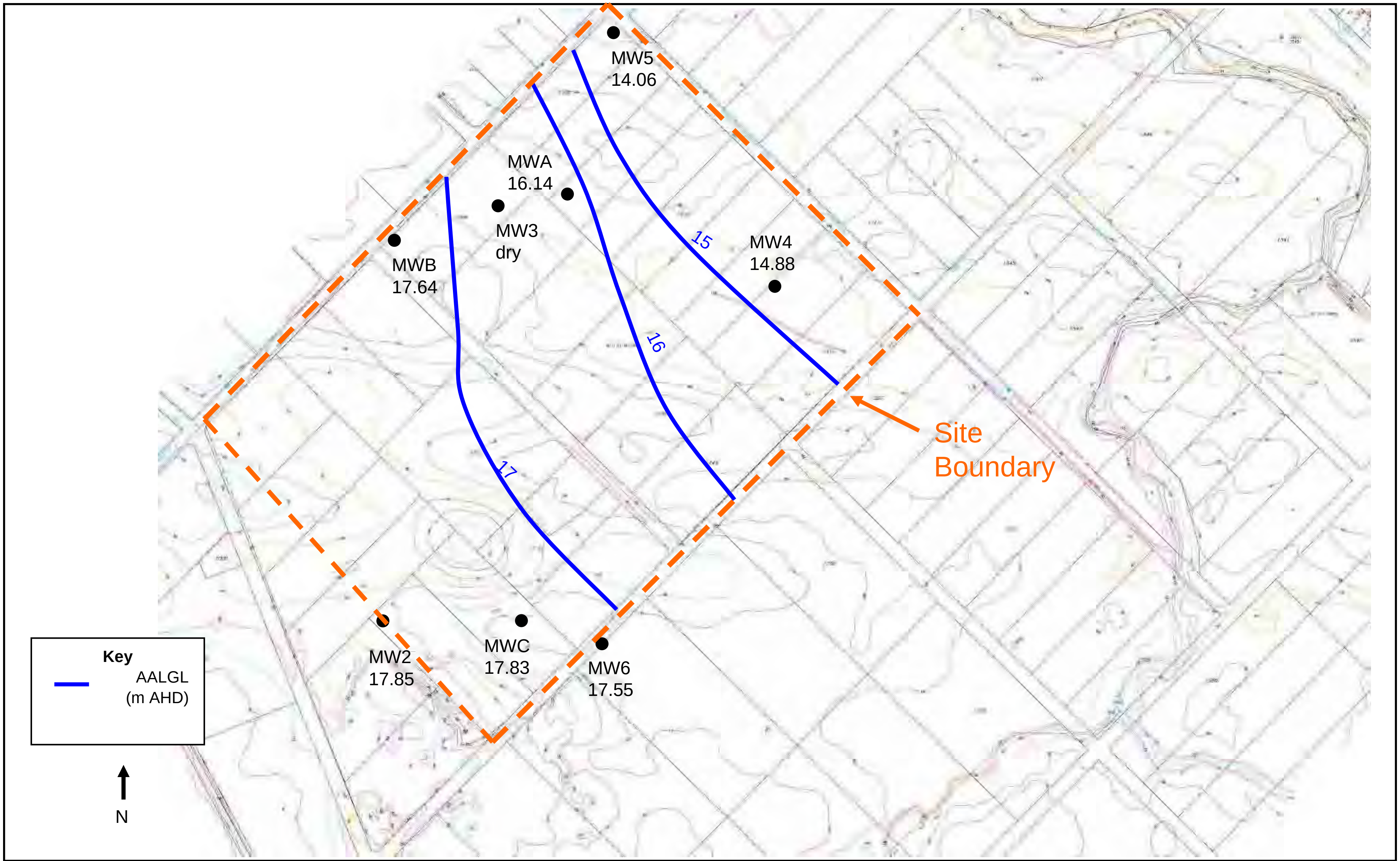
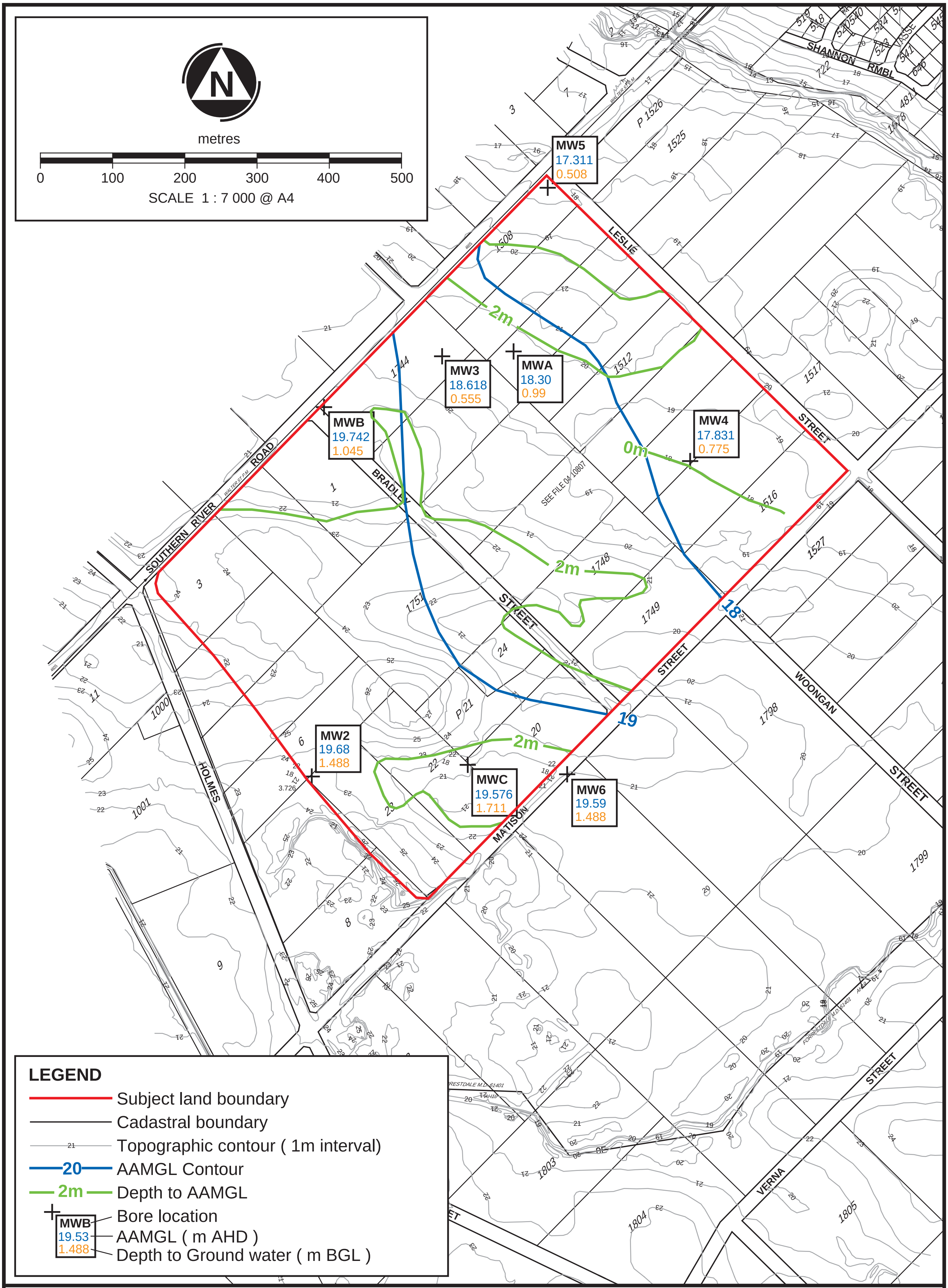


Figure 7: Annual Average Lowest Groundwater Levels. All values and contours in m AHD.

CLIENT: WRF Property Ltd	JOB NUMBER: 06.024	DRAWN BY: MD
DATE: 2/8/2006		CHECKED BY: DN

PRINTED: Mon 07 Apr 08



LEGEND

▬	Subject land boundary
▬	Cadastral boundary
21	Topographic contour (1m interval)
20	AAMGL Contour
2m	Depth to AAMGL
+	Bore location
MWB	
19.53	AAMGL (m AHD)
1.488	Depth to Ground water (m BGL)

07-084-AAMGL.dgn
DATUM: MGA50
DRAWN: TE 7-04-08
AUTHOR: MD 7-04-08

Topography and cadastre supplied by: SICAD, 2006

WRF PROPERTY PTY LTD
SOUTHERN RIVER PRECINCT 3A
AVERAGE ANNUAL MAXIMUM
GROUNDWATER LEVELS
FIGURE 8

env
Australia

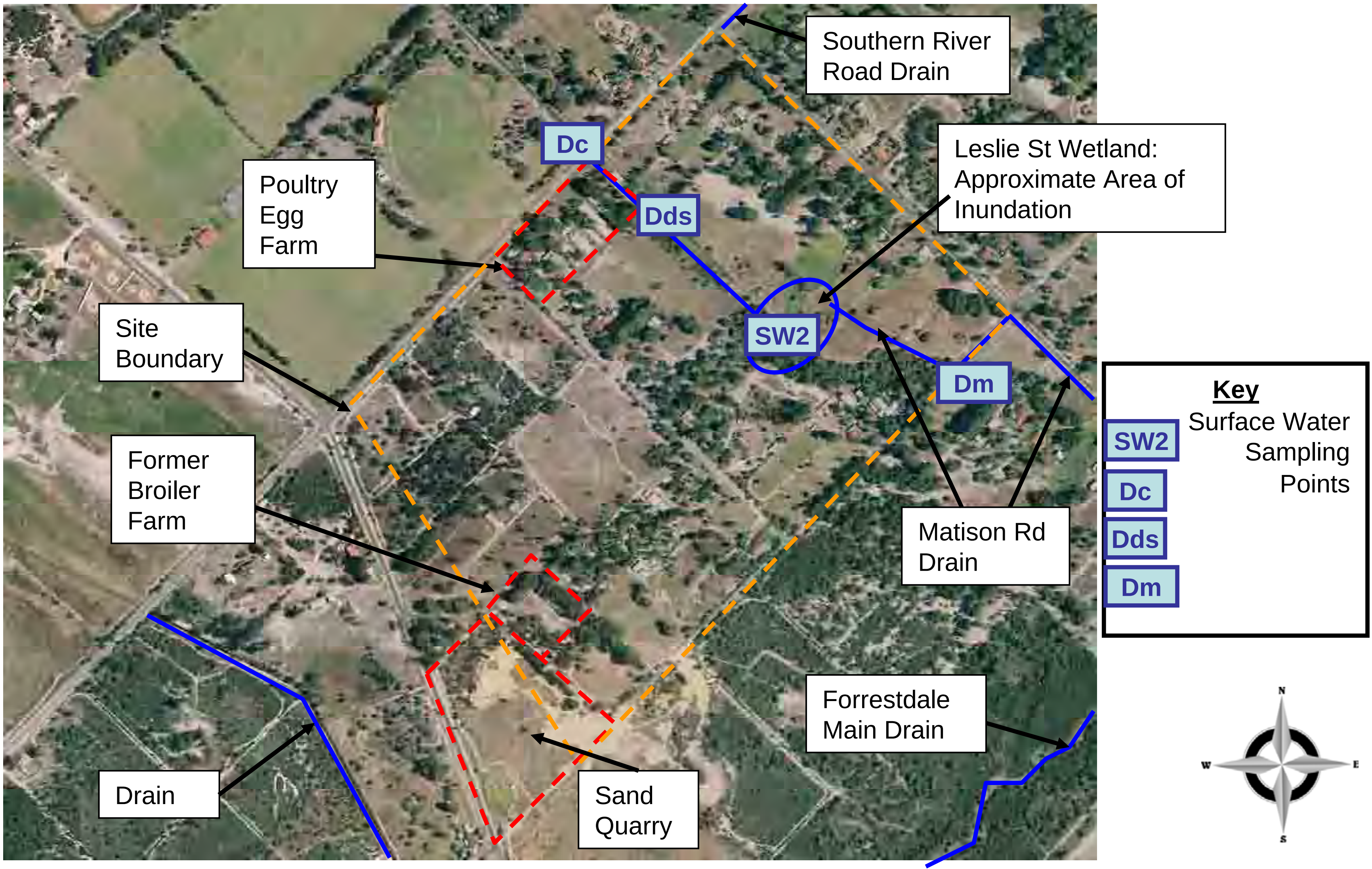
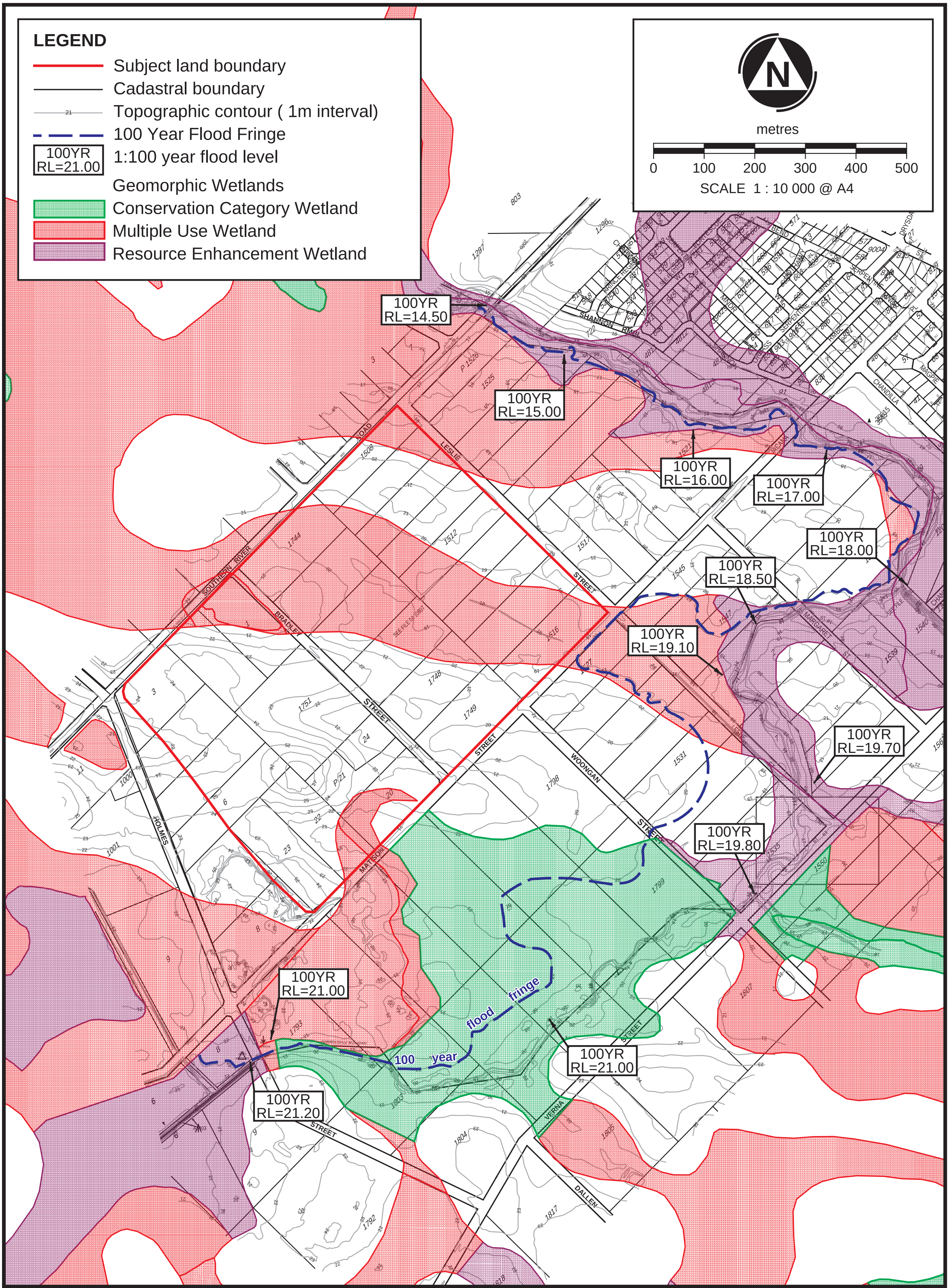


Figure 9: Drainage Features

CLIENT: WRF Property Ltd	JOB NUMBER: 06.024	DRAWN BY: MD
DATE: 31/3/2008		CHECKED BY: KL

PRINTED: Mon 07 Apr 08



06-024-F12.dgn
DATUM: MGA50
DRAWN: TE 1-03-08
AUTHOR: MD 1-03-08

Topography and cadastre supplied by: SICAD, 2006

WRF PROPERTY PTY LTD
SOUTHERN RIVER PRECINCT 3A

GEOMORPHIC WETLANDS OF THE SWAN COASTAL PLAIN

FIGURE 10

env Australia

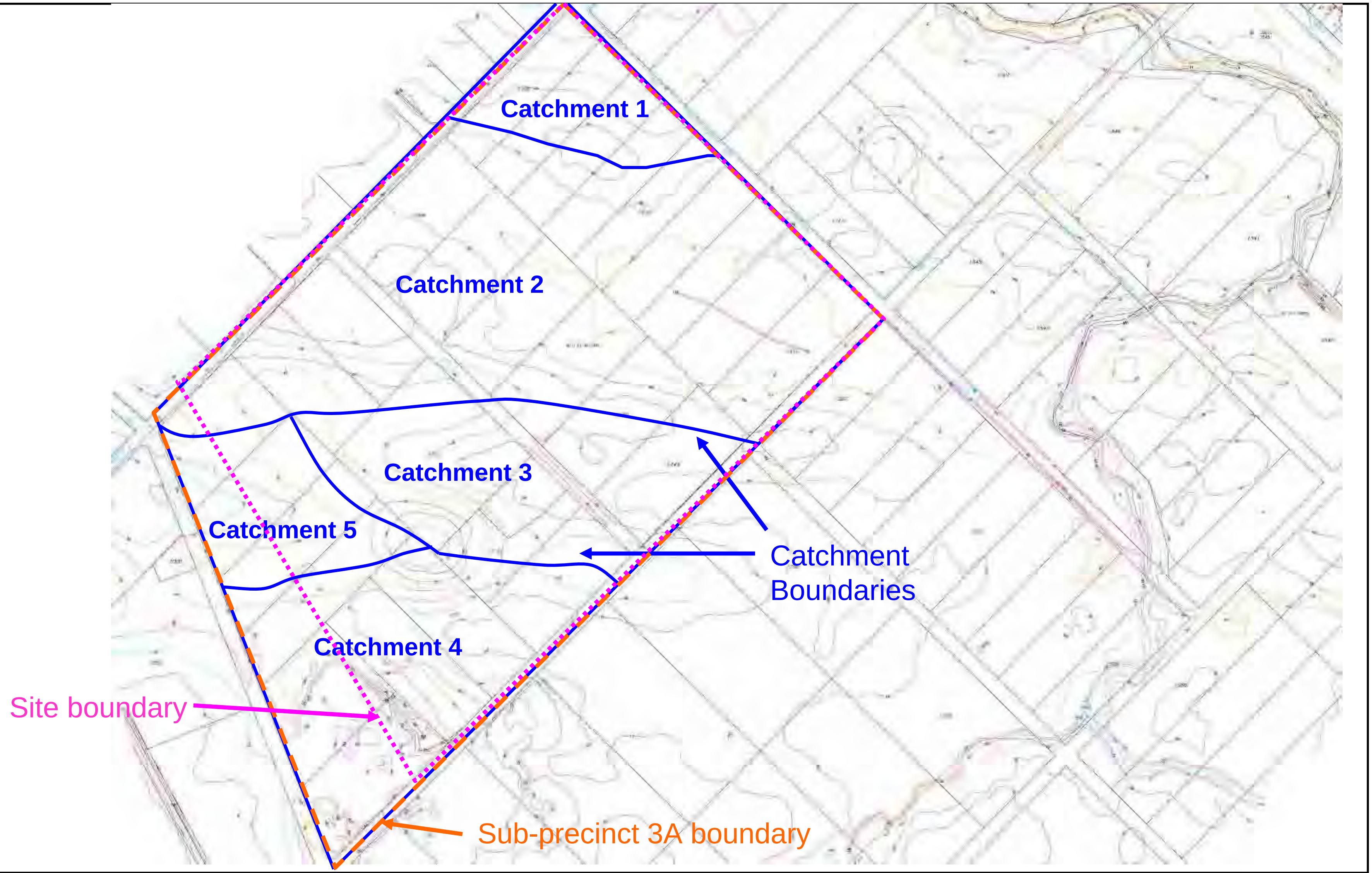


Figure 11 : Current Catchment Boundaries

CLIENT: WRF Property Ltd

JOB NUMBER : 06.024

DRAWN BY: MD

DATE: 31/3/2008

CHECKED BY: KL

env Australia

🟪 **Pristine - P**
Pristine or nearly so, no obvious signs of disturbance

🟩 **Excellent - E**
Vegetation structure intact, disturbance affecting individual species and weeds are non-aggressive species.

🟨 **Very Good - VG**
Vegetation structure altered, obvious signs of disturbance.
For example, disturbance to vegetation structure caused by repeated fires, the presence of some more aggressive weeds, dieback, logging and grazing.

🟨 **Good - G**
Vegetation structure significantly altered by very obvious signs of multiple disturbance. Retains basic vegetation structure or ability to regenerate it.
For example, disturbance to vegetation structure caused by very frequent fires, the presence of some very aggressive weeds at high density, partial clearing, dieback and grazing.

🟨 **Degraded - D**
Basic vegetation structure severely impacted by disturbance. Scope for regeneration but not to a state approaching good condition without intensive management.
For example, disturbance to vegetation structure caused by very frequent fires, the presence of very aggressive weeds, partial clearing, dieback and grazing.

🟥 **Completely Degraded - CD**
The structure of the vegetation is no longer intact and the area is completely or almost completely without native species. These areas are often described as 'parkland cleared' with the flora comprising weed or crop species with isolated native trees or shrubs.

NOTES

Base cadastral, land ownership and aerial photography used on this project supplied by City of Gosnells

Aerial photography based on the ECW files generated by DOLA of the Dec 2001/Jan 2002 aerial photography.

Bush Forever details supplied by Department of Planning and Infrastructure in June 2002

N

Client: WRF Property Pty Ltd

Project: Southern River Precinct 3A LWMS

FIGURE 12: Vegetation Condition Mapping (from ENV, 2006)

Job No:06.024

Drawn By: MD (31/3/2008)

Checked By: MD (31/3/2008)

Scale: NTS

env

PRINTED: Mon 07 Apr 08

LEGEND

▬ ▬ ▬	CATCHMENT BOUNDARY
—·—·—	SWALES (1 YEAR)
⊗	WATER GARDENS (1 YEAR)
🟪	LOCAL CATCHMENT BOUNDARIES
▭	PUBLIC OPEN SPACE
▨	DRAINAGE STORAGE (5 YEAR)
23.0	MIN. FILL LEVELS
19•58	MAX. GWL SPOT LEVELS
19.0	MAX. GWL CONTOURS
→	FLOW DIRECTION
•—•	PIPE DRAIN & JUNCTION PIT
○	CCW WETLANDS
C4	CATCHMENT

NOTES:

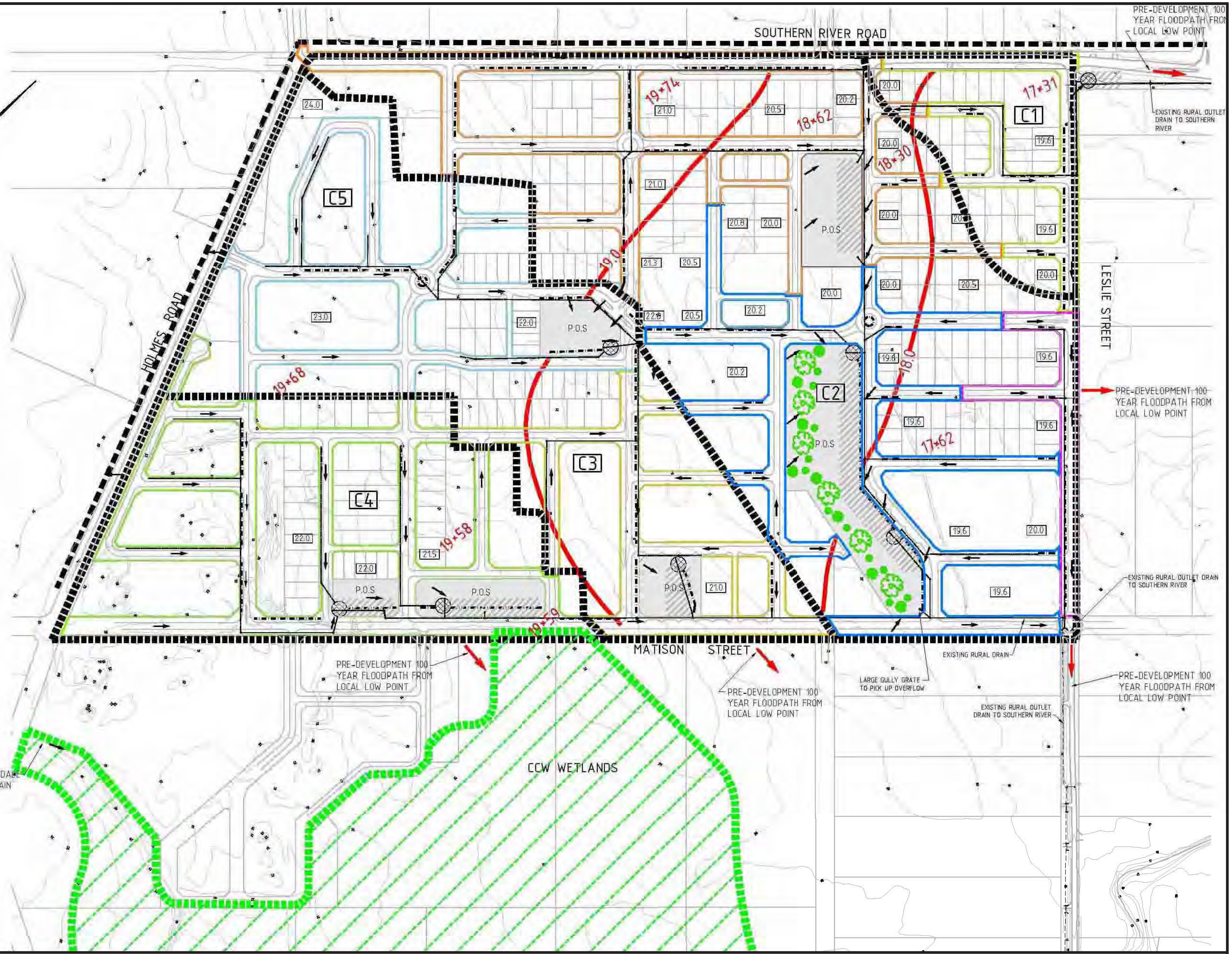
1. I IN 1 YEAR CONTAINED & INFILTRATED TO LOCAL SWALESOR WATER GARDENS.
2. 100 YEAR EVENT CONTAINED IN P.O.S & SWALE (OUTLET DESIGNED AS PER PRE-DEVELOPMENT FLOWS).
3. LOT/HOUSE DRAINAGE DISPOSED OF BY INFILTRATION ONSITE.
4. MIN. CLEARANCE OF 1.5m BETWEEN AAMGL AND FINISHED LOT SURFACE LEVEL.

CATCHMENT KEY

🟨	A
🟪	B
🟦	C
🟧	D
🟨	E
🟩	F
🟦	G

CATCHMENT	ROAD RESERVE AREAS (Ha)	LOT AREAS (Ha)	TOTAL
C1-A	1.44	2.28	3.72
C2-B	0.92	0.99	1.91
C2-C	3.40	7.17	10.57
C2-D	3.90	7.69	11.59
C3-E	2.13	3.97	6.10
C4-F	3.86	6.62	10.48
C5-G	2.90	6.95	9.85
TOTAL	18.55	35.67	54.22

CATCHMENT	1 IN 5 YEAR AREA OF INUNDATION
C1	-
C2	8816m²
C3 & C5	1346m²
C4	3116m²

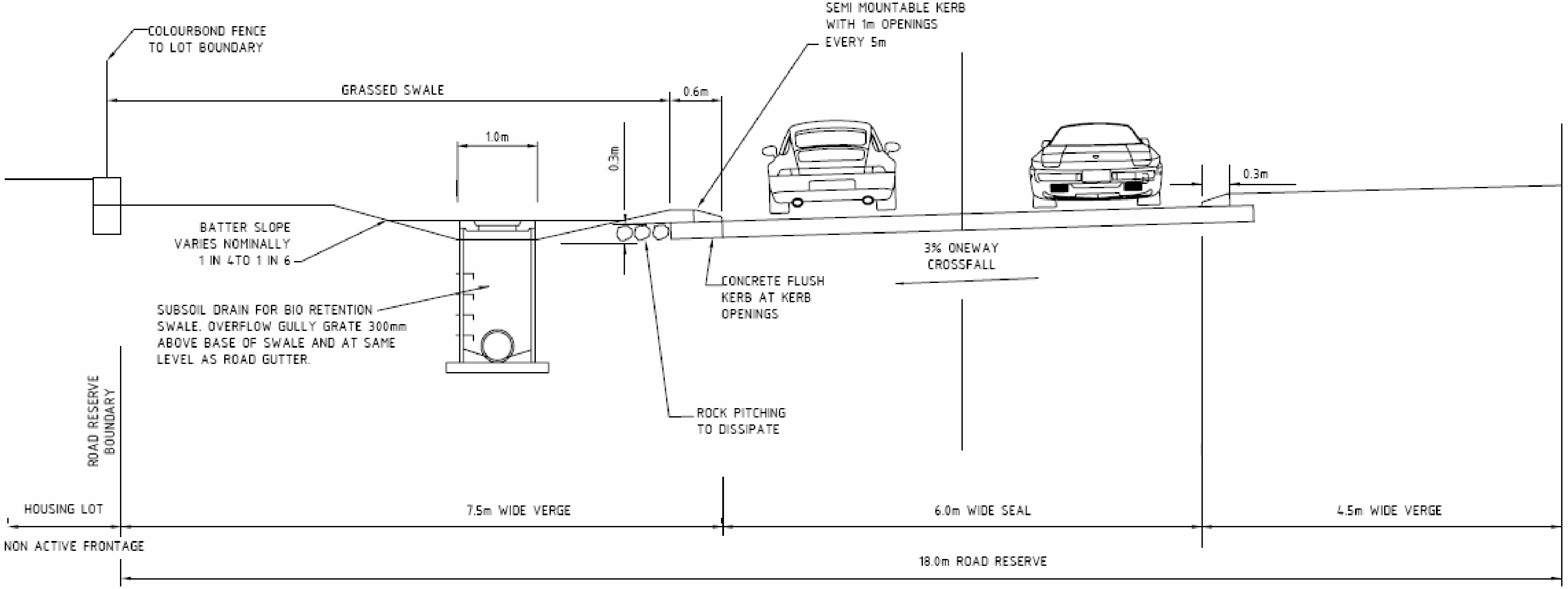


metres
0 50 100 150 200
Approximate SCALE 1 : 4 000 @ A3

06-024-F14.dgn
DATUM: Not spatially correct
DRAWN: TE 7-04-08
AUTHOR: MD 7-04-08
SOURCE: The Civil Group Consulting Civil Engineers, 7488-33B

WRF PROPERTY PTY LTD
SOUTHERN RIVER PRECINCT 3A
DRAINAGE CATCHMENT PLANNING
FOR WRF LAND HOLDING
FIGURE 14

env
Australia



TYPICAL SECTION ACROSS FUTURE ROAD

ADJACENT ROADSIDE SWALE

SCALE 1:50

FIGURE 15: Typical Section Across Future Road

Job No: 06.024

Drawn By: ES

Client: WRF Property

Checked By: MD

Project: Southern River Local Water Management Strategy

Scale: NTS Date: 3/4/08

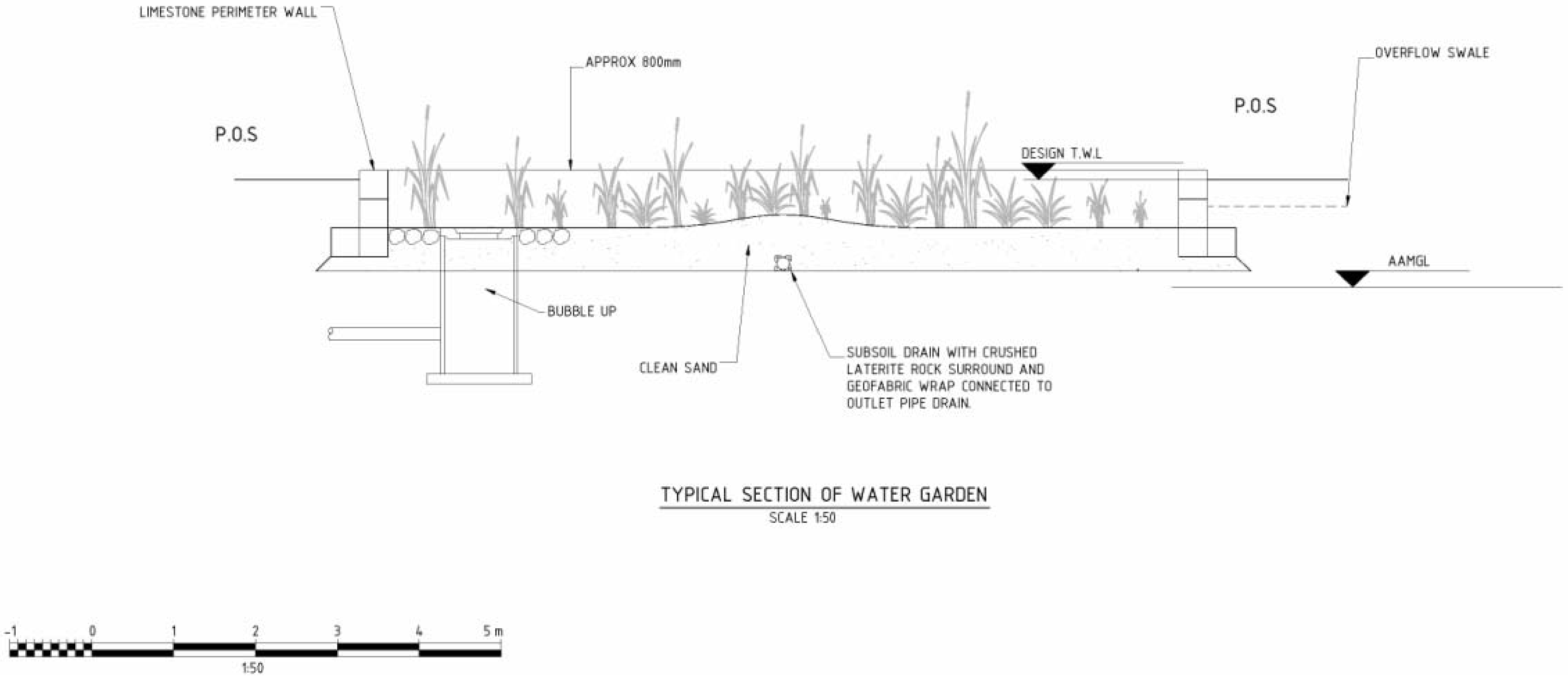


FIGURE 16: Water Garden Cross Section

	Job No: 06.024
	Drawn By: ES
Client: WRF Property	Checked By: MD
Project: Southern River Local Water Management Strategy	Scale: NTS Date: 2/04/08

APPENDIX A

CHANGES TO REPORT BETWEEN MARCH 2007 AND APRIL 2008 VERSIONS

env
Australia

4 April 2008

Water Corporation
PO Box 100
LEEDERVILLE WA 6902

ATTENTION: Frank Kroll

Dear Frank,

SUBJECT : LOCAL WATER MANGEMENT STRATEGY, PRECINCT 3A, SOUTHERN RIVER

Thank you for the comments from the MoU group on the Local Water Management Strategy (LWMS) for Precinct 3A, Southern River dated 20 January 2008. In response to these comments, the submissions on Amendment No.70 to City of Gosnells Town Planning Scheme No.6 and some updates to our understanding of the area, we would like to present this revised version of the LWMS. The updates and amendments to the report are outlined below.

1. Amendments in response to the letter dated 20 January 2008 (the comment is shown first, with the response in italics):

- 2.1 advises "A substantial area has been set aside in the north-western sector, extending from Matison Street, near Leslie Street; this area is aimed at protecting the main area of relatively undisturbed remnant bushland within the sub-precinct which is associated with an area of classified as a Multiple Use Wetland. This area also incorporates a natural drainage feature". Location is incorrect – should read north-eastern sector. – *Altered as requested.*

- 2.2.2 should be extrapolated to include a sediment management plan for construction works – *Included as requested.*

- 3.3 Drainage advises "...referred to as the Matison Street Drain. The drain intercepts seasonal groundwater and forms a seasonally inundated area in the south-eastern corner of the site..." The subject area coincides with that addressed in comment 1, above – text should also coincide. – *altered as requested.*

PO Box 7480, Cloisters Square
PERTH WA 6850
telephone (08) 9289 8360
email env@env.net.au
facsimile (08) 9322 4251
web www.env.net.au
ENV•Australia ABN 72 091 839 020

- Section 4.2 Site Proposal: there are two options mentioned in regards to 1 in 100 year events and the CCW. One option directs water to the wetland while another option bypasses the wetland and directs the water into the drain along Leslie Street. It also notes this will be agreed/discussed with the MOU group. The rest of the document notes that water will enter the CCW. If this is satisfactory the line within section 4.2 needs changing, however, if this is considered the wrong choice between the two options, then section 4.4; section 4.5; section 6.1.1 Acceptance of Drainage Philosophy and Drainage Infrastructure Location; and section 6.2 needs rewording in regard to this matter. Has a final decision been made? Has DEC been consulted? The default position is to maintain predevelopment conditions.

  The Water Corporation's Forrestdale Arterial Drainage Scheme *shows the 1 in 100 year event passing from Catchments 3, 4 and 5 through the wetland into the Drain, as is currently the case. The 1 in 100 year pre-development flow will be maintained. The report has been changed to support this option.*

- 5.1.2 fails to discuss waterwise landscaping - *altered as requested.*

- 5.1.5 should address water wise landscaping. Currently it appears to propose "business as usual" landscaping ("trees and lawns") with water efficient irrigation and use of native species. Whilst it might be argued that waterwise landscape design is implicit in this discussion, it should be made explicit and seek to push the envelope in terms of design. Retention of remnant vegetation should also be discussed – the proposal advises retention of a considerable area of remnant vegetation in the proposed POS in the north-eastern portion of the subject site (see comment 1). This is a landscape water efficiency initiative worthy of mention, but not mentioned here.

  The issue of landscaping was discussed with the City of Gosnells on 26 February 2008 and the report has been altered to reflect the outcomes of this meeting.

- Section 5.1.5: Any extraction of groundwater will require a licence. As identified, the groundwater sub area is fully allocated and the only option would be to buy water from current irrigators. The option of low flow bores into a holding tank would therefore not be considered an appropriate option, unless water is purchased, as this would still be an extraction of water and thus would require a licence.

  The Department of Water has recently increased the groundwater allocation for Gosnells. The proponent is therefore applying for a license based on this increased allocation.

- 5.3 – final para – the mix of incentive might need to be tweaked to ensure that rainwater tanks installed are connected to toilet/laundry plumbing. As it stands, a "free" rainwater tank will not necessarily be plumbed, and a great initiative might fail to some extent.

  A caveat will be placed on the title requiring the rainwater tank to be piped into the toilet and/or laundry. Under the second stage of Five Star Plus, new houses will be required to be plumbed in a way that makes this easy. Refer to Section 5.3.

- Section 6.1.1 Drainage Philosophy: The width of roads that swales can be associated with needs to be approved by council and identified within this document which is associated with the ODP stage.

  This issue was discussed with City of Gosnells in the meeting of 26 February and the report amended to reflect this request.

- Section 6.1.1 Drainage Philosophy: The basin and living stream should be set at or above the MGL. If this is not feasible, the retention time of water within the basin and living stream must be identified to ensure midge and mosquito breeding cannot occur. This would also need to prove that no negative impact will occur on the CCW. – *Amended as requested.*

- 6.1.1 Drainage Philosophy – p.44 - recent issues with swales on verges means that this strategy will need further discussion with the City's Infrastructure directorate to ensure appropriate design and maintenance arrangements.

- The ADS was published in May 2007, therefore comments could be added in section 7.2.3 for example "the drainage design must be such that that overflows are to the CCW and Forrestdale MD are maintained at predevelopment levels." and " the existing natural storage to the south has been retained, as shown in the DSP and overflows into the CCW post development remain the same as predevelopment. It is assumed that additional flows are diverted down stream to the Leslie Street Local Authority outlet via the Matison Street Drain." and " overflows into the Precinct 2 floodplain can no longer occur.....it has been assumed that this area has been diverted into the Leslie Street Local Authority outlet. "The ADS should be referenced in the LWMS. – *Amended as requested.*

- 8.2 – "It is recommended that the City of Gosnells design and coordinate a monitoring programme that can be contributed to by all parties who are undertaking activities that may impact upon the ecological health of the wetland. A financial or expertise contribution can then be made to this programme". This concept is supported by the City's Environmental Development unit, but also requires comment from City Planning .

This issue was discussed with Wayne van Lieven of the City. As outlined in Section 8.2, the impact of development on the CCW to the south of the site needs to be considered in the context of other potential impacts to the site, including the impacts of the proposed ADS and associated developments upstream of the wetland and within Sub-precinct 3C, which contains the wetland. The potential impacts of the development of Precinct 3A on the wetland are considered small when compared to the potential impacts of the proposed drainage scheme and the development of the wider catchment.

A co-ordinated effort will be required to monitor the ecological health of the wetland. While this could be achieved through the ADS project, the author understands that this project will not be referred to the EPA and thus monitoring will not be set as a condition by the EPA. It is therefore suggested that the MoU group consider the issue of, and responsibilities for, monitoring of the CCW. It is accepted that such a program may require a pro-rata contribution from local developers. This is supported in principle provided that contributions are equitable.

- 8.4 – buffers – as per comment previously provided, input should be sought from the City's Parks and Environmental Operations unit as to the proposed location, size and continuity of the (currently-proposed) three parcels of open space adjoining Matison Street.

  A meeting was held with the City of Gosnells Parks and Environmental Operations and Engineering units on 28 February 2008 to address these issues. The outcomes of this meeting were then discussed with the City's Planning Staff. The revised report reflects the outcomes of these meetings.

- Items that need to be identified further within the UWMP and have been noted with this document include shared bores and CSIRO involvement in the UWMP; the CGL and fill levels required for the site; and the EWR for the CCW wetland.

  The shared bore option has been removed based on discussions with Landgate that indicated that a strata of this sort was not feasible in the longer term (Section 5.2). The modelling by CSIRO was to be undertaken to prove up this option and to investigate the use of Controlled Groundwater Levels (CGLs). As the option has been removed, modelling by CSIRO (or another modeller) should only be required if a CGL is proposed.

2. Amendments and comments in response to the regulator's responses to the Town Planning Scheme Amendment (the comment is shown first, with the response in italics):

- The (Swan River) Trust remains concerned that the application of the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) to Swan Coastal Plain Conditions has serious limitations. In the first instance, it does not yet account for the hydrologic interaction of surface and groundwater systems and secondly, to the best of the Trust's knowledge, the Best Management Practices (BMPs) incorporated into the model's design have not been tested and/or designed based on literature and research in Swan Coastal Plain Conditions.

  MUSIC was used for the LWMS based on advice from the Department of Water and was used in compliance with their criteria and the criteria developed by Water Corporation for the use of MUSIC, including the way that the BMPs are modelled. The DoW at the time agreed that they had calibrated MUSIC for the Southern River area and the project team used the DoW's calibration methods in the model. We agree that there is limited data on which to base the model on, but this is due to a limit on the data that has been gathered regarding BMP performance on the Swan Coastal Plain (SCP). This is an acknowledged constraint for all stormwater models and all developments on the SCP. MUSIC was used it is the only commercially available model that will model whether the development meets the Southern River Design Criteria for Water Quality Management.

  The BMPs used by the development comply with the DoW's Stormwater Management Manual for Western Australia *and as such can be considered as 'Best Practice'. The system used for the site was first designed without using MUSIC, before checking whether it would meet the Water Quality Management criteria. MUSIC indicated that the stormwater system would comply with the guidelines. The use of MUSIC therefore did not affect the design of the stormwater system for the site.*

- While the treatment of surface water appears to meet current BMPs, the LWMS does not adequately address the question of nutrient transport through the groundwater system. It is acknowledged that this is a difficult area but it is likely that the groundwater system is a major pathway for nitrogen and phosphorus entering the Swan-Canning system. The total nitrogen and phosphorus levels recorded on the site (Tables 2 and 3 of the LWMS) indicate the potential problem. The report acknowledges the apparent decrease over time but does not offer an explanation for this observation. (Swan River Trust).

  The development plans to address nutrient transport through groundwater through the remediation of the former poultry farms in line with Department of

Environment and Conservation guidelines for Contaminated Sites and the use of nutrient retaining soil amendments in landscaping for both Public Open Space and residential lots. The top 300 mm of soil (where most of the nutrients are considered to lie) is also being removed from the Poultry Farm areas. This is considered to be Best Practice in terms of groundwater nutrient management.

The apparent decrease over time in the previous version of the LWMS is now considered to be due to laboratory error in the analysis of the last round of sampling, which resulted in an underestimation of the phosphorus concentrations. This has been proven through testing of subsequent samples. The new results are discussed in the revised LWMS. .

- The report acknowledges the need for more work to be carried out to address the issue (section 7.2) of nutrient and contaminant mobilisation but suggests that this can be carried out at the UWMP stage. In accordance with the *Interim Approach for Integrating Urban Water Management with Land Use Planning within the Southern River Area – Guidance for Developers* an UWMP is required at the subdivision application stage.

  In the Trust's view, this would be too late to address what is a fundamental concern and suggests that this matter be comprehensively addressed as part of a revised LWMS to be submitted with a future ODP. It should be noted that the Interim Approach requires an 80% reduction in total Phosphorus annual average load rather than the 60% quoted in the Scheme Amendment Report (Swan River Trust).

  We do not agree with the Trust on this matter. The Interim Approach *mentioned by the Trust has been superseded by the Water Corporation's* Southern River Interim Integrated Land and Water Management Plan *(2007) (The* IILWMP). *The IILMP does not require the issue of nutrient and contaminant mobilisation to be addressed at the ODP stage.*

  As outlined above, the development will use Best Practice to try and limit contaminants entering groundwater. The movement of contaminants and nutrients is therefore primarily an issue for the two former Poultry Farm sites. This issue must be addressed as part of the remediation of these sites in line with the Contaminated Sites Act *(2002). Remediation of the sites in line with the Act will be required as a condition of subdivision. This is considered to be the best way to address the issue of nutrient and contaminant movement.*

- Groundwater monitoring bores are only indicative of the short term (last 30 years) dry cycle. Designs of drainage basins and swales need to be based on longer term historical groundwater levels including the wet cycle experienced in the early

1960's. The final Rockwater groundwater study (July 2006) has modelled the effect of groundwater during wet and dry cycles and further reference should be mated to this report by the developers and CSIRO.

Separation of Average Annual Maximum Groundwater Level (AAMGL) and finished lot levels should be a minimum of 1.5 metres. Design of drainage infrastructure including roadside swales and dry detention basins will be very difficult to achieve with the 1.2 m separation proposed by the LWMS.

The interim Forrestdale Arterial Drainage System (ADS) has been completed and reference can be made to this document (DoW, May 2007). (Water Corporation)

The AAMGLs shown in the LWMS are very similar or slightly higher than the maximum groundwater levels shown under an average rainfall scenario in the Rockwater report. Maximum groundwater levels under this scenario are considered to represent the long term AAMGL in a wetter scenario. Because of this, the AAMGL in the LWMS is considered to be similar to the long term AAMGL. The swales and basins will include subsoil drains at or above this AAMGL to facilitate drainage. This will allow for drainage of excess water in wetter years.

The LWMS has been amended to allow for a 1.5 m separation and to reflect the Forrestdale ADS and make reference to this document.

3. Amendments to update the LWMS based on an improved understanding of the site

- Inclusion of additional water quality and quantity results, including the calculation of an Average Annual Maximum Groundwater Level (Section 3.2);

- Updates of the text to ensure that it complies with the Water Corporation's Forrestdale *Arterial Drainage Scheme* and the *Interim Integrated Land and Water Management Plan* (Section 6 and other locations as required);

- Confirmation of City of Gosnells requirements for the swales and POS to ensure these structures can be maintained and managed (Section 6.1.1); and

- Minor changes to the drainage design to reflect the City of Gosnells' preferences for street widths for swales and the alterations to the POS locations between the Outline Development Plan and the Subdivision Concept Plan.

We hope that these changes meet with your satisfaction. Should you have further queries or require additional information, please do not hesitate to contact Margaret Dunlop on 9289 8360.

Yours sincerely
ENV Australia Pty Ltd

MARGARET DUNLOP
Senior Environmental Engineer

Cc: Wayne van Lieven, City of Gosnells; Trevor Lynn, Department of Water

APPENDIX B
MONITORING BORE LOGS

Client: SPM
Logged By: S.McHarg
Drilled By: Strataprobe
Monitoring Bore: MW2

Project: Southern River
Job No: 05.103
Date Logged: 03-Aug-05
Installation Method: Hollow Stem Auger

Depth BGL (m)	Sample Taken	Monitor Well Log	Profile	Lithology	pH (f)	pH (fox)	Observations
			Metal riser used				
			0-0.8	SAND, grey, medium grained, medium sorting	6.76	4.67	
	0.5				7.47	5.08	
					7.43	5.13	
			0.8-3.7	SAND, light yellow, fine-medium grained			
1.0	1.0						
					7.18	5.08	
	1.5						
2.0	2.0				7.2	5.11	
	2.5				7.67	5.01	
3.0	3.0				6.69	5.15	
		▽		wet			
	3.5				6.41	5.14	
			3.7-4.0	SAND, light grey, fine-medium grained			
4.0	4.0				6.12	4.96	
			4.0-5.0	SAND, light brown, fine-medium grained, mottling			
	4.5				6	5.1	
5.0	5.0				5.86	4.89	
			5-6.0	Sandy CLAY, medium plasticity, sand medium grained, mottling present			
	5.5				5.82	5.1	
6.0	6.0				6.41	5	

NOTE:

▤ Monitor Well Screen
▦ Cement
Filter sock used
🟧 Indicates the presence of PASS

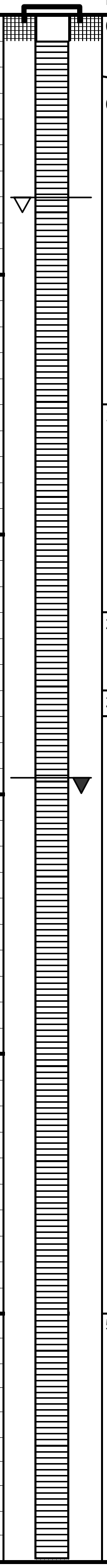
Initial water table at time drilling ▽

Meters are below top of casing
Monitoring bore 25mm diameter
Coordinates - 402 686E / 6 447 858N (GDA 94)

ENV. Australia
Level 7
182 St Georges Terrace
Perth, WA, 6000.

Client: SPM
Logged By: S.McHarg
Drilled By: Strataprobe
Monitoring Bore: MW3

Project: Southern River
Job No: 05.103
Date Logged: 03-Aug-05
Installation Method: Hollow Stem Auger

Depth BGL (m)	Sample Taken	Monitor Well Log	Profile	Lithology	pH (f)	pH (fox)	Observations
			Metal riser used				
			0-0.25	SAND, grey, moist, medium grained, medium sorting			
	0.25				5	4.09	
			0.25-1.5	SAND, light brown/yellow, medium grained, medium sorting			
	0.5				5.74	4.4	
				moist			
	0.75	▽		wet	5.9	4.87	
1.0	1.0				5.85	5	
	1.25				5.88	4.99	
	1.5				6.02	5.1	
			1.5-2.3	SAND, grey, fine-medium grained, well sorted			
	1.75				6.5	5.3	
2.0	2.0				6.8	5.25	
	2.3				6.49	4.43	
			2.3-2.6	Sandy CLAY, dark brown, moderately/weakly sorted, medium grained			
	2.6				5.33	3.79	
			2.6-2.7	Silty SAND, black, medium grained, weakly cemented			
3.0	3.0				5.66	4.95	
	3.25			High silt content	5.87	4.57	
	3.5				6.01	4.93	
	3.75				6.01	4.99	
4.0	4.0				6.03	4.96	
	4.25				6.1	4.99	
	4.5				6.1	4.76	
	4.75				6.15	4.35	
5.0	5.0				6.02	4.57	
			5-6	SAND, brown, medium grained			
	5.25				5.92	4.75	
	5.5				5.88	4.46	
	5.75				5.84	4.62	
6.0	6.0				5.14	🟧 1.2	

NOTE:

▤ Monitor Well Screen
▦ Cement
Filter sock used
🟧 Indicates the presence of PASS

Initial water table at time drilling ▽

Meters are below top of casing
Monitoring bore 25mm diameter
Coordinates - 379 448E / 6 427 378N (GDA 94)

ENV. Australia
Level 7
182 St Georges Terrace
Perth, WA, 6000.

Client: SPM
Logged By: S.McHarg
Drilled By: Strataprobe
Monitoring Bore: MW4

Project: Southern River
Job No: 05.103
Date Logged: 03-Aug-05
Installation Method: Hollow Stem Auger

Depth BGL (m)	Sample Taken	Monitor Well Log	Profile	Lithology	pH (f)	pH (fox)	Observations
			Metal riser used				
	0.25		0-0.25	Silty SAND, black and grey, fine-medium grained, medium sorting, moderate organic component	6.17	4.4	
	0.5				6.69	5.32	
	0.75	▽			6.52	5.54	
1.0	1.0				6.82	5.43	
	1.25				6.99	4.88	
				Non-cemented			
	1.5				6.46	4.25	
				Weakly cemented, iron and organic. Iron mottling			
2.0	2.0				6.9	4.14	
	2.15				6.08	4.05	
	2.2				3.83	🟧 1.77	
				Higher organic component			
	2.5			Sandy CLAY, blue/green, low-medium plasticity. Sand poorly sorted, medium grained.	5.31	🟧 1.92	
	2.75				6.87	🟧 2.96	
3.0	3.0	▼			7.22	5.73	
	3.25				8.44	7.2	
	3.5				8.31	5.56	
	3.75				8.33	5.1	
4.0	4.0			Clay content increasing	8.26	5.68	
	4.25				8.03	🟧 3.1	
	4.5				7.89	🟧 2.28	
	4.75				7.84	🟧 2.14	
5.0	5.0				7.8	🟧 1.87	
	5.25				7.79	🟧 1.82	
	5.5				7.64	🟧 1.6	
	5.75				7.55	🟧 1.4	
6.0	6.0				7.53	🟧 1.37	

NOTE:
▤ Monitor Well Screen
▦ Cement
Filter sock used
🟧 Indicates the presence of PASS

Initial water table at time drilling ▽
Meters are below top of casing
Monitoring bore 25mm diameter
Coordinates - 379 448E / 6 427 378N (GDA 94)

ENV. Australia
Level 7
182 St Georges Terrace
Perth, WA, 6000.

Client: SPM
Logged By: S.McHarg
Drilled By: Strataprobe
Monitoring Bore: MW5

Project: Southern River
Job No: 05.103
Date Logged: 03-Aug-05
Installation Method: Hollow Stem Auger

Depth BGL (m)	Sample Taken	Monitor Well Log	Profile	Lithology	pH (f)	pH (fox)	Observations
			Metal riser used				
				SAND, grey, medium grained, medium sorting			
				wet			
	0.5				5.9	4.85	
	0.75	▽			5.85	5.17	
			0.8-1.3	Silty SAND, brown, weakly cemented, "lumpy"			
1.0	1.0				4.93	4.25	
	1.25				5	3.92	
			1.3-6.0	Clayey SAND, light grey, medium plasticity, fine-medium grained, mottling			
	1.5				5.19	🟧 3.21	
	1.75				5.05	🟧 2.76	
2.0	2.0				5	3.6	
	2.5				4.7	3.84	Poor Recovery
3.0	3.0	▼			5.3	4.41	
	3.25				5.72	🟧 3	Sulphur like odour
	3.5				5.91	4.31	
	3.75				6.6	4.24	
4.0	4.0				6.15	4.05	
	4.25				6.25	4.6	
	4.5				6.44	🟧 1.67	Sulphur like odour
	4.75				6.37	🟧 2.39	
5.0	5.0				6.48	🟧 1.6	
	5.25						
	5.5						
							Sulphur like odour
	5.75						
6.0	6.0						

NOTE:

▤ Monitor Well Screen
▦ Cement
Filter sock used
🟧 Indicates the presence of PASS

Initial water table at time drilling ▽

Meters are below top of casing
Monitoring bore 25mm diameter
Coordinates - 403 011E / 6 448 666N (GDA 94)

ENV. Australia
Level 7
182 St Georges Terrace
Perth, WA, 6000.

Client:

Performed by: JS and Strataprobe

Borehole #: MW6

Project and Job No.: Southern River

Date Logged: 19/05/06

Drill Rig Method: Geoprobe

Easting: 403032

Northing: 6447844

Depth BGL (m)	Monitor Well Log	Horizon Depth (m)	Horizon Lithology	Observations (ie. H_2S odour)	pH Depth (m bgl)	pH_F	pH_{FOX}	pH Change	Reaction#	Sample Analysed
Indication Level						≤4	<3	-	-	-
		0-0.25	SAND,black to dark brown, medium grained, moderatley sorted.							
		0.25-0.30	SAND,dark whitey grey, medium grained, moderatley sorted.							
1.0										
	∇	0.3-2.25	SAND, white, medium grained, moderatley sorted.							
2.0										
		2.25-2.7	SAND, dark white grading to dark brown (coffee rock low cementing)at 2.7m							
		2.7-4.0	COFFEE ROCK, dark brown to dark tan, low cementing, Fine grained, well sorted.							
3.0										
4.0										
			End of Hole - 4.0m							
5.0										
6.0										

Reaction with H_2O_2; L= low, M = medium, H = high, X = extreme

▤ Monitor Well Screen

⬚ Sand Fill

SWL Standing Water Level ——∇——

Client:
Performed by: JS and Strataprobe
Borehole #: Mwa

Project and Job No.: Southern River
Date Logged: 19/06/06
Drill Rig Method: Geoprobe

Easting:
Northing:

Depth BGL (m)	Monitor Well Log	Horizon Depth (m)	Horizon Lithology	Observations (ie. H_2S odour)	pH Depth (m bgl)	pH_F	pH_{FOX}	pH Change	Reaction#	Sample Analysed
Indication Level						≤4	<3	-	-	-
		0-1.2m	SAND,Grey, moderately sorted, medium grained.							
			sorted.							
1.0										
		1.2-2.5	Coffee Rock, Dark brown, fine grained, well sorted							
2.0										
	▽			Saturated at 2.1m						
		2.5-3.8m	Coffee Rock, saturated sand, fine grained, well sorted							
3.0										
4.0										
			End of Hole - 3.8m							
5.0										
6.0										

#	Reaction with H_2O_2; L= low, M = medium, H = high, X = extreme
⊟	Monitor Well Screen
⬚	Sand Fill
SWL	Standing Water Level ▽

Client:
Performed by: JS and Strataprobe
Borehole #: MWb

Project and Job No.: Southern River
Date Logged: 19/06/06
Drill Rig Method: Geoprobe

Easting:
Northing:

Depth BGL (m)	Monitor Well Log	Horizon Depth (m)	Horizon Lithology	Observations (ie. H_2S odour)	pH Depth (m bgl)	pH_F	pH_{FOX}	pH Change	Reaction#	Sample Analysed
Indication Level						≤4	<3	-	-	-
		0-3	SAND, grey, medium grained, moderately sorted sorted.	Slight H2S odour						
1.0										
2.0										
	∇									
3.0		3-4.6	SANDY CLAY, grey greeny, fine to medium grained, moderatly sorted	Strong H2S odour						
4.0										
5.0			End of Hole - 4.8m							
6.0										

\# Reaction with H_2O_2; L= low, M = medium, H = high, X = extreme
▤ Monitor Well Screen
⬚ Sand Fill
SWL Standing Water Level ∇

Client:
Performed by: JS and Strataprobe
Borehole #: MWc

Project and Job No.: Southern River
Date Logged: 19/06/06
Drill Rig Method: Geoprobe

Easting: 403032
Northing: 6447844

Depth BGL (m)	Monitor Well Log	Horizon Depth (m)	Horizon Lithology	Observations (ie. H_2S odour)	pH Depth (m bgl)	pH_F	pH_{FOX}	pH Change	Reaction#	Sample Analysed
Indication Level						≤4	<3	-	-	-
		0-4m	SAND, grey to browney grey, medium grained,							
			moderaltely sorted							
1.0										
	▽									
2.0										
3.0										
4.0		4-4.2m	SANDY CLAY, grey green, fine grained, well sorted							
			End of Hole - 4.2m							
5.0										
6.0										

Reaction with H_2O_2; L= low, M = medium, H = high, X = extreme
▤ Monitor Well Screen
⬚ Sand Fill
SWL Standing Water Level ▽

APPENDIX C

RECORDED GROUNDWATER LEVELS

APPENDIX C
RECORDED GROUNDWATER LEVELS

Date	16/08/2005	23/08/2005	7/03/2006	24/05/2006	4/07/2006	10/08/2006	13/09/2006	19/10/2006	21/03/2007	11/10/2007	25/10/2007	21/11/2007	
Rain *	21.8 / 29	0		23/05/2006									
Recorded Level													
MB1	-	0.87											
MB2	-	3.56	4.41	4.863	4.981	5.254	5.552	4.684	dry	4.29	4.25	4.54	
MB3	1.14	1.24	dry	dry	blocked	2.394	2.024	2.054	dry	1.603	1.76	2.012	
MB4	1.261	1.27	3.63	3.47	3.269	3.05	1.776	2.698	4.64	1.452	1.78	2.775	
MB5	-	0.82	2.19	3.334	3.111	2.29	1.195	1.679	4.69	0.995	1.257	1.57	
MB6				2.439	2.502	2.39	1.859	2.049	3.06	1.595	1.695	1.935	
MBA					2.525	2.281	1.854	2.03	2.925	1.493	1.635	1.863	
MBB					2.45	2.175	1.775	2.081	dry	1.485	1.71	1.97	
MBC					2.803	2.654	2.339	2.476	dry	2.192	2.228	2.44	
T75			2.231		1.993	1.811	2.133	1.824	2.83	1.425	1.608	2.262	
T85													
DoE 8285				3.432	3.476	3.404	3.814	3.38		2.688	2.78	2.93	bore decon
	16/08/2005	**23/08/2005**	**7/03/2006**	**24/05/2006**	**4/07/2006**	**10/08/2006**	**13/09/2006**	**19/10/2006**	**21/03/2007**	**11/10/2007**	**25/10/2007**	**21/11/2007**	
MB2		20.182	19.330	18.879	18.761	18.488	18.190	19.058		19.452	19.492	19.202	
MB3	18.853	18.753				17.599	17.969	17.939		18.39	18.233	17.981	
MB4	17.794	17.785	15.427	15.585	15.786	16.005	17.279	16.357	14.415	17.603	17.275	16.28	
MB5		17.263	15.890	14.744	14.967	15.788	16.883	16.399	13.388	17.083	16.821	16.508	
MB6				18.521	18.458	18.570	19.101	18.911	17.900	19.3645	19.2645	19.0245	
MBA					17.044	17.288	17.715	17.539	16.644	18.076	17.934	17.706	
MBB					18.549	18.824	19.224	18.918		19.514	19.289	19.029	
MBC					18.737	18.886	19.201	19.064		19.348	19.312	19.1	
T75			18.126		18.364	18.546	18.224	18.533	17.527	18.932	18.749	18.095	
DoE 8285				23.584	23.540	23.612	23.202	23.636		24.328	24.236	24.086	

* rain given as rainfall in mm that day / day previous from data taken at Perth Airport
Note: meter used on 23/8 was only marked down to the cm, therefore all estimates are +/- 0.25 cm

APPENDIX D

AVERAGE ANNUAL MAXIMUM AND LOWEST GROUNDWATER LEVEL CALCULATIONS

APPENDIX D
ANNUAL AVERAGE LOWEST GROUNDWATER LEVEL CALCULATIONS

Monitoring bores

Date	16/08/2005	23/08/2005	7/03/2006	24/05/2006	4/07/2006	10/08/2006	13/09/2006	19/10/2006	21/03/2007	11/10/2007	25/10/2007	21/11/2007		
Rain *	21.8 / 29	0		23/05/2006										
Recorded Level														
MB1	-	0.87												
MB2	-	3.56	4.41	4.863	4.981	5.254	5.552	4.684	dry	4.29	4.25	4.54		
MB3	1.14	1.24	dry	dry	blocked	2.394	2.024	2.054	dry	1.603	1.76	2.012		
MB4	1.261	1.27	3.63	3.47	3.269	3.05	1.776	2.698	4.64	1.452	1.78	2.775		
MB5	-	0.82	2.19	3.334	3.111	2.29	1.195	1.679	4.69	0.995	1.257	1.57		
MB6				2.439	2.502	2.39	1.859	2.049	3.06	1.595	1.695	1.935		
MBA					2.525	2.281	1.854	2.03	2.925	1.493	1.635	1.863		
MBB					2.45	2.175	1.775	2.081	dry	1.485	1.71	1.97		
MBC					2.803	2.654	2.339	2.476	dry	2.192	2.228	2.44		
T75			2.231		1.993	1.811	2.133	1.824	2.83	1.425	1.608	2.262		
T85														
DoE 8285				3.432	3.476	3.404	3.814	3.38		2.688	2.78	2.93	bore decomissioned	
	16/08/2005	**23/08/2005**	**7/03/2006**	**24/05/2006**	**4/07/2006**	**10/08/2006**	**13/09/2006**	**19/10/2006**	**21/03/2007**	**11/10/2007**	**25/10/2007**	**21/11/2007**		**depth from GL**
MB2		20.182	19.330	18.879	18.761	18.488	18.190	19.058		19.452	19.492	19.202	MB2	3.726
MB3	18.853	18.753				17.599	17.969	17.939		18.39	18.233	17.981	MB3	0.999
MB4	17.794	17.785	15.427	15.585	15.786	16.005	17.279	16.357	14.415	17.603	17.275	16.28	MB4	0.779
MB5		17.263	15.890	14.744	14.967	15.788	16.883	16.399	13.388	17.083	16.821	16.508	MB5	0.508
MB6				18.521	18.458	18.570	19.101	18.911	17.900	19.3645	19.2645	19.0245	MB6	1.488
MBA					17.044	17.288	17.715	17.539	16.644	18.076	17.934	17.706	MBA	0.99
MBB					18.549	18.824	19.224	18.918		19.514	19.289	19.029	MBB	1.045
MBC					18.737	18.886	19.201	19.064		19.348	19.312	19.1	MBC	1.711
T75			18.126		18.364	18.546	18.224	18.533	17.527	18.932	18.749	18.095		
DoE 8285				23.584	23.540	23.612	23.202	23.636		24.328	24.236	24.086		

* rain given as rainfall in mm that day / day previous from data taken at Perth Airport
Note: meter used on 23/8 was only marked down to the cm, therefore all estimates are +/- 0.25 cm

Surface Water sites

Date	16/08/2005	13/08/2005		24/05/2006					21/03/2007	11/10/2007	25/10/2007	21/11/2007
Rain *	21.8 / 29	0		23/05/2006								
Recorded Level												
SW1	-	0.68	0.00	0	Dry				Dry			
SW2	-	0.57	0.00	0	Dry					0.51	0.68 (0.315m under water)	dry
Dm	-	-	0.00	0	Dry					0.081	dry	dry
Level (AHD)												
SW1	-	18.07										
SW2	-	20.80										
Dm	-	-										
Water Depth												
SW1	-	0.31										
SW2	-	0.49										
Dm	-	-										

APPENDIX D
AVERAGE ANNUAL MAXIMUM GROUNDWATER LEVEL CALCULATIONS

08:35:00 12/01/1995	17.917	
10:25:00 06/04/1995	17.387	
11:00:00 28/06/1995	18.577	
09:45:00 12/10/1995	18.817	18.817
08:55:00 11/01/1996	18.297	
10:55:00 22/04/1996	18.157	
07:50:00 10/07/1996	18.957	
07:45:00 10/10/1996	19.037	19.037
07:55:00 16/01/1997	18.197	
09:05:00 15/04/1997	18.167	
08:35:00 09/07/1997	18.497	
08:55:00 08/10/1997	18.727	18.727
13:25:00 13/01/1998	18.277	
09:10:00 24/03/1998	17.687	
08:25:00 09/07/1998	18.487	
08:58:00 09/10/1998	18.627	18.627
10:10:00 12/01/1999	18.147	
09:00:00 14/04/1999	17.827	
09:06:00 17/09/1999	18.957	18.957
09:20:00 29/05/2000	18.057	
08:43:00 06/10/2000	18.877	18.877
08:26:00 03/05/2001	18.187	
08:18:00 12/10/2001	18.927	18.927
10:55:00 09/05/2002	18.407	
08:35:00 09/10/2002	18.857	18.857
08:06:00 08/05/2003	18.117	
08:33:00 08/10/2003	18.987	18.987
09:59:00 18/05/2004	18.397	
08:46:00 21/10/2004	18.767	18.767

AAMGL

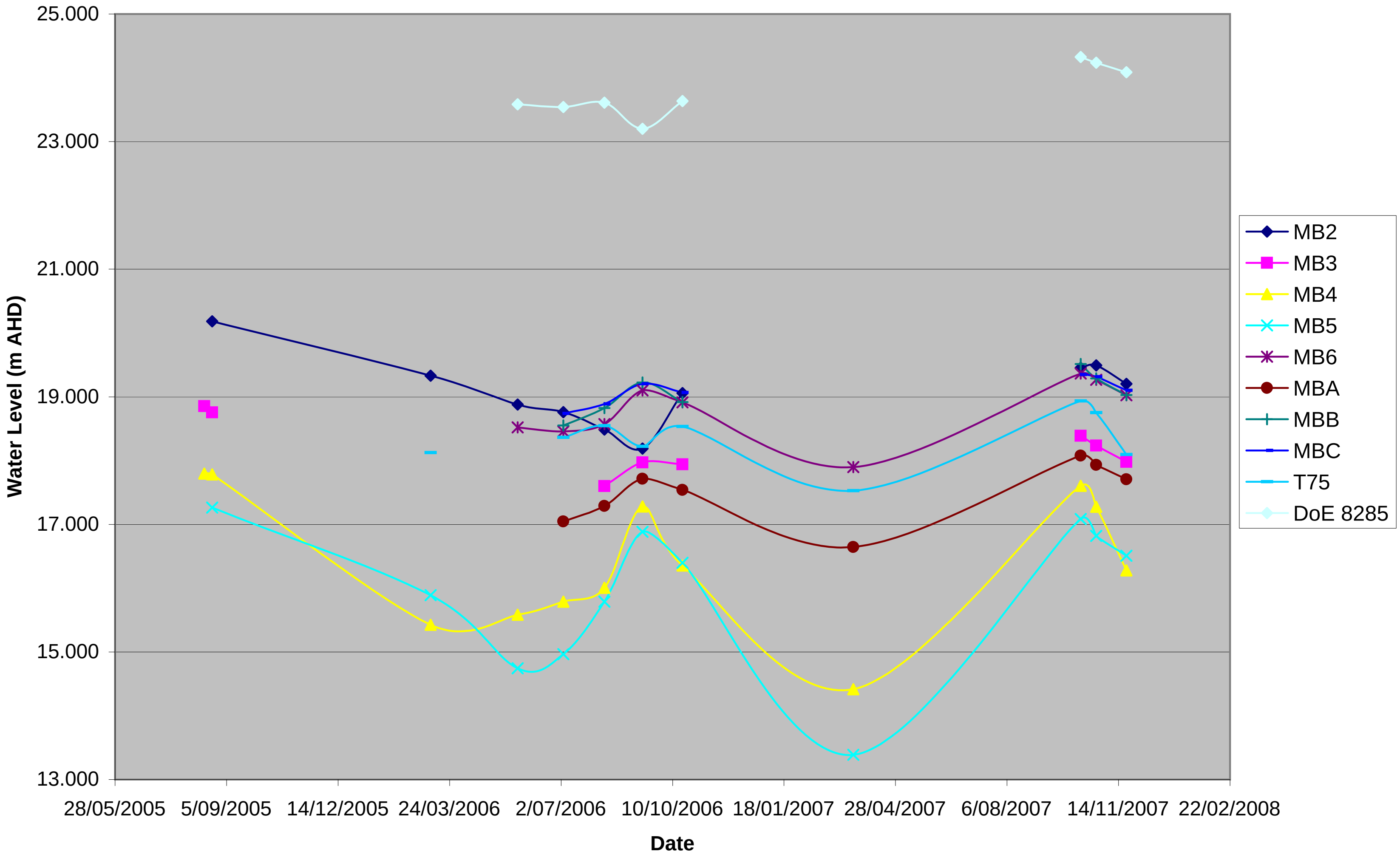
18.858

	known WL on **11/10/2007**		**calculated AAMGL**
MB2	19.452		19.378
MB3	18.39		18.316
MB4	17.603		17.529
MB5	17.083		17.009
MB6	19.3645		19.2905
MBA	18.076		18.002
MBB	19.514		19.44
MBC	19.348		19.274
T75	18.932		18.858
DoE 8285	24.328		24.254

difference between calculated and observed

-0.074

Levels Graph



APPENDIX D - Based on readings from 4/7/06

Bore Name	Reading		AALGL known	AALGL Calculated
MW2	18.761	20.182		17.854
MW3	dry	18.753		
MW4	15.786	17.785		14.879
MW5	14.967	17.263		14.060
MW6	18.4575			17.551
MWA	17.044			16.137
MWB	18.549			17.642
MWC	18.737			17.830
T75	18.364		17.457	

AAMGL
Decided to use T75, as it is the closer bore
Therefore difference = -0.907 m

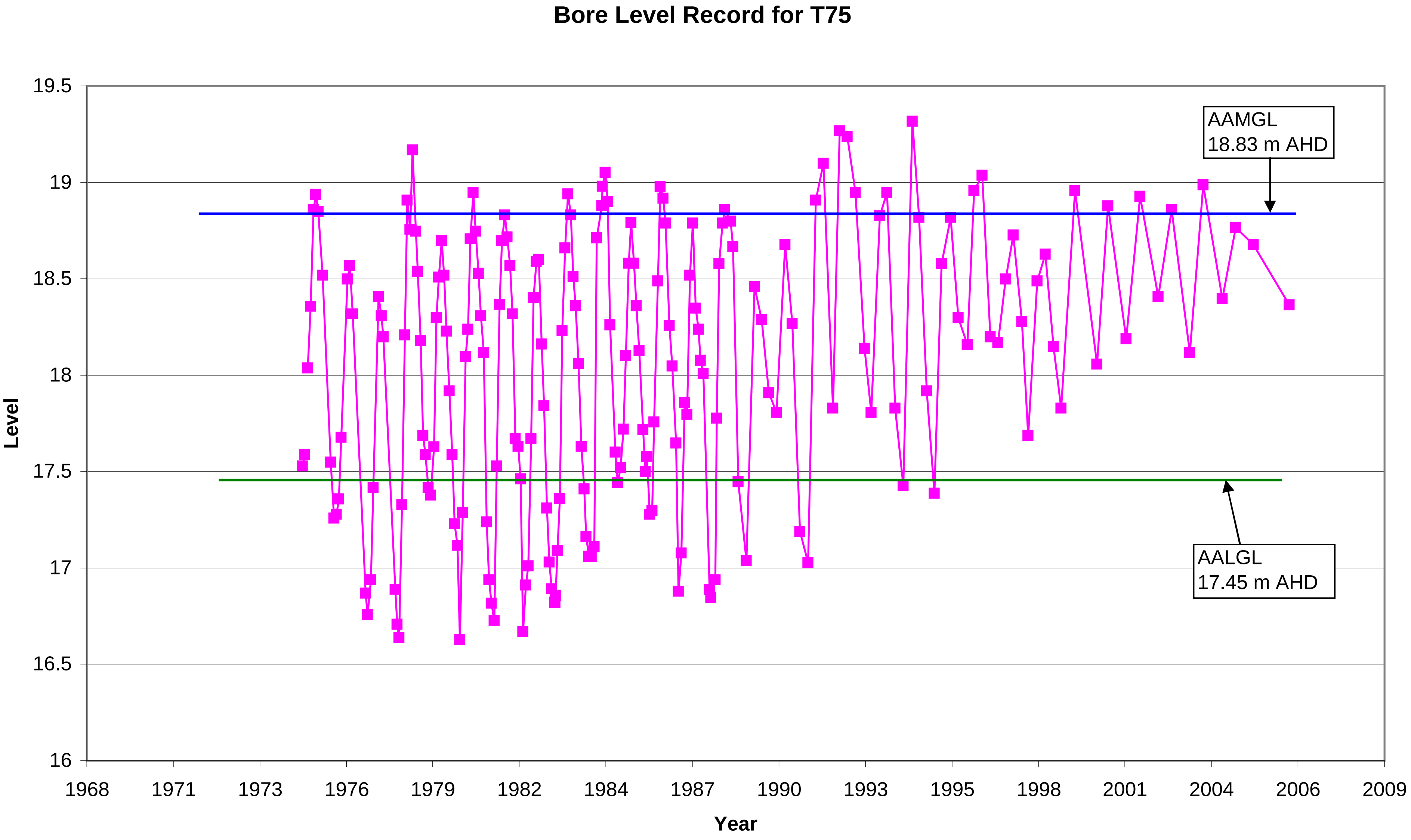
AAMGL for T75 (4880), 1975-2004

TOC = 20.357 m AHD

Date	Level	Max for year	AAMGL		Min for year	AALGL	
12:00:00 09/04/1975	17.527		18.834	**For whole record**		17.457	**For whole record**
12:00:00 08/05/1975	17.587		18.900	**For 1994-2004**		18.041	**For 1994-2004**
00:00:00 05/06/1975							
12:00:00 11/06/1975	18.037						
12:00:00 10/07/1975	18.357						
12:00:00 14/08/1975	18.857						
12:00:00 09/09/1975	18.937						
12:00:00 09/10/1975	18.847						
12:00:00 25/11/1975	18.517	18.937			17.527		
12:00:00 02/03/1976	17.547						
12:00:00 06/04/1976	17.257						
12:00:00 03/05/1976	17.277						
12:00:00 01/06/1976	17.357						
12:00:00 02/07/1976	17.677						
12:00:00 08/09/1976	18.497						
12:00:00 05/10/1976	18.567						
12:00:00 09/11/1976	18.317	18.567			17.257		
12:00:00 06/04/1977	16.867						
12:00:00 02/05/1977	16.757						
12:00:00 07/06/1977	16.937						
12:00:00 04/07/1977	17.417						
12:00:00 02/09/1977	18.407						
12:00:00 06/10/1977	18.307						
12:00:00 01/11/1977	18.197	18.407			16.757		
12:00:00 15/03/1978	16.887						
12:00:00 07/04/1978	16.707						
12:00:00 01/05/1978	16.637						
12:00:00 01/06/1978	17.327						
12:00:00 04/07/1978	18.207						
12:00:00 01/08/1978	18.907						
12:00:00 03/09/1978	18.757						
12:00:00 04/10/1978	19.167						
12:00:00 09/11/1978	18.747						
12:00:00 04/12/1978	18.537	19.167			16.637		
12:00:00 03/01/1979	18.177						
12:00:00 01/02/1979	17.687						
12:00:00 01/03/1979	17.587						
12:00:00 02/04/1979	17.417						
12:00:00 01/05/1979	17.377						
12:00:00 05/06/1979	17.627						
12:00:00 03/07/1979	18.297						
12:00:00 01/08/1979	18.507						
12:00:00 04/09/1979	18.697						
12:00:00 01/10/1979	18.517						
12:00:00 01/11/1979	18.227						
12:00:00 03/12/1979	17.917	18.697			17.377		
12:00:00 03/01/1980	17.587						
12:00:00 01/02/1980	17.227						
12:00:00 04/03/1980	17.117						
12:00:00 01/04/1980	16.627						
12:00:00 07/05/1980	17.287						
12:00:00 08/06/1980	18.097						
12:00:00 02/07/1980	18.237						
12:00:00 01/08/1980	18.707						
12:00:00 02/09/1980	18.947						
12:00:00 03/10/1980	18.747						
12:00:00 03/11/1980	18.527						
12:00:00 01/12/1980	18.307	18.947			16.627		
12:00:00 05/01/1981	18.117						
12:00:00 03/02/1981	17.237						
12:00:00 03/03/1981	16.937						
12:00:00 03/04/1981	16.817						
12:00:00 03/05/1981	16.727						
12:00:00 02/06/1981	17.527						
12:00:00 02/07/1981	18.367						
12:00:00 03/08/1981	18.697						
12:00:00 01/09/1981	18.831						
12:00:00 01/10/1981	18.717						
12:00:00 02/11/1981	18.567						
12:00:00 02/12/1981	18.317	18.831			16.727		
12:00:00 04/01/1982	17.670						

Date	Level	Max for year	AAMGL	Min for year	AALGL
12:00:00 04/02/1982	17.630				
12:00:00 02/03/1982	17.460				
12:00:00 01/04/1982	16.670				
12:00:00 03/05/1982	16.910				
12:00:00 01/06/1982	17.010				
12:00:00 02/07/1982	17.670				
12:00:00 02/08/1982	18.400				
12:00:00 01/09/1982	18.590				
12:00:00 01/10/1982	18.600				
12:00:00 03/11/1982	18.160				
12:00:00 02/12/1982	17.840	18.600		16.670	
12:00:00 05/01/1983	17.310				
12:00:00 01/02/1983	17.030				
12:00:00 01/03/1983	16.890				
12:00:00 04/04/1983	16.820				
12:00:00 06/04/1983	16.820				
12:00:00 10/04/1983	16.857				
12:00:00 04/05/1983	17.090				
12:00:00 03/06/1983	17.360				
12:00:00 01/07/1983	18.230				
12:00:00 01/08/1983	18.660				
12:00:00 01/09/1983	18.940				
12:00:00 06/10/1983	18.830				
12:00:00 02/11/1983	18.510				
12:00:00 01/12/1983	18.360	18.940		16.820	
12:00:00 05/01/1984	18.060				
12:00:00 02/02/1984	17.630				
12:00:00 06/03/1984	17.410				
12:00:00 02/04/1984	17.160				
12:00:00 02/05/1984	17.060				
12:00:00 01/06/1984	17.060	18.060		17.060	
12:00:00 02/07/1984	17.110				
12:00:00 01/08/1984	18.710				
12:00:00 30/09/1984	18.880				
12:00:00 03/10/1984	18.980				
12:00:00 06/11/1984	19.050				
12:00:00 03/12/1984	18.900	19.050		17.110	
12:00:00 03/01/1985	18.260				
12:00:00 05/03/1985	17.600				
12:00:00 01/04/1985	17.440				
12:00:00 01/05/1985	17.520				
12:00:00 05/06/1985	17.720				
12:00:00 03/07/1985	18.100				
12:00:00 06/08/1985	18.580				
12:00:00 02/09/1985	18.790				
12:00:00 02/10/1985	18.580				
12:00:00 02/10/1985	18.580				
12:00:00 04/11/1985	18.360				
12:00:00 02/12/1985	18.127	18.790		17.440	
10:49:00 15/01/1986	17.717				
10:09:00 12/02/1986	17.497				
10:04:00 05/03/1986	17.577				
16:21:00 04/04/1986	17.277				
11:03:00 05/05/1986	17.297				
10:31:00 26/05/1986	17.757				
09:50:00 07/07/1986	18.487				
10:49:00 07/08/1986	18.977				
13:16:00 08/09/1986	18.917				
10:04:00 03/10/1986	18.787				
12:20:00 20/11/1986	18.257				
12:00:00 22/12/1986	18.047	18.977		17.277	
09:49:00 02/02/1987	17.647				
09:30:00 03/03/1987	16.877				
10:00:00 07/04/1987	17.077				
09:09:00 12/05/1987	17.857				
10:49:00 12/06/1987	17.797				
09:09:00 16/07/1987	18.517				
09:21:00 18/08/1987	18.787				
09:28:00 18/09/1987	18.347				
15:38:00 19/10/1987	18.237				
15:02:00 12/11/1987	18.077				
14:50:00 14/12/1987	18.007	18.787		16.877	
14:04:00 25/02/1988	16.887				

Date	Level	Max for year	AAMGL	Min for year	AALGL
15:15:00 14/03/1988	16.847				
11:19:00 29/04/1988	16.937				
15:17:00 17/05/1988	17.777				
13:41:00 13/06/1988	18.577				
13:29:00 22/07/1988	18.787				
15:07:00 18/08/1988	18.857				
14:50:00 26/10/1988	18.797				
14:01:00 22/11/1988	18.667	18.857		16.847	
08:53:00 20/01/1989	17.447				
14:16:00 27/04/1989	17.037				
09:17:00 28/07/1989	18.457				
09:55:00 18/10/1989	18.287	18.457		17.037	
09:55:00 12/01/1990	17.907				
10:04:00 09/04/1990	17.807				
09:22:00 17/07/1990	18.677				
09:00:00 11/10/1990	18.267	18.677		17.807	
15:41:00 07/01/1991	17.187				
11:32:00 09/04/1991	17.027				
12:17:00 08/07/1991	18.907				
09:29:00 01/10/1991	19.097	19.097		17.027	
11:25:00 24/01/1992	17.827				
11:10:00 07/04/1992	19.267				
10:12:00 07/07/1992	19.237				
09:39:00 09/10/1992	18.947				
10:36:00 18/01/1993	18.137				
09:15:00 08/04/1993	17.807				
09:04:00 15/07/1993	18.827				
09:54:00 06/10/1993	18.947	19.267		17.807	
08:22:00 11/01/1994	17.827				
11:24:00 12/04/1994	17.427				
09:10:00 25/07/1994	19.317				
08:54:00 12/10/1994	18.817	19.317		17.427	
08:35:00 12/01/1995	17.917				
10:25:00 06/04/1995	17.387				
11:00:00 28/06/1995	18.577				
09:45:00 12/10/1995	18.817	18.817		17.387	
08:55:00 11/01/1996	18.297				
10:55:00 22/04/1996	18.157				
07:50:00 10/07/1996	18.957				
07:45:00 10/10/1996	19.037	19.037		18.157	
07:55:00 16/01/1997	18.197				
09:05:00 15/04/1997	18.167				
08:35:00 09/07/1997	18.497				
08:55:00 08/10/1997	18.727	18.727		18.167	
13:25:00 13/01/1998	18.277				
09:10:00 24/03/1998	17.687				
08:25:00 09/07/1998	18.487				
9/10/1998	18.6270043	18.627		17.687	
12/01/1999	18.1469933				
14/04/1999	17.8270012				
17/09/1999	18.957	18.957		17.8270012	
29/05/2000	18.057			18.057	
6/10/2000	18.877	18.877			
3/05/2001	18.187			18.187	
12/10/2001	18.927	18.927			
9/05/2002	18.407			18.407	
9/10/2002	18.857	18.857			
8/05/2003	18.117			18.117	
8/10/2003	18.987	18.987			
18/05/2004	18.397			18.397	
21/10/2004	18.767	18.767			
11/05/2005	18.677			18.677	
4/07/2006	18.364				


Bore Level Record for T75
Level
19.5
19
18.5
18
17.5
17
16.5
16
Year
1968
1971
1973
1976
1979
1982
1984
1987
1990
1993
1995
1998
2001
2004
2006
2009
AAMGL
18.83 m AHD
AALGL
17.45 m AHD

APPENDIX E

GROUNDWATER SAMPLING RESULTS

APPENDIX E
GROUNDWATER SAMPLING RESULTS

Monitoring Bores

Date	16/08/2005	23/08/2005	7/03/2006	24/05/2006	4/07/2006	10/08/2006	13/09/2006	19/10/2006	21/03/2007	11/10/2007	25/10/2007	21/11/2007	
Rain *	21.8 / 29	0		23/05/2006									
Recorded Level													
MB1	-	0.87											
MB2	-	3.56	4.41	4.863	4.981	5.254	5.552	4.684	dry	4.29	4.25	4.54	
MB3	1.14	1.24	dry	dry	blocked	2.394	2.024	2.054	dry	1.603	1.76	2.012	
MB4	1.261	1.27	3.63	3.47	3.269	3.05	1.776	2.698	4.64	1.452	1.78	2.775	
MB5	-	0.82	2.19	3.334	3.111	2.29	1.195	1.679	4.69	0.995	1.257	1.57	
MB6				2.439	2.502	2.39	1.859	2.049	3.06	1.595	1.695	1.935	
MBA					2.525	2.281	1.854	2.03	2.925	1.493	1.635	1.863	
MBB					2.45	2.175	1.775	2.081	dry	1.485	1.71	1.97	
MBC					2.803	2.654	2.339	2.476	dry	2.192	2.228	2.44	
T75			2.231		1.993	1.811	2.133	1.824	2.83	1.425	1.608	2.262	
T85													
DoE 8285				3.432	3.476	3.404	3.814	3.38		2.688	2.78	2.93	bore decomissioned
	16/08/2005	**23/08/2005**	**7/03/2006**	**24/05/2006**	**4/07/2006**	**10/08/2006**	**13/09/2006**	**19/10/2006**	**21/03/2007**	**11/10/2007**	**25/10/2007**	**21/11/2007**	
MB2		20.182	19.330	18.879	18.761	18.488	18.190	19.058		19.452	19.492	19.202	
MB3	18.853	18.753				17.599	17.969	17.939		18.39	18.233	17.981	
MB4	17.794	17.785	15.427	15.585	15.786	16.005	17.279	16.357	14.415	17.603	17.275	16.28	
MB5		17.263	15.890	14.744	14.967	15.788	16.883	16.399	13.388	17.083	16.821	16.508	
MB6				18.521	18.458	18.570	19.101	18.911	17.900	19.3645	19.2645	19.0245	
MBA					17.044	17.288	17.715	17.539	16.644	18.076	17.934	17.706	
MBB					18.549	18.824	19.224	18.918		19.514	19.289	19.029	
MBC					18.737	18.886	19.201	19.064		19.348	19.312	19.1	
T75			18.126		18.364	18.546	18.224	18.533	17.527	18.932	18.749	18.095	
DoE 8285				23.584	23.540	23.612	23.202	23.636		24.328	24.236	24.086	

* rain given as rainfall in mm that day / day previous from data taken at Perth Airport

Note: meter used on 23/8 was only marked down to the cm, therefore all estimates are +/- 0.25 cm

Surface Water Sites

Date	16/08/2005	13/08/2005		24/05/2006					21/03/2007	11/10/2007	25/10/2007	21/11/2007
Rain *	21.8 / 29	0		23/05/2006								
Recorded Level												
SW1	-	0.68	0.00	0	Dry				Dry			
SW2	-	0.57	0.00	0	Dry					0.51	0.68 (0.315m under water)	dry
Dm	-	-	0.00	0	Dry					0.081	dry	dry
Level (AHD)												
SW1	-	18.07										
SW2	-	20.80										
Dm	-	-										
Water Depth												
SW1	-	0.31										
SW2	-	0.49										
Dm	-	-										

APPENDIX E
GROUNDWATER SAMPLING RESULTS

Total Nitrogen

Date	MB2	MB3	MB4	MB5	MB6	MBA	MBB	MBC
16/08/2005	5.6	7.8	22.4	14.9	#	#	#	#
7/03/2006	3.0	dry	14.0	17.0	#	#	#	#
4/07/2006	1.1	dry	3.0	1.9	5.0	2.4	10.4	5.6
10/08/2006	2.4	3.3	2.6	2.1	4.9	4.9	7.5	4.8
13/09/2006	2.9	3.9	3.6	8.2	3.5	8.0	2.8	9.1
21/03/2007	dry	dry	2.2	5.9	3.6	2.9	dry	dry

8.2

5.6

Total Phosphorus

Date	MB2	MB3	MB4	MB5	MB6	MBA	MBB	MBC
16/08/2005	1.72	8.56	2.71	1.14	#	#	#	#
7/03/2006	0.6	dry	0.35	1.2	#	#	#	#
4/07/2006	0.19	dry	0.08	0.2	0.09	0.12	0.44	11.2
10/08/2006	0.25	5.7	<0.05	<0.05	<0.05	0.1	0.25	<0.05
13/09/2006	0.14	5.9	<0.01	0.29	0.06	0.05	0.14	15
21/03/2007	dry	dry	0.05	1.1	0.14	0.11	dry	dry

2.0

0.52

All values in mg/L.
(a) Sampling was attempted on 24/5/06 but all wells purged dry before sample could be taken.
bores constructed in 2006

⬜	Meets long term SRT guideline (1 mg/L TN and 0.1 mg/L TP)
🟨	Meets short term SRT guideline (2 mg/L TN and 0.2 mg/L TP)
🟨	Does not meet either guideline

APPENDIX E
GROUNDWATER SAMPLING RESULTS

Matrix:	WATER
Workorder:	EP0500814
Project name/number:	5.103
Project site:	Southern River
Purchase order number:	

				Sample type:	REG	REG	REG	REG	REG	REG	REG	REG	REG	REG	REG	REG	REG	REG	MS	MS	MB	MB	MB	LCS	LCS	LCS	LCS	DUP	DUP	DUP	DUP	DUP	DUP
				ALS Sample number:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	112531-011	112537-006	112511-001	112531-001	112537-001	112511-002	112531-002	112531-003	112537-002	112511-004	112511-014	112531-005	112531-022	112537-004	112537-017
				Client sample ID (Primary):	MW1	MW2	MW3	MW4	MW5	Dc	Dc(filtered)	Dm	Dm(filtered)	SW1	SW1(filtered	SW2	SW2(filtered	DUP	EP0500814002	EP0500814002								EP0500806001	EP0500816004	EP0500814001	EP0500814011	EP0500814001	EP0500814012
				Client sample ID (Secondary):																													
				Sample date:	16/08/2005	16/08/2005	16/08/2005	16/08/2005	16/08/2005	16/08/2005	16/08/2005	16/08/2005	16/08/2005	16/08/2005	16/08/2005	16/08/2005	16/08/2005	16/08/2005	18/08/2005	18/08/2005	17/08/2005	18/08/2005	18/08/2005	17/08/2005	18/08/2005	18/08/2005	18/08/2005	17/08/2005	17/08/2005	18/08/2005	18/08/2005	18/08/2005	18/08/2005
Analyte grouping/Analyte	**CAS Number**	**Units**	**LOR**																														
EA025: Suspended Solids																																	
Suspended Solids (SS)		mg/L	1		- - -	- - -	- - -	- - -	- - -	7	- - -	6	- - -	5	- - -	4	- - -	- - -	- - -	- - -	<1	- - -	- - -	- - -	- - -	- - -	- - -	157	6	- - -	- - -	- - -	- - -
EK059G: NOX as N by Discrete Analyser																																	
Nitrite + Nitrate as N		mg/L	0.01		0.57	0.038	0.054	<0.010	0.015	<0.010	<0.010	0.118	0.026	0.01	<0.010	0.013	<0.010	0.052	- - -	- - -	- - -	- - -	<0.010	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	0.49	<0.010
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser																																	
Total Kjeldahl Nitrogen as N		mg/L	0.1		7.4	5.6	7.7	22.4	14.9	2.9	2.6	4.6	4.5	4.2	4.1	1.6	1.4	7.7	- - -	- - -	- - -	<0.1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	6.2	4.2	- - -	- - -
EK062G: Total Nitrogen AsN By Discrete Analyset																																	
Total Nitrogen as N		mg/L	0.1		8	5.6	7.8	22.4	14.9	2.9	2.6	4.7	4.5	4.2	4.1	1.6	1.4	7.8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
EK067G: Total Phosphorous-As P by Discrete Analyser																																	
Total Phosphorus as P		mg/L	0.01		1.21	1.72	8.56	2.71	1.14	0.3	0.35	0.88	0.76	0.77	0.75	0.07	0.04	8.42	- - -	- - -	- - -	<0.01	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1.2	0.81	- - -	- - -

APPENDIX E
GROUNDWATER SAMPLING RESULTS

			MW1	MW2	MW3	MW4	MW5	DUP
		LoD	16/08/2005	16/08/2005	16/08/2005	16/08/2005	16/08/2005	16/08/2005
Nitrite + Nitrate as N	mg/L	0.01	0.57	0.038	0.054	<0.010	0.015	0.052
Total Kjeldahl Nitrogen as N	mg/L	0.1	7.4	5.6	7.7	22.4	14.9	7.7
Total Nitrogen as N	mg/L	0.1	8	5.6	7.8	22.4	14.9	7.8
Total Phosphorus as P	mg/L	0.01	1.21	1.72	8.56	2.71	1.14	8.42

			Dc	Dm	SW1	SW2
		LOD	16/08/2005	16/08/2005	16/08/2005	16/08/2005
Suspended Solids (SS)	mg/L	1	7	6	5	4
Particulate Nutrients						
Nitrite + Nitrate as N	mg/L	0.01	0	0.092	0	<0.013
Total Kjeldahl Nitrogen as N	mg/L	0.1	0.3	0.1	0.1	0.2
Total Nitrogen as N	mg/L	0.1	0.3	0.2	0.1	0.2
Total Phosphorus as P	mg/L	0.01	0.05	0.12	0.02	0.03
Dissolved Nutrients						
Nitrite + Nitrate as N	mg/L	0.01	<0.010	0.026	<0.010	<0.010
Total Kjeldahl Nitrogen as N	mg/L	0.1	2.6	4.5	4.1	1.4
Total Nitrogen as N	mg/L	0.1	2.6	4.5	4.1	1.4
Total Phosphorus as P	mg/L	0.01	0.35	0.76	0.75	0.04
Total Nutrients						
Nitrite + Nitrate as N	mg/L	0.01	<0.01	0.118	0.01	0.013
Total Kjeldahl Nitrogen as N	mg/L	0.1	2.9	4.6	4.2	1.6
Total Nitrogen as N	mg/L	0.1	2.9	4.7	4.2	1.6
Total Phosphorus as P	mg/L	0.01	0.4	0.88	0.77	0.07

			Dc	Dds	Dm	SW1	SW2
		LOD	23/08/2005	23/08/2005	23/08/2005	23/08/2005	23/08/2005
Suspended Solids (SS)	mg/L	1	7	<5	<5	<5	8
Particulate Nutrients							
Total Nitrogen as N	mg/L	0.1	*-0.5*	*-0.4*	*-0.4*	-0.1	0
Total Phosphorus as P	mg/L	0.01	*-0.3*	*0*	*0*	0.2	0.05
Dissolved Nutrients							
Total Nitrogen as N	mg/L	0.1	4.8	6.3	5.2	3.1	4.8
Total Phosphorus as P	mg/L	0.01	0.5	0.3	0.55	0.05	0.2
Total Nutrients							
Total Nitrogen as N	mg/L	0.1	4.3	5.9	4.8	3	4.8
Total Phosphorus as P	mg/L	0.01	0.2	0.3	0.55	0.25	0.25

APPENDIX E
GROUNDWATER SAMPLING RESULTS

		LOD	MW2	DupW	*% RPD*	Tripw	*% RPD*	MW4	MW5
			7/03/2006	7/03/2006		7/03/2006		7/03/2006	7/03/2006
pH	pH	0.1	7.5	6.3	*17*	-	-	7	6.2
Conductivity @25oC	µS/cm	2	130	130	*0*	-	-	3,100	800

		LOD	MW2	DupW	*% RPD*	TripW	*% RPD*	MW4	MW5	Rin
			7/03/2006	7/03/2006		7/03/2006		7/03/2006	7/03/2006	7/03/2006
Total persulfate Nitrogen as N	mg/L	0.05	3	2.9	*3*	2.4	*22*	14	17	0.18
Total persulfate Phosphorus as P	mg/L	0.01	0.6	0.63	*-5*	0.61	*-2*	0.35	1.2	0.01

OC Pesticides(DOE F/W)		LOD	MW2	DupW	*% RPD*	TripW	*%RPD*	MW4	MW5	Rin
			7/03/2006	7/03/2006		7/03/2006		7/03/2006	7/03/2006	7/03/2006
alpha Chlordane	µg/L	0.015	<0.01	<0.01	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.01
gamma Chlordane	µg/L	0.015	<0.01	<0.01	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.01
p,p'-DDT	µg/L	0.006	<0.006	<0.006	*#VALUE!*	<2	*#VALUE!*	-	-	<0.006
Endosulfan Sulphate	µg/L	0.01	<0.01	<0.01	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.01
Endrin	µg/L	0.01	<0.01	<0.01	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.01
Heptachlor	µg/L	0.01	<0.01	<0.01	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.01
Lindane	µg/L	0.07	<0.07	<0.07	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.07
Aldrin	µg/L	0.01	<0.01	<0.01	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.01
p,p'-DDE	µg/L	0.01	<0.01	<0.01	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.01
p,p'-DDD	µg/L	0.01	<0.01	<0.01	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.01
Dieldrin	µg/L	0.002	<0.002	<0.002	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.002
alpha Endosulfan	µg/L	0.01	<0.01	<0.01	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.01
beta Endosulfan	µg/L	0.01	<0.01	<0.01	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.01
Methoxychlor	µg/L	0.04	<0.04	<0.04	*#VALUE!*	<2	*#VALUE!*	-	-	<0.04
Mirex	µg/L	0.01	<0.01	<0.01	*#VALUE!*	-	*#VALUE!*	-	-	<0.01
HCB	µg/L	0.01	<0.01	<0.01	*#VALUE!*	<0.5	*#VALUE!*	-	-	<0.01

APPENDIX E
GROUNDWATER SAMPLING RESULTS

Wells ran dry after bailing 3 or 4 times. This is either because there was no groundwater, too silty/sandy to allow water into the small bailer or the bore was not recharging.
Waited for 10-20 mins and was bailing for a considerable amount of time with very small quantities of water purged.
No samples collected

APPENDIX E
GROUNDWATER SAMPLING RESULTS

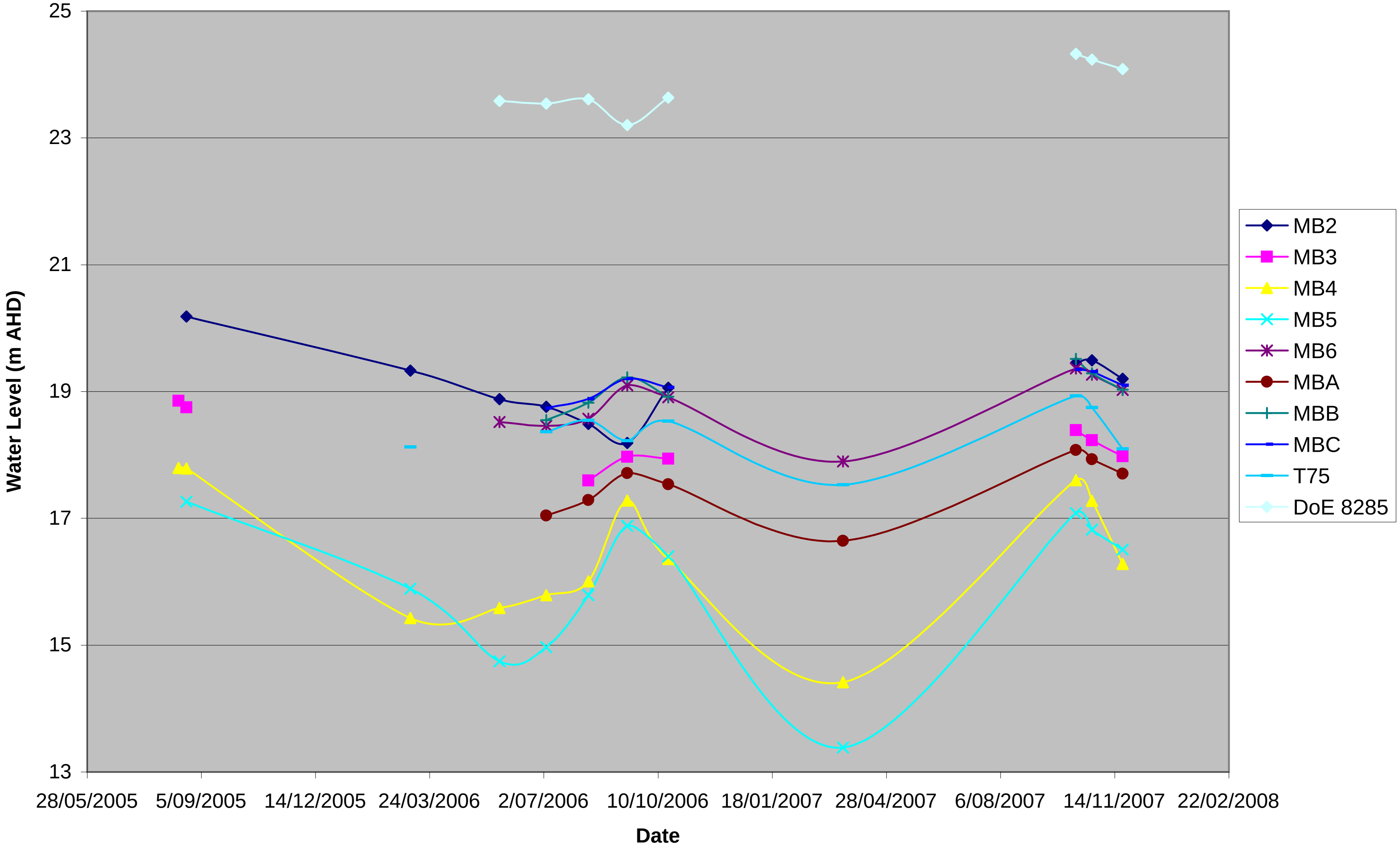
Reference	Description	Analyte Description	Units	Method	PQL	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Sample Description						MWA	MWB	MWC	MW2	MW3	MW4	MW5	MW6
Date Sampled						11/08/2006	10/08/2006	10/08/2006	10/08/2006	10/08/2006	10/08/2006	10/08/2006	10/08/2006
Type of Sample						Water	Water	Water	Water	Water	Water	Water	Water
97760	05.182, MIESS, CoC 1721	Ammonia Nitrogen NH_3-N	mg/L	PEI-010	<0.1	0.9	1.1	0.94	1.2	1.1	0.4	0.2	0.9
97760	05.182, MIESS, CoC 1721	Nitrate-Nitrogen, NO_3-N	mg/L	PEI-020	<0.05	1.1	0.1	0.82	0.39	<0.05	<0.05	1.1	0.16
97760	05.182, MIESS, CoC 1721	Nitrite-Nitrogen, NO_2-N	mg/L	PEI-020	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
97760	05.182, MIESS, CoC 1721	Kjeldahl Nitrogen	mg/L	PEI-012	<0.1	2.9	6.3	3	0.8	2.2	2.2	0.8	3.8
97760	05.182, MIESS, CoC 1721	Total Phosphorus, P	mg/L	PEI-014	<0.05	0.1	0.25	<0.05	0.25	5.7	<0.05	<0.05	<0.05
97760	05.182, MIESS, CoC 1721	Total Dissolved Solids (grav) @ 180^{o}C	mg/L	PEI-002	<10	760	850	790	250	340	4300	300	290
97760	05.182, MIESS, CoC 1721	Ortho Phosphorus, PO_4-P	mg/L	PEI-015	<0.05	<0.05	0.1	<0.05	0.2	5.5	<0.05	<0.05	<0.05
97760	05.182, MIESS, CoC 1721	Conductivity @25^{o}C	µS/cm	AN-106	<2	1300	1500	1500	400	460	7500	580	190

APPENDIX E
GROUNDWATER SAMPLING RESULTS

Reference	Description	Analyte Description	Units	Method	PQL	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Sample Description						MW2	MW3	MW4	MW5	MW6	MWA	MWB	MWC
Type of Sample						Water	Water	Water	Water	Water	Water	Water	Water
98394	05.182 Southern River CoC#1778	Total Persulphate Nitrogen, N	mg/L	PEI-069	<0.05	2.9	3.9	3.6	8.2	3.5	8	2.8	9.1
98394	05.182 Southern River CoC#1778	Total Persulphate Phosphorus, P	mg/L	PEI-070	<0.01	0.14	5.9	<0.01	0.29	0.06	0.05	0.14	15
98394	05.182 Southern River CoC#1778	Ortho Phosphorus, PO_4-P	mg/L	PEI-064	<0.003	0.086	5.6	<0.003	0.22	0.04	0.016	0.057	14
98394	05.182 Southern River CoC#1778	Ammonia Nitrogen, NH_3-N	mg/L	PEI-063	<0.005	0.19	0.29	0.013	0.04	0.27	0.61	0.16	0.61
98394	05.182 Southern River CoC#1778	Nitrate, NO_3	mg/L	PEI-061	<0.05	<0.05	<0.05	0.26	5.3	0.63	7.5	<0.05	<0.05
98394	05.182 Southern River CoC#1778	Nitrite, NO_2	mg/L	PEI-061	<0.05	0.07	0.11	<0.05	0.14	0.22	<0.05	0.07	<0.05
98394	05.182 Southern River CoC#1778	Kjeldahl Nitrogen (calculated)	mg/L	PEI-061/069	<0.05	2.9	3.9	3.5	6.9	3.3	6.3	2.8	9.1

APPENDIX E
GROUNDWATER SAMPLING RESULTS

Reference	Description	Analyte Description	Units	Method	PQL	Sample 1	Sample 2	Sample 3	Sample 4
Sample Description						MWA	MW4	MW6	MW5
Date Sampled						21/03/2007	21/03/2007	21/03/2007	21/03/2007
Type of Sample						Water	Water	Water	Water
11236	06.024 CoC#1958	Total Persulphate Nitrogen, N	mg/L	PEI-069	<0.05	2.9	2.2	3.6	5.9
11236	06.024 CoC#1958	Total Persulphate Phosphorus, P	mg/L	PEI-070	<0.01	0.11	0.05	0.14	1.1
11236	06.024 CoC#1958	Ortho Phosphorus, PO_4-P	mg/L	PEI-064	<0.003	0.08	0.05	0.13	0.01
11236	06.024 CoC#1958	Ammonia Nitrogen, NH_3-N	mg/L	PEI-063	<0.005	0.56	0.24	0.79	0.2
11236	06.024 CoC#1958	Nitrate-Nitrogen, NO_3-N	mg/L	PEI-061	<0.005	0.011	<0.005	<0.005	0.048
11236	06.024 CoC#1958	Nitrite-Nitrogen, NO_2-N	mg/L	PEI-061	<0.005	0.016	0.009	0.066	0.015
11236	06.024 CoC#1958	Kjeldahl Nitrogen	mg/L	PEI-065	<0.05	2.8	2.2	3.6	5.8



Water Level (m AHD)
25
23
21
19
17
15
13
28/05/2005
5/09/2005
14/12/2005
24/03/2006
2/07/2006
10/10/2006
18/01/2007
28/04/2007
6/08/2007
14/11/2007
22/02/2008
Date
MB2
MB3
MB4
MB5
MB6
MBA
MBB
MBC
T75
DoE 8285

APPENDIX E
GROUNDWATER SAMPLING RESULTS

%RPD Calculations
Southern River Water

16/08/2005	Primary Sample MW3	Duplicate Sample Dup	%RPD
Analyte			
Metals			
Nitrite + Nitrate as N	0.054	0.052	-4
Total Kjeldahl Nitrogen as N	7.7	7.7	0
Total Nitrogen as N	7.8	7.8	0
Total Phosphorus as P	8.56	8.42	2

APPENDIX E
GROUNDWATER SAMPLING RESULTS

pH, EC and Temperature

Bore	MW-A			MW-B			MW-C			MW-2			MW-3			MW-4			MW-5			MW-6		
Date	pH	EC	Temp	pH	EC	Temp	pH	EC	Temp	pH	EC	Temp	pH	EC	Temp	pH	EC	Temp	pH	EC	Temp	pH	EC	Temp
19/10/2006	4.53	1.13	18.1	5.8	1.33	20.4	5.64	0.99	18.4	5.51	0.21	20.6	5.39	0.65	19.2	6.22	2.13	20.6	4.58	0.57	21.6	5.42	0.18	20.1
22/03/2007	4.88	1.04	20.92													6.34	4.34	22.22	5.08	0.39	20.39	4.72	0.201	24

APPENDIX E
GROUNDWATER SAMPLING RESULTS

SURFACE WATER									
Date Received:	24/08/2005								
PO Number:									
Description:	05.103 CofC 1263								
-									

Our Reference:	UNITS	91069-1	91069-2	91069-3	91069-4	91069-5	91069-6	91069-7	91069-8
Your Reference	--	1U	1F	2U	2F	3U	3F	4U	4F
Date Sampled:	--	23/08/2005	23/08/2005	23/08/2005	23/08/2005	23/08/2005	23/08/2005	23/08/2005	23/08/2005
Total Suspended Solids @103oC	mg/L	<5	[NA]	8	[NA]	7	[NA]	<5	[NA]
Electrical Conductivity @25oC	µS/cm	170	[NA]	1,100	[NA]	1,600	[NA]	1,600	[NA]
Total Nitrogen, N	mg/L	3	3.1	4.8	4.8	4.3	4.7	5.9	6.3
Total Phosphorus, P	mg/L	0.25	0.2	0.55	0.5	0.2	0.2	0.3	0.3

Our Reference:	UNITS	91069-9	91069-10	91069-11					
Your Reference	--	5U	5F	DUP					
Date Sampled:	--	23/08/2005	23/08/2005	23/08/2005					
Total Suspended Solids @103oC	mg/L	<5	[NA]	[NA]					
Electrical Conductivity @25oC	µS/cm	1,100	[NA]	[NA]					
Total Nitrogen, N	mg/L	4.8	5.2	5.4					
Total Phosphorus, P	mg/L	0.55	0.55	0.65					

1=SW1
2=SW2
3=Dc
5=Dm

APPENDIX F

RAINWATER TO TOILET FLUSHING CALCULATIONS

APPENDIX F - Toilet Water Supply for a 210 m2 house

Assume 210 m2 roof area
Assume 3500 L tank
Assume 85% of rainfall enters the tank

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*		*Total*
Rain	15	6	23	25	91	140	149	123	84	43	26	5	15	745
Epan	323	280	242	152	97	64	66	80	108	168	227	290		2099
Epot	0	0	0	0	0	0	0	0	0	0	0	0		0
Roof rain (kL)	3.17	1.23	4.91	5.26	19.06	29.39	31.19	25.85	17.73	9.01	5.41	1.10	3.15	
Rain entering tank (kL)	2.69	1.04	4.18	4.47	16.20	24.98	26.51	21.97	15.07	7.66	4.60	0.93	2.68	130.31
Storage from prev month	0.00	0.00	0.00	0.70	1.71	3.50	3.50	3.50	3.50	3.50	3.50	3.50	0.96	
Rainfall plus prev month	2.69	1.04	4.18	5.18	17.91	28.48	30.01	25.47	18.57	11.16	8.10	4.43	3.64	
Toilet water use (kL)	3.472	3.136	3.472	3.472	3.472	3.472	3.472	3.472	3.472	3.472	3.472	3.472	3.472	41.328
Volume over monthly use	0.00	0.00	0.70	1.71	14.44	25.01	26.54	22.00	15.10	7.68	4.63	0.96	0.00	118.77
Monthly storage	0	0	0.70	1.71	3.50	3.50	3.50	3.50	3.50	3.50	3.50	0.96	0.00	
Monthly overflow	0	0	0.00	0.00	10.94	21.51	23.04	18.50	11.60	4.18	1.13	0.00	0.00	90.89
Potable water required	0.78	2.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.54	0.79	5.41

Rainfall Used 35.91

Inflow 135.72
Outflow 132.22
-3.50

Percentage of Rainwater as total toilet use **87 %**

APPENDIX G
SITE WATER BALANCES

APPENDIX G
SITE WATER BALANCES

Predevelopment

Bushland, assuming 75%of rainfall is transpired (as per Rockwater)

Total flow to groundwater/streams	100378	kL/yr for site
	100	ML/yr for site
	401510	

APPENDIX G
SITE WATER BALANCES

Assumptions

Commercial development - 80% roof, 10% paved (Perth Urban Water Balance Study, WAWA 1997)
4.99 ha of road reserve, of which 60% is verge
Assume verge is 40% driveway, 60% grass
Average lot size is assumed to be 404 m2.
Assume average house size is 210 m2. Therefore there is 194 m2 of lawn and paving. Assume that 60% of the remainder is lawn/garden and remainder is paving
Therefore Lawn/garden area = 116 m2, paving/hardstand = 78 m2.
Non-waterwise garden water use is based on 155 kL/house/yr or 424.7 L/house/day as given by E. Sahouryeh of Water Corporation
References to GHD (2005) are to *Non-potable Water Use: Guidelines for developers and their consultants* (draft) (GHD, 2005 b in the references)

Irrigation of POS occurs at a rate of 60% of the evaporation rate between September and April. (DoE turf management)
70% of houses have lot drainage. Lot drainage and any sub-surface drainage are assumed not to affect recharge rates.
Goal of potable water use of 40-60 kL/person/yr. We assume that each house has 2.4 residents (ABS 2001 Data)
Drainage areas in POS do not require irrigation.
Potable and non-potable water consumption from commercial areas is assumed to be negligible.

Rain on Hard Surfaces is 4.5% Evap, 95.5% stormwater (WAWA, 1987)
Rain and Irriation on Soft Surfaces has a 17.5% evap/surface loss (GHD, 2005 b)

Rainfall and Evaporation as per Perth Airport Averages 1995 - 2005

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Total*
Monthly Rainfall	15	6	23	25	91	140	149	123	84	43	26	5	730
Monthly Evaporation	323	280	242	152	97	64	66	80	108	168	227	290	2099
Rainfall - Evaporation	-308	-274	-219	-127	-6	76	83	43	-24	-125	-202	-284	-1369

Input parameters

A	Total Lots	802	From planners	
B	Residential (Ha)	32.41	From planners	
C	Commercial (Ha)	1	From planners	
D	POS (Ha)	4.85	From planners	
E	Drainage in POS (Ha)	*2.96*	From DPM	
F	Non-Drainage POS (Ha)	1.89	F=D-E	
G	Road Reserve (Ha)	16.74	From planners	
H	Total Area (Ha)	55	H=B+C+D+G	
I	Road Reserve as road (Ha)	10.044	I=0.6*G	Assumes 60% of road reserve is road
J	Road Reserve as swale (Ha)	2.2	From DPM	
K	Road Reserve as verge (Ha)	4.496	K=G-I-J	
L	Verge per house (m2/house)	56.06	L=10000*K/A	
M	Verge driveway per house (m2/house)	22.42	M=0.4*L	Driveway assumed to run off onto lawns
N	Verge lawn per house	33.64	N=0.6*L	
O	Commercial Irrigated Area	0.10	O=0.1*C	

From Above, on a per house basis, excluding verges

O	Lot Area (m2)	404
P	Average house size (m2)	210
Q	Non verge lawn/garden (m2)	116
R	External paving/hardstand (m2)	78

APPENDIX G
SITE WATER BALANCES

Total Recharge to groundwater from Household Irrigation and Household runoff. Excludes Swales
Non-waterwise scenario
Assumes that household irrigation includes non-swale verges, calculated as per assumptions sheet
Assumes that driveway is 40% of verge and runs off onto the lawn
From GHD (2005)
Epot=0.7*Pan Evaporation

Annual Evaporation

		Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	***Total***
A	Rain	15	6	23	25	91	140	149	123	84	43	26	5	**730**
B	Epan	323	280	242	152	97	64	66	80	108	168	227	290	**2099**
C	Epot	226	196	170	107	68	45	46	56	76	118	159	203	**1469**

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
D	GHD (2005)- gives ratios over an annual basis	911	911	841	561	280	140	35	35	70	351	771	911	**484.75**	From GHD (2005)
D	Irrigation in our subdivision (L/house/day)	798	798	737	492	245	123	31	31	61	308	675	798	**424.7**	Based on E.Sahouryeh, Water Corp.
E	kL/house/month	24.74	24.74	22.84	15.24	7.60	3.80	0.95	0.95	1.90	9.53	20.94	24.74	**157.9884**	
F	Garden Rainfall including verge (kL/house/month)	2.26	0.87	3.50	3.75	13.58	20.94	22.22	18.42	12.63	6.42	3.86	0.78	**109.23694**	
G	Roof splash (10% of rain falling on rooves)	0.32	0.12	0.49	0.53	1.91	2.94	3.12	2.58	1.77	0.90	0.54	0.11	**15.330382**	
H	Paving runoff (includes driveway)	1.45	0.56	2.24	2.40	8.71	13.42	14.24	11.81	8.10	4.11	2.47	0.50	**70.012294**	
I	**Total input to gardens (kL/house/month)**	28.76	26.30	29.08	21.91	31.80	41.11	40.53	33.76	24.40	20.97	27.81	26.14	**352.57**	
J	Surface evaporation and interception losses	5.03	4.60	5.09	3.84	5.57	7.19	7.09	5.91	4.27	3.67	4.87	4.57	**61.70**	
K	**Total input - surface evap**	23.73	21.70	23.99	18.08	26.24	33.91	33.44	27.85	20.13	17.30	22.94	21.56	**290.87**	
L	**Potential Evap for area**	33.86	39.83	34.44	21.63	13.74	9.15	9.37	11.41	15.39	23.91	32.32	41.17		
M	**Total input - potential evap**	-10.13	-18.13	-10.45	-3.55	12.50	24.77	24.07	16.44	4.75	-6.61	-9.38	-19.60		
N	**Therefore infiltration to groundwater from gardens(kL/house)**	0	0	0.00	0.00	12.50	24.77	24.07	16.44	4.75	0.00	0.00	0.00	**82.52**	
O	**TOTAL GARDEN INFILTRATION FOR ESTATE**	0	0	0	0	10025	19864	19304	13183	3806	0	0	0	**66184**	
P	**Water to soakwells or drains from roof (kL/house/month)**	2.9	1.1	4.5	4.8	17.6	27.1	28.7	23.8	16.3	8.3	5.0	1.0	**141.3**	
Q	**TOTAL SOAKWELL OR DRAIN INFILTRATION FOR ESTATE (kL)**	2339	906	3632	3889	14090	21723	23049	19104	13102	6657	3999	813	**113301**	
R	**Total Irrigation Water Use for Residential areas (kL)**	19844	19844	18319	12220	6099	3049	762	762	1525	7646	16794	19844	**126707**	

APPENDIX G
SITE WATER BALANCES

Total Recharge to groundwater from Household Irrigation and Household runoff. Excludes Swales
Waterwise scenario
Assumes that household irrigation includes non-swale verges, calculated as per assumptions sheet
Assumes that driveway is 40% of verge and runs off onto the lawn
From GHD (2005)
Epot=0.7*Pan Evaporation

Annual Evaporation

		Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	***Total***
A	Rain	15	6	23	25	91	140	149	123	84	43	26	5	**730**
B	Epan	323	280	242	152	97	64	66	80	108	168	227	290	**2099**
C	Epot	226	196	170	107	68	45	46	56	76	118	159	203	**1469**

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		
D	GHD (2005)- gives ratios over an annual basis	911	911	841	561	280	140	35	35	70	351	771	911	**484.75**	From GHD (2005)
D	Irrigation in our subdivision (L/house/day)	798	798	737	492	245	123	31	31	61	308	675	798	**425**	
E	kL/house/month	24.74	24.74	22.84	15.24	7.60	3.80	0.95	0.95	1.90	9.53	20.94	24.74	**157.9884**	
F	Garden Rainfall (kL/house/month) includes verge	2.26	0.87	3.50	3.75	13.58	20.94	22.22	18.42	12.63	6.42	3.86	0.78	**109.2369**	
G	Roof splash (10% of rain falling on rooves)	0.32	0.12	0.49	0.53	1.91	2.94	3.12	2.58	1.77	0.90	0.54	0.11	**15.33038**	
H	Paving runoff (includes driveway)	1.45	0.56	2.24	2.40	8.71	13.42	14.24	11.81	8.10	4.11	2.47	0.50	**70.01229**	
I	**Total input to gardens (kL/house/month)**	28.76	26.30	29.08	21.91	31.80	41.11	40.53	33.76	24.40	20.97	27.81	26.14	**352.57**	
J	Surface evaporation and interception losses	5.03	4.60	5.09	3.84	5.57	7.19	7.09	5.91	4.27	3.67	4.87	4.57	**61.70**	
K	**Total input - surface evap**	23.73	21.70	23.99	18.08	26.24	33.91	33.44	27.85	20.13	17.30	22.94	21.56	**290.87**	
L	**Potential Evap for area**	33.86	39.83	34.44	21.63	13.74	9.15	9.37	11.41	15.39	23.91	32.32	41.17		
M	**Total input - potential evap**	-10.13	-18.13	-10.45	-3.55	12.50	24.77	24.07	16.44	4.75	-6.61	-9.38	-19.60		
N	**Therefore infiltration to groundwater from gardens(kL/house)**	0	0	0.00	0.00	12.50	24.77	24.07	16.44	4.75	0.00	0.00	0.00	**82.52**	
O	**TOTAL GARDEN INFILTRATION FOR ESTATE**	0	0	0	0	10025	19864	19304	13183	3806	0	0	0	**66184**	
P	**Water to soakwells or drains from roof and paving (kL/house/month)**	2.9	1.1	4.5	4.8	17.6	27.1	28.7	23.8	16.3	8.3	5.0	1.0	**141.3**	
Q	**TOTAL SOAKWELL OR DRAIN INFILTRATION FOR ESTATE (kL)**	2339	906	3632	3889	14090	21723	23049	19104	13102	6657	3999	813	**113301**	
R	**Total Irrigation Water Use for Residential areas (kL)**	19844	19844	18319	12220	6099	3049	762	762	1525	7646	16794	19844	**126707**	

APPENDIX G
SITE WATER BALANCES

Total Recharge to groundwater from Non-Drainage POS and irrigated Commerical areas
Includes both irrigation and rainfall
Irrigated commercial areas (ie green space around shopping centres) assumed to be irrigated as per non-drainage POS

From GHD (2005)
Epot=0.7*Pan Evaporation
Assume that 30% is shrubs, rest is irrigated lawn

Annual Evaporation

		Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Total*
A	Rain	15	6	23	25	91	140	149	123	84	43	26	5	730
B	Epan	323	280	242	152	97	64	66	80	108	168	227	290	2099
C	Epot	226	196	170	107	68	45	46	56	76	118	159	203	1469
	Turf Irrig (kL/d/ha) from GHD (2005)	52	51	34	17	0	0	0	0	0	18	28	47	247
	Shrub Irrig (kL/d/ha) from GHD (2005)	34	33	21	9	0	0	0	0	0	9	15	31	152
	Average volume per ha assuming 30% shrubs (kl/d/ha)	46.6	45.6	30.1	14.6	0	0	0	0	0	15.3	24.1	42.2	218.5
E	**For Total Irrigated POS Monthly irrigation (kL/month)**	**2874.75**	**2813.06**	**1856.87**	**900.67**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**943.86**	**1486.73**	**2603.32**	**13479.265**
F	Rainfall (kL/month)	299.95	116.14	465.66	498.59	1806.56	2785.28	2955.33	2449.51	1679.92	853.53	512.70	104.20	7300.18
I	Total input (kL/ha/month)	3174.70	2929.21	2322.53	1399.26	1806.56	2785.28	2955.33	2449.51	1679.92	1797.39	1999.43	2707.52	20779.45
J	Surface evaporation and interception losses	1105.59	1020.10	808.82	487.29	629.13	969.97	1029.19	853.04	585.03	625.94	696.30	942.89	3636.40
K	Total input - surface evap	2069.11	1909.11	1513.71	911.97	1177.42	1815.30	1926.14	1596.47	1094.89	1171.45	1303.13	1764.63	17143.04
L	Evapotransipiration for area	4502.81	3904.45	3376.13	2119.89	1346.52	896.59	918.62	1118.83	1508.24	2343.66	3168.44	4035.65	29239.83
M	Total input - evapotranspiration	-2433.70	-1995.34	-1862.42	-1207.93	-169.10	918.72	1007.52	477.64	-413.35	-1172.21	-1865.32	-2271.02	
N	**Therefore infiltration to groundwater from non-drainage POS (kL/month)**	0	0	0	0	0	918.7184	1007.517	477.6353	0	0	0	0	2403.87

APPENDIX G
SITE WATER BALANCES

Total Recharge to groundwater from Drainage POS, Drainage Swales and Roads
Assumes no irrigation of these areas
Verges are included in 'Household irrigation' spreadsheets

From GHD (2005)
Epot=0.7*Pan Evaporation
Assume that drainage
structures are not irrigted

Annual Evaporation

		Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Total*
A	Rain	15	6	23	25	91	140	149	123	84	43	26	5	730
B	Epan	323	280	242	152	97	64	66	80	108	168	227	290	2099
C	Epot	226	196	170	107	68	45	46	56	76	118	159	203	1469
	Rainfall falling on roads (kL)	1513.90	586.20	2350.30	2516.48	9118.13	14057.95	14916.25	12363.25	8478.96	4307.96	2587.70	525.94	73323.03
	Interception losses (kL)	68.13	26.38	105.76	113.24	410.32	632.61	671.23	556.35	381.55	193.86	116.45	23.67	3299.54
	Runoff from roads (kL)	1445.78	559.83	2244.53	2403.24	8707.81	13425.34	14245.02	11806.90	8097.41	4114.10	2471.25	502.27	70023.49
	Rain falling on drainage structures (kL)	777.75	301.16	1207.44	1292.81	4684.34	7222.12	7663.07	6351.49	4355.98	2213.17	1329.40	270.20	37668.94
	Interception losses (kL)	136.11	52.70	211.30	226.24	819.76	1263.87	1341.04	1111.51	762.30	387.30	232.65	47.28	6592.06
	Evapotranspiration (kL)	8172.94	7086.88	6127.92	3847.77	2444.04	1627.37	1667.36	2030.76	2737.57	4253.92	5750.96	7325.00	53072.50
	Total rainfall on roads and drainage structures minus total losses (kL)	-6085.51	-6278.60	-2887.25	-377.96	10128.35	17756.22	18899.69	15016.12	8953.52	1686.05	-2182.95	-6599.82	48027.87
	Therefore infiltration to groundwater from drainage structures (kL/month)	0	0	0	0	10128.35	17756.222	18899.689	15016.12	8953.523	1686.053	0	0	72439.95

APPENDIX G
SITE WATER BALANCES

Commercial Areas

Breakdown of land use as Perth Urban Water Balance, WAWA, 1987

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Total*
Monthly Rainfall	15	6	23	25	91	140	149	123	84	43	26	5	730
Monthly Evaporation	323	280	242	152	97	64	66	80	108	168	227	290	2099
Rainfall - Evaporation	-308	-274	-219	-127	-6	76	83	43	-24	-125	-202	-284	-1369

Commercial Area	1 Ha
Commercial Roof	0.8 Ha
Commerical Paving	0.1 Ha
Commercial Irrigated	0.1 Ha

Note: Commerical irrigated has been added to POS irrigated for ease of calculations

Rainfall falling on roof and paving(kL)	135.65	52.53	210.60	225.49	817.04	1259.67	1336.58	1107.82	759.76	386.02	231.87	47.13	6570.16
Roof Interception losses (kL)	6.10	2.36	9.48	10.15	36.77	56.69	60.15	49.85	34.19	17.37	10.43	2.12	295.66
Total Runoff from commercial (kL)	129.55	50.16	201.12	215.34	780.27	1202.99	1276.44	1057.97	725.57	368.65	221.44	45.01	**6274.51**

APPENDIX G
SITE WATER BALANCES

From Rockwater Report, with revised ex-house use
Estimated ex-house water use is 424.7 L/house/day as per Water Corp
post restrictions estimation

Domestic Water Use					
Goal of 60 kL/person/yr =	201	kL/house/yr	161202	kL/estate/yr	550.6849315
Goal of 40 kL/person/yr =	134	kL/house/yr	107468	kL/estate/yr	367.1232877

	Conventional Daily L/house/day	**Annual kL/house/yr**	**Waterwise Daily L/house/day**	**Annual kL/house/yr**	**% conventional**		
In-house							
Bath and shower	171	62	161	59	94		
Washing Machine	139	51	89	32	64		
Toilet	112	41	75	27	67		
Tap	83	30	69	25	83		
other	18	7	14	5	78		
	523	191	408	149	78		
Ex-house							
Irrigation	425	155	425	155	100	39867.125	39838.98
Total	948	346	833	304	88		

Conventional use as per Perth Domestic Water Use Study
I'm not sure what they used to get the waterwise numbers

Estate Potable Water Use

	Conventional No bore use kL/estate/yr	**Conventional one third bores kL/estate/yr**	**Conventional All bores kL/estate/yr**	**Waterwise No bore use kL/estate/yr**	**Waterwise one third bores kL/estate/yr**	**Waterwise All bores kL/estate/yr**
In-house						
Bath and shower	50057	50057	50057	47130	47130	47130
Washing Machine	40689	40689	40689	26053	26053	26053
Toilet	32786	32786	32786	21654	21654	21654
Tap	24297	24297	24297	20198	20198	20198
other	5269	5269	5269	4098	4098	4098
Total in-house or wastewater produced	**153098**	**153098**	**153098**	**119133**	**119133**	**119133**
Ex-house						
Irrigation	124322	82882	0	124410	82940	0
Total Potable Water	277420	235979	153098	243543	202073	119133
Bore water use	0	**41441**	**124322**	**0**	**41470**	**124410**

Note: ex-house water use is not proportional to lot size for single residential units (Perth Domestic Water Use Study)

APPENDIX G
SITE WATER BALANCES

Post Development Water Balance, Assuming POS Irrigated from Bore water and 1/3 of Households Use Bores
Non-waterwise scenario

All values in ML on this sheet, as opposed to kL on other sheets

	Drainage and Infiltration (ML)	Bore Water Use (ML)
Houses	179.48	41.44
Non-drainage POS and commercial irrigated areas	2.40	13.48
Drainage areas and roads	72.44	0.00
Commerical	6.27	0.00

Total recharge to groundwater and drains	**260.60**	**ML**
Total bore water use	**54.92**	**ML**
Net Recharge (Recharge minus bore water use)	**205.68**	**ML**
Total potable water use	**235.98**	**ML**
Total non-potable water use	**54.92**	**ML**

APPENDIX G
SITE WATER BALANCES

Post Development Water Balance, Assuming POS Irrigated from Bore water and All Households Use Bores
Non-Waterwise scenario

All values in ML on this sheet, as opposed to kL on other sheets

	Drainage and Infiltration (ML)	Bore Water Use (ML)
Houses	179.48	124.32
Non-drainage POS and commercial irrigated areas	2.40	13.48
Drainage areas and roads	72.44	0.00
Commerical	6.27	0.00

Total recharge to groundwater and drains	**260.60**	**ML**
Total bore water use	**137.80**	**ML**
Net Recharge (Recharge minus bore water use)	**122.80**	**ML**
Total potable water use	**235.98**	**ML**
Total non-potable water use	**137.80**	**ML**

APPENDIX G
SITE WATER BALANCES

Post Development Water Balance, Assuming POS Irrigated from Bore water and 1/3 of Households Use Bores Waterwise scenario

All values in ML on this sheet, as opposed to kL on other sheets

	Drainage and Infiltration (ML)	Bore Water Use (ML)
Houses	179.48	41.47
Non-drainage POS and commercial irrigated areas	2.40	13.48
Drainage areas and roads	72.44	0.00
Commerical	6.27	0.00

Total recharge to groundwater and drains	**205.65**	**ML**
Total bore water use	**54.95**	**ML**
Net Recharge (Recharge minus bore water use)	**150.70**	**ML**
Total potable water use	**235.98**	**ML**
Total non-potable water use	**54.95**	**ML**

APPENDIX G
SITE WATER BALANCES

Post Development Water Balance, Assuming POS Irrigated from Bore water and All Households Use Bores

Waterwise scenario

All values in ML on this sheet, as opposed to kL on other sheets

	Drainage and Infiltration (ML)	Bore Water Use (ML)
Houses	179.48	124.41
Non-drainage POS and commercial irrigated areas	2.40	13.48
Drainage areas and roads	72.44	0.00
Commerical	6.27	0.00

Total recharge to groundwater and drains	**260.60**	**ML**
Total bore water use	**137.89**	**ML**
Nett Recharge (Recharge minus bore water use)	**122.71**	**ML**
Total potable water use	**235.98**	**ML**
Total non-potable water use	**137.89**	**ML**

APPENDIX G
SITE WATER BALANCES

Toilet Water Supply for a 210 m2 house
Actual house area used in Model

Assume 210 m2 roof area
Assume 3500 L tank
Assume 85% of rainfall enters the tank

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*		*Total*
Rain	15	6	23	25	91	140	149	123	84	43	26	5	15	745
Epan	323	280	242	152	97	64	66	80	108	168	227	290		2099
Epot	0	0	0	0	0	0	0	0	0	0	0	0		0
Roof rain (kL)	3.17	1.23	4.91	5.26	19.06	29.39	31.19	25.85	17.73	9.01	5.41	1.10	3.15	
Rain entering tank (kL)	2.69	1.04	4.18	4.47	16.20	24.98	26.51	21.97	15.07	7.66	4.60	0.93	2.68	130.31
Storage from prev month	0.00	0.00	0.00	0.70	1.71	3.50	3.50	3.50	3.50	3.50	3.50	3.50	0.96	
Rainfall plus prev month	2.69	1.04	4.18	5.18	17.91	28.48	30.01	25.47	18.57	11.16	8.10	4.43	3.64	
Toilet water use (kL)	3.472	3.136	3.472	3.472	3.472	3.472	3.472	3.472	3.472	3.472	3.472	3.472	3.472	41.328
Volume over monthly use	0.00	0.00	0.70	1.71	14.44	25.01	26.54	22.00	15.10	7.68	4.63	0.96	0.00	118.77
Monthly storage	0	0	0.70	1.71	3.50	3.50	3.50	3.50	3.50	3.50	3.50	0.96	0.00	
Monthly overflow	0	0	0.00	0.00	10.94	21.51	23.04	18.50	11.60	4.18	1.13	0.00	0.00	90.89
Potable water required	0.78	2.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.54	0.79	5.41

Rainfall Used	35.91
Inflow	135.72
Outflow	132.22
	-3.50

Percentage of Rainwater as total toilet use	**87 %**

APPENDIX G
SITE WATER BALANCES

Post Development Water Balance, Assuming POS Irrigated from Bore water and 1/3 of Households Use Bores Waterwise scenario with Rainwater tanks piped to toilets

All values in ML on this sheet, as opposed to kL on other sheets

	Drainage and Infiltration (ML)	Bore Water Use (ML)	Rainwater use (ML)
Houses	150.68	41.47	28.8038
Non-drainage POS and commercial irrigated areas	2.40	13.48	0
Drainage areas and roads	72.44	0.00	0
Commerical	6.27	0.00	0

Total recharge to groundwater and drains	**176.85**	**ML**
Total bore water use	**54.95**	**ML**
Nett Recharge (Recharge minus bore water use)	**121.90**	**ML**

Total potable water use	**207.18**	**ML**
Total non-potable water use	**83.75**	**ML**

APPENDIX H

DETAILS OF DRAINAGE PIPE SIZING AND FLOW RATES

LEGEND

■ ■ ■ ■	CATCHMENT BOUNDARY
– · – · –	SWALES (1 YEAR)
⊗	WATER GARDENS (1 YEAR)
🟪	LOCAL CATCHMENT BOUNDARIES
▢	PUBLIC OPEN SPACE
▨	DRAINAGE STORAGE (5 YEAR)
23.0	MIN. FILL LEVELS
19•58	MAX. GWL SPOT LEVELS
19.0	MAX. GWL CONTOURS
→	FLOW DIRECTION
–·–·–●	PIPE DRAIN & JUNCTION PIT
🟩	CCW WETLANDS
C4	CATCHMENT

NOTES:

1. 1 IN 1 YEAR CONTAINED & INFILTRATED TO LOCAL SWALESOR WATER GARDENS.

2. 100 YEAR EVENT CONTAINED IN P.O.S & SWALE (OUTLET DESIGNED AS PER PRE-DEVELOPMENT FLOWS)

3. LOT/HOUSE DRAINAGE DISPOSED OF BY INFILTRATION ONSITE.

4. MIN CLEARANCE OF 1.5m BETWEEN AAMGL AND FINISHED LOT SURFACE LEVEL.

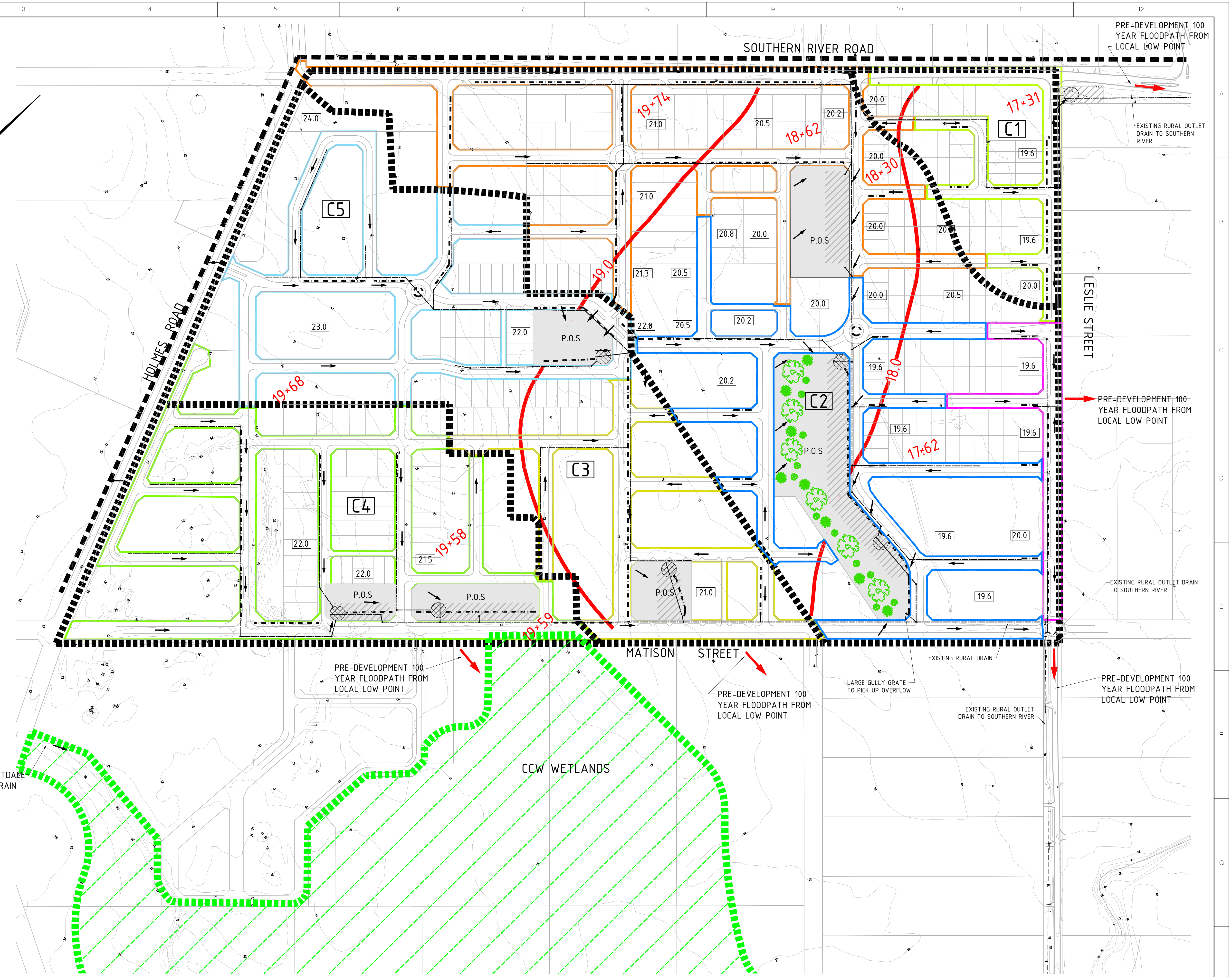
CATCHMENT KEY

🟩	A
🟪	B
🟦	C
🟧	D
🟨	E
🟩	F
🟦	G

CATCHMENT	ROAD RESERVE AREAS (Ha)	LOT AREAS (Ha)	TOTAL
C1-A	1.44	2.28	3.72
C2-B	0.92	0.99	1.91
C2-C	3.40	7.17	10.57
C2-D	3.90	7.69	11.59
C3-E	2.13	3.97	6.10
C4-F	3.86	6.62	10.48
C5-G	2.90	6.95	9.85
TOTAL	18.55	35.67	54.22

CATCHMENT	1 IN 5 YEAR AREA OF INUNDATION
C1	-
C2	8816m²
C3 & C5	1346m²
C4	3116m²

EXISTING SERVICES - INFORMATION ON THESE DRAWINGS PURPORTING TO RELATE TO EXISTING SERVICES IS INDICATIVE ONLY AND MAY NOT BE COMPLETE REFER TO SPECIFICATION AND CLAUSE 12 OF AS4000



-40 0 40 80 120 160 200m
1:2000

REV	REVISION	DATE	APPROVED
B	1 IN 5 YEAR DRAINAGE STORAGE AMENDED		
A	ISSUED FOR APPROVAL		

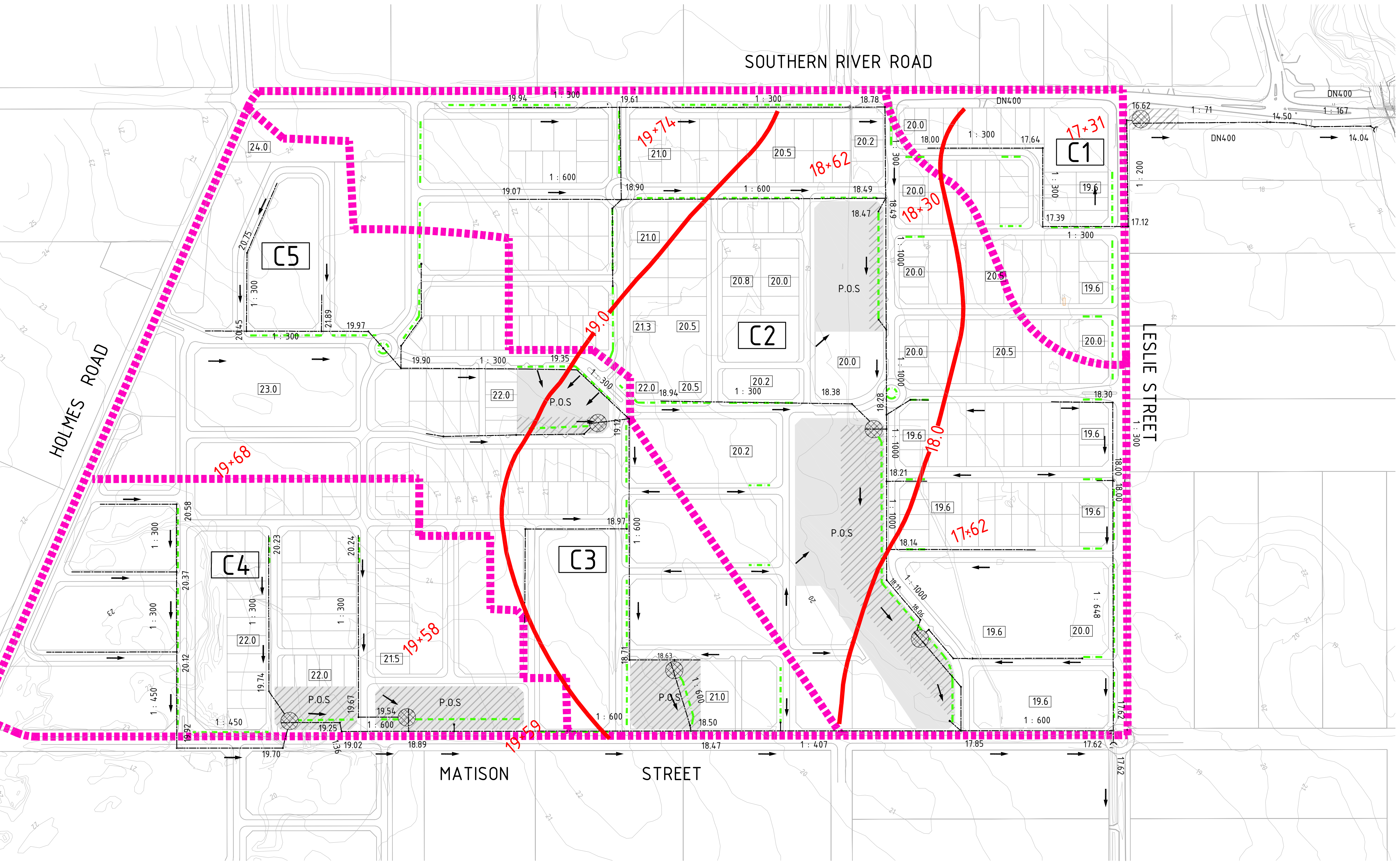
CLIENT
WRF PROPERTY LTD

THE CIVIL GROUP
CONSULTING CIVIL ENGINEERS
38 Richardson Street West Perth WA 6005
Telephone: (08) 9481 4255
Facsimile: (08) 9481 3900

DRAWN L. Fisher
DESIGNED L. Fisher
CHECKED
APPROVED
DATE

TITLE
CELL 3A SOUTHERN RIVER
DRAINAGE CATCHMENT PLANNING FOR WRF LAND HOLDING

ORIGINAL SHEET SIZE A1
DO NOT SCALE
SCALE 1:2000
LEVEL DATUM : AHD
SHEET OF
DRAWING No 7488-33
REV B



LEGEND

▬ ▬ ▬	CATCHMENT BOUNDARY
- - - -	SWALES (1 YEAR)
⊗	WATER GARDENS (1 YEAR)
▭	PUBLIC OPEN SPACE
▨	DRAINAGE STORAGE (100 YEAR)
▭	MIN. FILL LEVELS
19+58	MAX. GWL SPOT LEVELS
—19.0—	MAX. GWL CONTOURS
→	FLOW DIRECTION
-·-·-·●	PIPE DRAIN & JUNCTION PIT
C4	CATCHMENT

NOTES:

1. 1 IN 1 YEAR CONTAINED & INFILTRATED TO LOCAL SWALES.
2. 10 YEAR EVENT CONTAINED IN P.O.S & SWALE
3. LOT/HOUSE DRAINAGE DISPOSED OF BY INFILTRATION ONSITE.
4. MIN CLEARANCE OF 1.5m BETWEEN AAMGL AND FINISHED SURFACE LEVEL.

EXISTING SERVICES - INFORMATION ON THESE DRAWINGS PURPORTING TO RELATE TO EXISTING SERVICES IS INDICATIVE ONLY AND MAY NOT BE COMPLETE REFER TO SPECIFICATION AND CLAUSE 12 OF AS4000

-50 0 50 100 150 200 250m
1:2500

WAPC No

REV	REVISION	DATE	APPROVED
A	ISSUED FOR APPROVAL		

CLIENT
WRF PROPERTY LTD

THE CIVIL GROUP
CONSULTING CIVIL ENGINEERS
38 Richardson Street West Perth WA 6005
Telephone: (08) 9481 4255
Facsimile: (08) 9481 3900

DRAWN L. Fisher
DESIGNED L. Fisher
CHECKED
APPROVED
DATE

TITLE
CELL 3A SOUTHERN RIVER
PRELIMINARY DRAINAGE PIPE LAYOUT (CRITICAL LINES)

ORIGINAL SHEET SIZE A1
DO NOT SCALE
SCALE 1:2500
LEVEL DATUM : AHD
SHEET OF
DRAWING No 7488-34
REV A

13 Feb 2009 1:46 PM

WRF Property Pty Ltd
Southern River Cell 3A (1)

DETAILS OF SWALES, WATER GARDENS AND POS DETENTION STORAGES

all levels in AHD

Catchment C4

1 in 1 Year 1 Hour Event - Infiltration and Storage in Roadside Swales and Water Gardens for Roads

1 Road Catchment Area = 3.86Ha x C=0.8 x 15.9mm/Hr = 491m3 runoff
2 Swale Length = 460m Surface Area @ one third full = 1,012m2
3 Swale Volume (Full to 300mm depth) = 386m3 Swale infiltration @1m/day = 42m3/hr - Total = 428m3
4 Excess required for Water Garden = 491m3 - 428m3 = 63m3
0.8mdeep = ~ 80m2 (diameter of 10m)
5 Lots and Commercial sites to contain the 1 in 1 Year 1 Hour event on site via detention and infiltration

1 in 100 Year Event - Detention Storage with a Restricted Outflow equivalent to the Pre-Developed Flows

1 Outlet Pipe 300dia at 1 in 300 grade (minimum practical outflow pipe)
2 Outlet Pipe IL = 19.60m (at AAMGL)
Base of Detention storage = 20.0m
100year TWL = 21.0m
3 A pipe discharges events greater then the 1 in 1 year and up to the 1 in 5 year indirectly to Southern River via drains on Matison St then Leslie St ie bypasses the Forrestdale Main Drain
4 Flood Path via a Weir (Leslie St) at RL 21.0. AHD L=70m
overflows the pre-developed 100 year event flow to the CCW adjacent to the Forrestdale Main Drain
5 The POS will require some earthworks to achieve the required storages
6 Drainage modelling uses an Initial Loss of 15.9mm based on storage and infiltration of the 1 in 1 year 1 hour event for roads, lots and commercial developments. A continuing loss of 2.5mm/hr is used.

Storage - Height - Discharge Relationship

RL (m)	Available Storage (m3)	Available Discharge (L/s)	Notes
20.0	0	5	adopt a subsoil flow of 5L/s
20.2	522	35	
20.4	1128	55	(outflow based on 300dia at 1 in 300 flowing full but not under head)
20.6	1819	55	
20.8	2596	55	
21.0	5000	55	Wier operates at RL 21.0m AHD - overflow of pre-developed flow
21.2	10000	19800	

note actual comp basin will be constructed in two parts with two separate levels but modelled as one for simplicity
storages based on using 100% of the POS for storage of the 100 Year event

Catchment C3

1 in 1 Year 1 Hour Event - Infiltration and Storage in Roadside Swales and Water Gardens for Roads

1 Road Catchment Area = 2.13Ha x C=0.8 x 15.9mm/Hr = 271m3 runoff
2 Swale Length = 320m Surface Area @ one third full = 704m2
3 Swale Volume (Full to 300mm depth) = 269m3 Swale infiltration @1m/day = 29m3/hr - Total = 298m3
4 Excess required for Water Garden = Nil - only for treatment of roads not connect to a swale
adopt a 10m diameter x 0.8m deep = 63m3
5 Lots and Commercial sites to contain the 1 in 1 Year 1 Hour event on site via detention and infiltration

1 in 100 Year Event - Detention Storage with a Restricted Outflow equivalent to the Pre-Developed Flows

1 Outlet Pipe 300 dia at 1 in 300 grade
2 Outlet IL = 18.50m AHD (AAMGL)
discharges indirectly to Southern River ie bypasses the Forrestdale Main Drain
Base of Detention Storage = RL19.4m
100 year TWL = RL20.2m
3 A pipe discharges events greater then the 1 in 1 year and up to the 1 in 5 year indirectly to Southern River
via drains on Matison St then Leslie St ie bypasses the Forrestdale Main Drain
4 Flood Path via a Weir (Leslie St) at RL 20.2. AHD L=15m
overflows the pre-developed 100 year event flow to the site to the south east of the POS
5 The POS will require some earthworks to achieve the required storages
6 Drainage modelling uses an Initial Loss of 15.9mm based on storage and infiltration of the 1 in 1 year 1 hour event
for roads, lots and commercial developments. A continuing loss of 2.5mm/hr is used.

Storage - Height - Discharge Relationship

RL (m)	Available Storage (m3)	Available Discharge (L/s)	Notes
19.4	0	5	
19.6	217	35	
19.8	470	55	
20.0	1161	55	
20.2	1891	55	Weir operates at RL 20.2m
20.4	3000	9000	

Catchments C3 & C5 now linked and modeled as one for simplicity

Catchment C5

1 in 1 Year 1 Hour Event - Infiltration and Storage in Roadside Swales and Water Gardens for Roads

1 Road Catchment Area = 2.90Ha x C=0.8 x 15.9mm/Hr = 369m3 runoff
2 Swale Length = 360m Surface Area @ one third full = 792m2
3 Swale Volume (Full to 300mm depth) = 302m3 Swale infiltration @1m/day = 33m3/hr - Total = 335m3
4 Excess required for Water Garden = 369-335 = 34m3 and for treatment of roads not connect to a swale
adopt a 10m diameter x 0.8m deep = 63m3
5 Lots and Commercial sites to contain the 1 in 1 Year 1 Hour event on site via detention and infiltration

1 in 100 Year Event - Detention Storage with a Restricted Outflow equivalent to the Pre-Developed Flows

1 Outlet Pipe 300 dia at 1 in 300 grade
2 Outlet IL = 18.90m AHD (AAMGL)
discharges to Catchment C3
Base of Detention Storage = RL20.0m
100 year TWL = RL21.2
3 A pipe discharges events greater then the 1 in 1 year and up to the 1 in 5 year indirectly to Southern River
via drains on Matison St then Leslie St ie bypasses the Forrestdale Main Drain
4 Flood Path via a Weir (road reserve) at RL 21.2. AHD L=15m
overflows the pre-developed 100 year event flow to Catchment C3
5 The POS will require some earthworks to achieve the required storages
6 Drainage modelling uses an Initial Loss of 15.9mm based on storage and infiltration of the 1 in 1 year 1 hour event
for roads, lots and commercial developments. A continuing loss of 2.5mm/hr is used.

Storage - Height - Discharge Relationship

RL (m)	Available Storage (m3)	Available Discharge (L/s)	Notes
20.0	0	5	base of comp basin = RL20.0
20.2	382	35	
20.4	809	55	
20.6	1284	55	
20.8	1809	55	
21.0	3000	55	
21.2	5000	55	Weir operates at RL 21.2m
21.4	10000	3050	
		8650	

Catchments C3 & C5 now linked and modeled as one for simplicity

Catchment C2

1 in 1 Year 1 Hour Event - Infiltration and Storage in Roadside Swales and Water Gardens for Roads

1 Road Catchment Area = 8.22Ha x C=0.8 x 15.9mm/Hr = 1,046m3 runoff
2 Swale Length = 1,600m Surface Area @ one third full = 3,520m2
3 Swale Volume (Full to 300mm depth) = 1,344m3 Swale infiltration @1m/day = 147m3/hr - Total = 1,491m3
4 Excess required for Water Garden = nil - only required for treatment of roads not connect to a swale
adopt a 2 x 10m diameter x 0.8m deep = 63m3
5 Lots and Commercial sites to contain the 1 in 1 Year 1 Hour event on site via detention and infiltration

1 in 100 Year Event - Detention Storage with a Restricted Outflow equivalent to the Pre-Developed Flows

1 Outlet Pipe 375dia at 1 in 300 grade
2 Outlet Pipe IL = 17.85m AHD (at AAMGL) - Comp Basin outlet pipe at base RL18.0
discharges indirectly to Southern River ie bypasses the Forrestdale Main Drain
Base of detention storage modelled at RL18.0 but will be min 300mm above the AAMGL
100year TWL 19.10m (or greater to exceed the 100 year flood levels from Southern River)
3 A pipe discharges events greater then the 1 in 1 year and up to the 1 in 5 year indirectly to Southern River
via drains on Matison St then Leslie St ie bypasses the Forrestdale Main Drain
4 Weir at RL 19.0m AHD L=20m - overflows to Leslie St and the existing drain
5 The POS will require some earthworks to achieve the required storages
6 Drainage modelling uses an Initial Loss of 15.9mm based on storage and infiltration of the 1 in 1 year 1 hour event
for roads, lots and commercial developments. A continuing loss of 2.5mm/hr is used.

Storage - Height - Discharge Relationship

RL (m)	Available Storage (m3)	Available Discharge (L/s)	Notes
18.0	0	140	
18.2	1459	140	
18.4	3196	140	
18.6	5209	140	
18.8	7499	140	Weir operates at RL18.8
19.0	10071	3150	
19.2	12926	8750	

note actual comp basin will be constructed in three parts with separate levels but modelled as one for simplicity
Base of detention storage in actual practice will be 300mm min above the AAMGL

Catchment C1

1 in 1 Year 1 Hour Event - Infiltration and Storage in Roadside Swales and Water Gardens for Roads

1 Road Catchment Area = 1.44Ha x C=0.8 x 15.9mm/Hr = 183m3 runoff
2 Swale Length = 220m Surface Area @ one third full = 484m2
3 Swale Volume (Full to 300mm depth) = 184m3 Swale infiltration @1m/day = 20m3/hr - Total = 204m3
4 Excess required for Water Garden = nil - only required for treatment of roads not connect to a swale
adopt a 1 x 10m diameter x 0.8m deep = 63m3
5 Lots and Commercial sites to contain the 1 in 1 Year 1 Hour event on site via detention and infiltration

1 in 100 Year Event - Detention Storage with a Restricted Outflow equivalent to the Pre-Developed Flows

1 Outlet Pipe 300dia at 1 in 200 grade
2 Outlet Pipe IL = 16.6m AHD (at AAMGL)
discharges indirectly to Southern River ie bypasses the Forrestdale Main Drain
3 A pipe discharges events greater then the 1 in 1 year and up to the 1 in 5 year indirectly to Southern River
via drains on Southern River Rd ie bypasses the Forrestdale Main Drain
4 Drainage modelling uses an Initial Loss of 15.9mm based on storage and infiltration of the 1 in 1 year 1 hour event
for roads, lots and commercial developments. A continuing loss of 2.5mm/hr is used.

iWBNM Lite

iWBNM Lite

1 Project Details

Project ID: **SOUTHERN RIVER CELL 3A**
Project Description: **PRE DEVELOPMENT FLOWS FROM RURAL CATCHMENT**
Project Location: **CATCHMENT C1**

2 General Parameters

Lag Parameter (C)	1.6	
Stream Lag Factor	1	
Calculation Timestep	1	mins
Initial Loss	10	mm
Continuing Loss Rate	4	mm/hr

3 Rain Gauge Data

Choose Rain Gauge from Database

W_Perth ▼

Add to Database: Name ______ Zone ______ Add

	2yr	50yr				
1 hr				F2	Ave Rain	
12 hr				F50	%Rough	
72 hr				G	MAF (0.0-1.0)	

4 Topology

Subarea	Name	Connects to	Area ha	Impervious %
1	C1	SINK	3.72	0
2				
3				
4				
5				
6				
7				
8				
9				
10				
Total			3.7	0.0

5 Structure Data

Subarea	IWL	Storage_Fac	Type

Weir	1	2
Diverts to Sub		
Crest Elev [m]		
Length [m]		
Weir Coeff		
Disch-Factor		
Directed to		
Delay [mins]		

Pipe/Box	1	2	3
Diverts to Sub			
Invert [m]			
No. Barrels			
Ent. Type			
Dia/(Width)[mm]			
(Height)[mm]			
Disch-Factor			
Directed to			
Delay [mins]			

Elevation m	Storage m^3

6 Storm Data

Storm	ARI	Duration [mins]
1	1	25
2	2	25
3	5	25
4	10	25
5	20	25
6	50	20
7	100	20
8	PMF	20

7 Save & Run

Save & Run

Shortcut: Shift + Ctrl + L

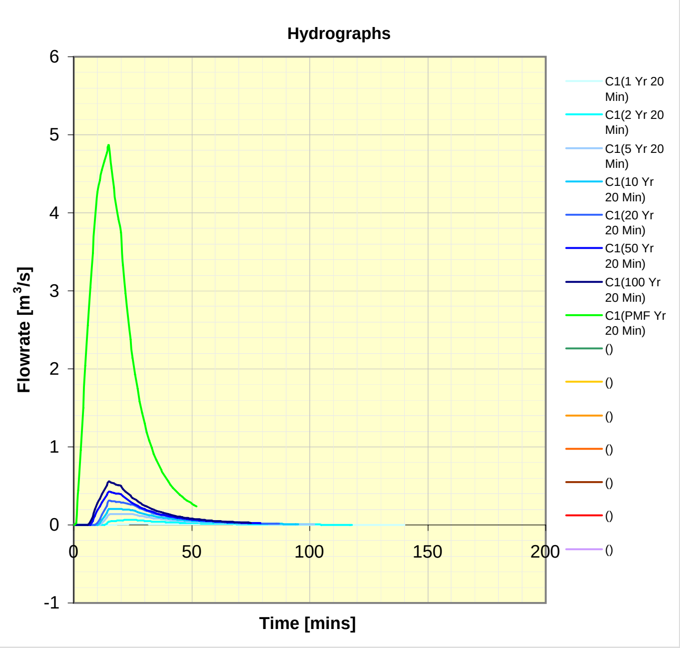
Most Recent File: Y:\7488\7488 Correspondence\WBNM\C1 RURAL.wbn
Location of WBNMRun.exe: C:\Documents and Settings\Peterg\My Documents\DRAINAGE\WBNM2007\WBNMrun.exe

8 Results

RESULTS FOR: Y:\7488\7488 Correspondence\WBNM\C1 RURAL_Meta.out

Storm	1	2	3	4	5	6	7	8
	1 Yr 25 Min	2 Yr 25 Min	5 Yr 25 Min	10 Yr 25 Min	20 Yr 25 Min	50 Yr 20 Min	100 Yr 20 Min	PMF Yr 20 Min
Peak Flowrates at Subarea Outlet [Q m^3/s]								
C1	0.015	0.065	0.143	0.205	0.309	0.426	0.557	4.863

Inflow Peak									m^3/s
Outflow Peak									m^3/s
Inflow Volume									m^3
Max Vol Stored									m^3
Max Water Elev									m



iWBNM Lite

iWBNM Lite

1 Project Details

Project ID	SOUTHERN RIVER CELL 3A - Job No. 7488
Project Description	100 YEAR URBAN
Project Location	CATCHMENT C1

2 General Parameters

Lag Parameter (C)	1.6	
Stream Lag Factor	1	
Calculation Timestep	5	mins
Initial Loss	15.9	mm (swales capture)
Continuing Loss Rate	2.5	mm/hr

3 Rain Gauge Data

Choose Rain Gauge from Database

W_Perth ▼

Add to Database: Name ☐ Zone ☐ Add

	2yr	50yr				
1 hr				F2	Ave Rain	
12 hr				F50	%Rough	
72 hr				G	MAF (0.0-1.0)	

4 Topology

	Subarea Name	Connects to	Area	Impervious
			ha	%
1	c1	SINK	3.72	80
2				
3				
4				
5				
6				
7				
8				
9				
10				
Total			3.7	80.0

5 Structure Data

Subarea	IWL	Storage_Fac	Type
c1	17	1	OUTLET

Weir	1	2
Diverts to Sub	sink	
Crest Elev [m]	18	
Length [m]	20	
Weir Coeff	2	
Disch-Factor	1	
Directed to	TOP	
Delay [mins]	0	

Pipe/Box	1	2	3
Diverts to Sub	SINK		
Invert [m]	17		
No. Barrels	1		
Ent. Type	1		
Dia/(Width)[mm]	300		
(Height)[mm]			
Disch-Factor	1		
Directed to	TOP		
Delay [mins]	0		

Elevation	Storage
m	m^3
17	0
17.2	200
17.4	300
17.6	300
17.8	300
18	300
18.2	300
18.4	300
18.6	

6 Storm Data

Storm	ARI	Duration [mins]
1	100	10
2	100	15
3	100	30
4	100	60
5	100	360
6	100	720
7	100	1440
8	100	4320

7 Save & Run

Save & Run

Shortcut: Shift + Ctrl + L

Most Recent File: Y:\7488\7488 Correspondence\WBNM\c1 100 year urban - limited storage.wbn

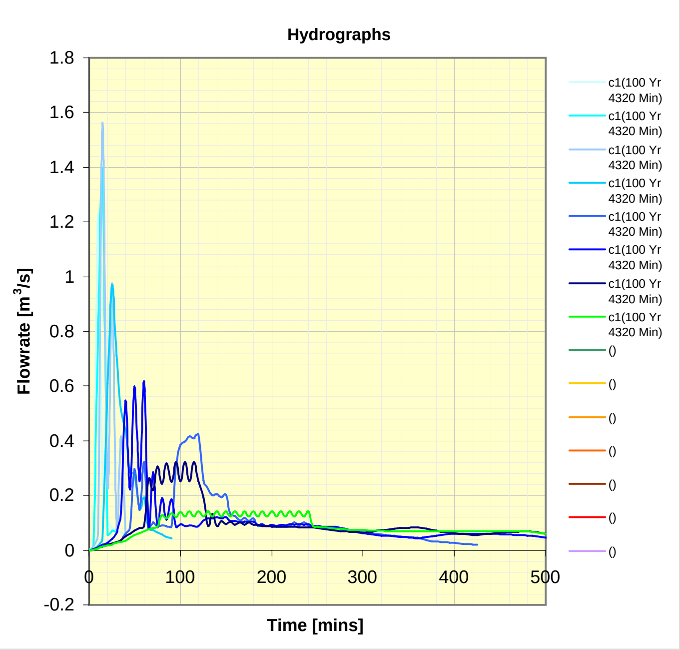
Location of WBNMRun.exe: C:\Documents and Settings\Peterg\My Documents\DRAINAGE\WBNM2007\WBNMrun.exe

8 Results

RESULTS FOR: Y:\7488\7488 Correspondence\WBNM\c1 100 year urban - limited storage_Meta.out

Storm	1	2	3	4	5	6	7	8
	100 Yr 10 Min	100 Yr 15 Min	100 Yr 30 Mi	100 Yr 60 Min	00 Yr 360 Mi	100 Yr 720 Min	100 Yr 1440 Min	100 Yr 4320 Min
Peak Flowrates at Subarea Outlet [Q m^3/s]								
c1	1.229	1.380	1.564	0.970	0.422	0.615	0.323	0.142

Inflow Peak	1.207	1.316	1.164	1.010	0.416	0.436	0.288	0.133	m^3/s
Outflow Peak	1.229	1.380	1.564	0.970	0.422	0.615	0.323	0.142	m^3/s
Inflow Volume	812	986	1291	1587	2794	3403	4479	6393	m^3
Max Vol Stored	300	300	300	300	300	300	300	300	m^3
Max Water Elev	18.058	18.067	18.077	18.044	18.014	18.024	18.008	17.706	m



iWBNM Lite

iWBNM Lite

1 Project Details

Project ID	SOUTHERN RIVER CELL 3A
Project Description	PRE DEVELOPMENT FLOWS FROM RURAL CATCHMENT
Project Location	CATCHMENT C2

2 General Parameters

Lag Parameter (C)	1.6	
Stream Lag Factor	1	
Calculation Timestep	1	mins
Initial Loss	10	mm
Continuing Loss Rate	4	mm/hr

3 Rain Gauge Data

Choose Rain Gauge from Database

W_Perth

Add to Database: Name Zone Add

	2yr	50yr				
1 hr				F2	Ave Rain	
12 hr				F50	%Rough	
72 hr				G	MAF (0.0-1.0)	

4 Topology

Subarea	Name	Connects to	Area	Impervious
			ha	%
1	C2	SINK	26.98	0
2				
3				
4				
5				
6				
7				
8				
9				
10				
Total			27.0	0.0

5 Structure Data

Subarea	IWL	Storage_Fac	Type

Weir	1	2
Diverts to Sub		
Crest Elev [m]		
Length [m]		
Weir Coeff		
Disch-Factor		
Directed to		
Delay [mins]		

Pipe/Box	1	2	3
Diverts to Sub			
Invert [m]			
No. Barrels			
Ent. Type			
Dia/(Width)[mm]			
(Height)[mm]			
Disch-Factor			
Directed to			
Delay [mins]			

Elevation	Storage
m	m^3

6 Storm Data

Storm	ARI	**Duration** [mins]
1	1	90
2	2	60
3	5	60
4	10	60
5	20	60
6	50	60
7	100	60
8	PMF	60

7 Save & Run

Save & Run

Shortcut: Shift + Ctrl + L

Most Recent File: Y:\7488\7488 Correspondence\WBNM\C2 RURAL.wbn

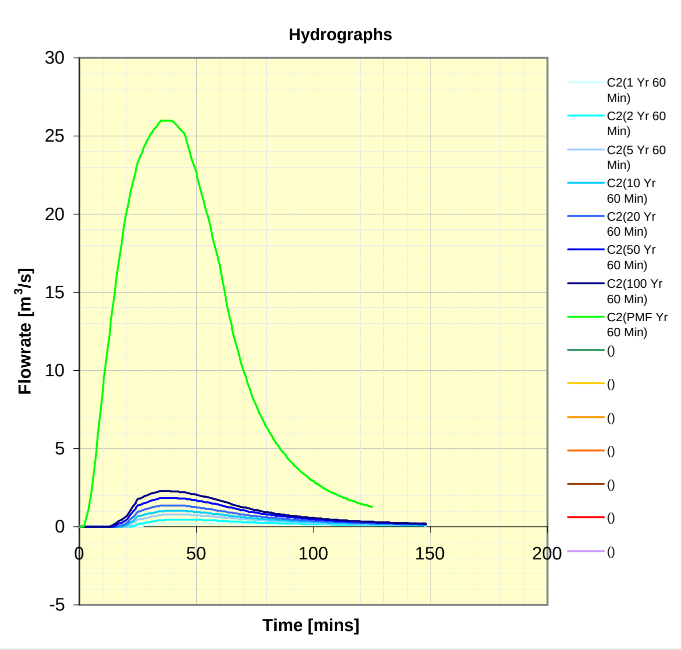
Location of WBNMRun.exe: C:\Documents and Settings\Peterg\My Documents\DRAINAGE\WBNM2007\WBNMrun.exe

8 Results

RESULTS FOR: Y:\7488\7488 Correspondence\WBNM\C2 RURAL_Meta.out

Storm	1	2	3	4	5	6	7	8
	1 Yr 90 Min	2 Yr 60 Min	5 Yr 60 Min	10 Yr 60 Min	20 Yr 60 Min	50 Yr 60 Min	100 Yr 60 Min	PMF Yr 60 Min
Peak Flowrates at Subarea Outlet [Q m^3/s]								
C2	0.250	0.466	0.786	1.021	1.366	1.837	2.283	25.992

Inflow Peak									m^3/s
Outflow Peak									m^3/s
Inflow Volume									m^3
Max Vol Stored									m^3
Max Water Elev									m



iWBNM Lite

iWBNM Lite

1 Project Details

Project ID	SOUTHERN RIVER CELL 3A - Job No. 7488
Project Description	100 YEAR URBAN
Project Location	CATCHMENT C2

2 General Parameters

Lag Parameter (C)	1.6	
Stream Lag Factor	1	
Calculation Timestep	5	mins
Initial Loss	15.9	mm (swales capture)
Continuing Loss Rate	2.5	mm/hr

3 Rain Gauge Data

Choose Rain Gauge from Database

W_Perth

Add to Database: Name Zone Add

	2yr	50yr				
1 hr				F2	Ave Rain	
12 hr				F50	%Rough	
72 hr				G	MAF (0.0-1.0)	

4 Topology

	Subarea Name	Connects to	Area	Impervious
			ha	%
1	C2	SINK	22.16	80
2				
3				
4				
5				
6				
7				
8				
9				
10				
Total			22.2	80.0

5 Structure Data

Subarea	IWL	Storage_Fac	Type
C2	18	1	OUTLET

Weir	1	2
Diverts to Sub	sink	
Crest Elev [m]	19.2	
Length [m]	20	
Weir Coeff	2	
Disch-Factor	1	
Directed to	TOP	
Delay [mins]	0	

Pipe/Box	1	2	3
Diverts to Sub	SINK		
Invert [m]	18		
No. Barrels	1		
Ent. Type	1		
Dia/(Width)[mm]	375		
(Height)[mm]			
Disch-Factor	1		
Directed to	TOP		
Delay [mins]	0		

Elevation	Storage
m	m^3
18	0
18.2	1459
18.4	3196
18.6	5209
18.8	7499
19	10071
19.2	12926
19.4	20000

6 Storm Data

Storm	ARI	Duration [mins]
1	100	10
2	100	15
3	100	30
4	100	60
5	100	360
6	100	720
7	100	1440
8	100	4320

7 Save & Run

Save & Run

Shortcut: Shift + Ctrl + L

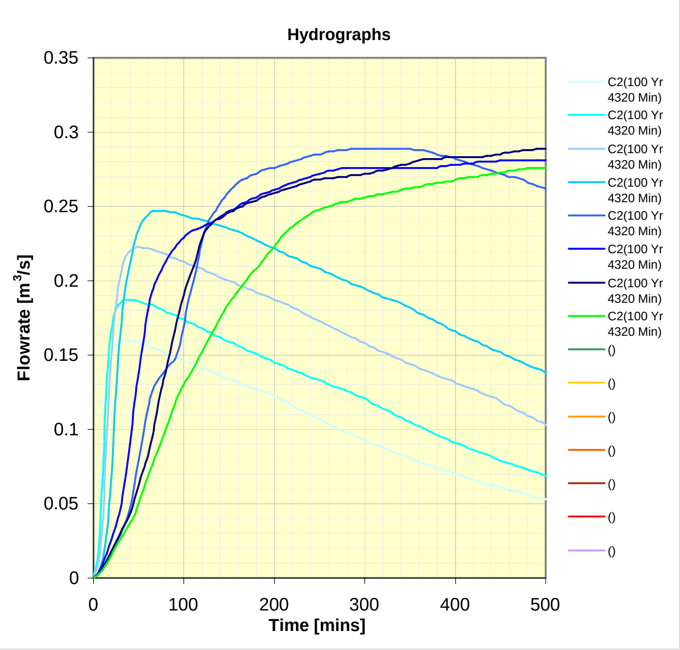
Most Recent File: Y:\7488\7488 Correspondence\WBNM\C2 URBAN 100 YEAR.wbn

Location of WBNMRun.exe: C:\Documents and Settings\Peterg\My Documents\DRAINAGE\WBNM2007\WBNMrun.exe

8 Results

RESULTS FOR: Y:\7488\7488 Correspondence\WBNM\C2 URBAN 100 YEAR_Meta.out

Storm	1	2	3	4	5	6	7	8	
	100 Yr 10 Min	100 Yr 15 Min	100 Yr 30 Min	100 Yr 60 Min	100 Yr 360 Min	100 Yr 720 Min	100 Yr 1440 Min	100 Yr 4320 Min	
Peak Flowrates at Subarea Outlet [Q m^3/s]									
C2	0.160	0.187	0.223	0.247	0.289	0.281	0.289	0.276	
Inflow Peak	6.140	6.390	5.897	5.119	2.414	2.483	1.701	0.792	m^3/s
Outflow Peak	0.160	0.187	0.223	0.247	0.289	0.281	0.289	0.276	m^3/s
Inflow Volume	4844	5878	7692	9456	16651	20289	26701	38156	m^3
Max Vol Stored	4450	5386	7019	8542	11883	11199	11881	10748	m^3
Max Water Elev	18.525	18.615	18.758	18.881	19.127	19.079	19.127	19.047	m



iWBNM Lite

iWBNM Lite

1 Project Details

Project ID: **SOUTHERN RIVER CELL 3A**
Project Description: **PRE DEVELOPMENT FLOWS FROM RURAL CATCHMENT**
Project Location: **CATCHMENT C3 & C5**

2 General Parameters

Lag Parameter (C)	1.6	
Stream Lag Factor	1	
Calculation Timestep	1	mins
Initial Loss	10	mm
Continuing Loss Rate	4	mm/hr

3 Rain Gauge Data

Choose Rain Gauge from Database

W_Perth

Add to Database: Name ____ Zone ____ Add

	2yr	50yr				
1 hr				F2	Ave Rain	
12 hr				F50	%Rough	
72 hr				G	MAF (0.0-1.0)	

4 Topology

Subarea	Name	Connects to	Area ha	Impervious %
1	C3C5	SINK	16.87	0
2				
3				
4				
5				
6				
7				
8				
9				
10				
Total			16.9	0.0

5 Structure Data

Subarea	IWL	Storage_Fac	Type

Weir	1	2
Diverts to Sub		
Crest Elev [m]		
Length [m]		
Weir Coeff		
Disch-Factor		
Directed to		
Delay [mins]		

Pipe/Box	1	2	3
Diverts to Sub			
Invert [m]			
No. Barrels			
Ent. Type			
Dia/(Width)[mm]			
(Height)[mm]			
Disch-Factor			
Directed to			
Delay [mins]			

Elevation m	Storage m^3

6 Storm Data

Storm	ARI	**Duration** [mins]
1	1	60
2	2	60
3	5	60
4	10	60
5	20	60
6	50	60
7	100	60
8	PMF	60

7 Save & Run

Save & Run

Shortcut: Shift + Ctrl + L

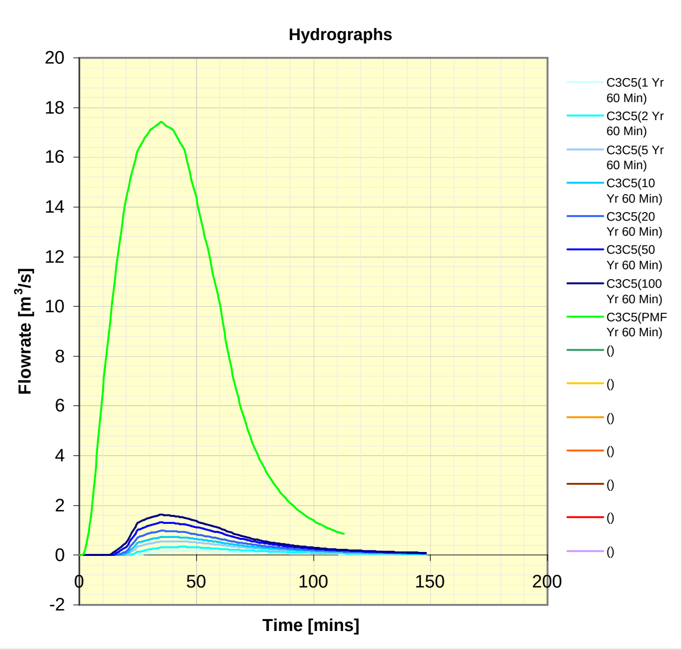
Most Recent File: Y:\7488\7488 Correspondence\WBNM\C3C5 RURAL.wbn
Location of WBNMRun.exe: C:\Documents and Settings\Peterg\My Documents\DRAINAGE\WBNM2007\WBNMrun.exe

8 Results

RESULTS FOR: Y:\7488\7488 Correspondence\WBNM\C3C5 RURAL_Meta.out

Storm	1	2	3	4	5	6	7	8
	1 Yr 60 Min	2 Yr 60 Min	5 Yr 60 Min	10 Yr 60 Min	20 Yr 60 Min	50 Yr 60 Min	100 Yr 60 Min	PMF Yr 60 Min
Peak Flowrates at Subarea Outlet [Q m^3/s]								
C3C5	0.177	0.334	0.563	0.728	0.980	1.311	1.626	17.419

Inflow Peak									m^3/s
Outflow Peak									m^3/s
Inflow Volume									m^3
Max Vol Stored									m^3
Max Water Elev									m



iWBNM Lite

iWBNM Lite

1 Project Details

Project ID	SOUTHERN RIVER CELL 3A - Job No. 7488
Project Description	100 YEAR URBAN
Project Location	CATCHMENT C3 & C5

2 General Parameters

Lag Parameter (C)	1.6	
Stream Lag Factor	1	
Calculation Timestep	5	mins
Initial Loss	15.9	mm (swales capture)
Continuing Loss Rate	2.5	mm/hr

3 Rain Gauge Data

Choose Rain Gauge from Database

W_Perth ▼

Add to Database: Name ☐ Zone ☐ Add

	2yr	50yr				
1 hr				F2	Ave Rain	
12 hr				F50	%Rough	
72 hr				G	MAF (0.0-1.0)	

4 Topology

	Subarea Name	Connects to	Area ha	Impervious %
1	C3C5	SINK	15.95	80
2				
3				
4				
5				
6				
7				
8				
9				
10				
Total			16.0	80.0

5 Structure Data

Subarea	IWL	Storage_Fac	Type
C3C5	19.4	1	OUTLET

Weir	1	2
Diverts to Sub	sink	
Crest Elev [m]	20.5	
Length [m]	20	
Weir Coeff	2	
Disch-Factor	1	
Directed to	TOP	
Delay [mins]	0	

Pipe/Box	1	2	3
Diverts to Sub	SINK		
Invert [m]	19.4		
No. Barrels	1		
Ent. Type	1		
Dia/(Width)[mm]	300		
(Height)[mm]			
Disch-Factor	1		
Directed to	TOP		
Delay [mins]	0		

Elevation m	Storage m^3
19.4	0
19.6	599
19.8	1279
20	2445
20.2	3700
20.4	6000
20.6	15000
20.8	20000

6 Storm Data

Storm	ARI	Duration [mins]
1	100	10
2	100	15
3	100	30
4	100	60
5	100	360
6	100	720
7	100	1440
8	100	4320

7 Save & Run

Save & Run

Shortcut: Shift + Ctrl + L

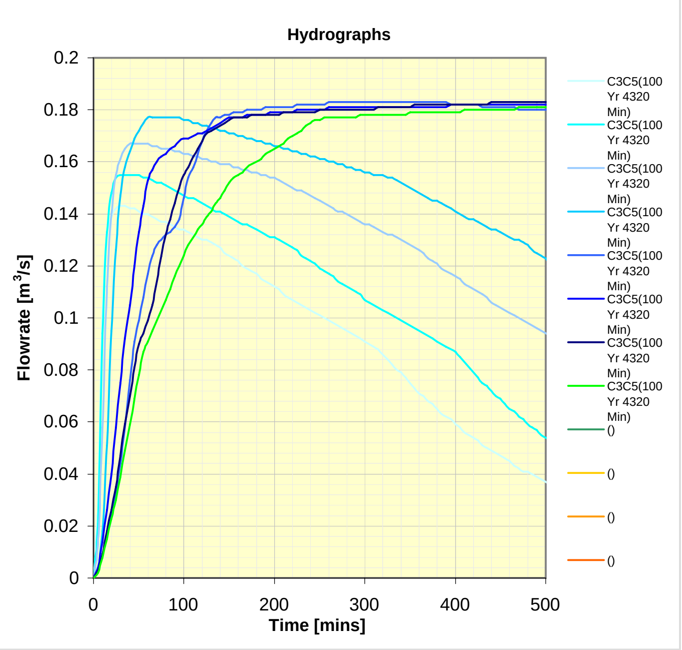
Most Recent File: Y:\7488\7488 Correspondence\WBNM\c3c5 100year urban.wbn

Location of WBNMRun.exe: C:\Documents and Settings\Peterg\My Documents\DRAINAGE\WBNM2007\WBNMrun.exe

8 Results

RESULTS FOR: Y:\7488\7488 Correspondence\WBNM\c3c5 100year urban_Meta.out

Storm	1	2	3	4	5	6	7	8	
	100 Yr 10 Min	100 Yr 15 Min	100 Yr 30 Min	100 Yr 60 Min	100 Yr 360 Min	100 Yr 720 Min	100 Yr 1440 Min	100 Yr 4320 Min	
Peak Flowrates at Subarea Outlet [Q m^3/s]									
C3C5	0.143	0.155	0.167	0.177	0.183	0.182	0.184	0.181	
Inflow Peak	4.578	4.799	4.390	3.801	1.751	1.806	1.227	0.570	m^3/s
Outflow Peak	0.143	0.155	0.167	0.177	0.183	0.182	0.184	0.181	m^3/s
Inflow Volume	3486	4231	5536	6806	11984	14602	19218	27463	m^3
Max Vol Stored	3168	3849	5031	6127	8617	8260	8884	7731	m^3
Max Water Elev	20.115	20.213	20.316	20.403	20.458	20.45	20.464	20.438	m



iWBNM Lite

iWBNM Lite

1 Project Details

Project ID	SOUTHERN RIVER CELL 3A
Project Description	PRE DEVELOPMENT FLOWS FROM RURAL CATCHMENT
Project Location	CATCHMENT C4

2 General Parameters

Lag Parameter (C)	1.6	
Stream Lag Factor	1	
Calculation Timestep	1	mins
Initial Loss	10	mm
Continuing Loss Rate	4	mm/hr

3 Rain Gauge Data

Choose Rain Gauge from Database

W_Perth ▾

Add to Database: Name Zone Add

	2yr	50yr				
1 hr				F2	Ave Rain	
12 hr				F50	%Rough	
72 hr				G	MAF (0.0-1.0)	

4 Topology

Subarea	Name	Connects to	Area ha	Impervious %
1	C4	SINK	11.31	0
2				
3				
4				
5				
6				
7				
8				
9				
10				
Total			11.3	0.0

5 Structure Data

Subarea	IWL	Storage_Fac	Type

Weir	1	2
Diverts to Sub		
Crest Elev [m]		
Length [m]		
Weir Coeff		
Disch-Factor		
Directed to		
Delay [mins]		

Pipe/Box	1	2	3
Diverts to Sub			
Invert [m]			
No. Barrels			
Ent. Type			
Dia/(Width)[mm]			
(Height)[mm]			
Disch-Factor			
Directed to			
Delay [mins]			

Elevation m	Storage m^3

6 Storm Data

Storm	ARI	**Duration** [mins]
1	1	60
2	2	60
3	5	60
4	10	60
5	20	60
6	50	60
7	100	60
8	PMF	60

7 Save & Run

Save & Run

Shortcut: Shift + Ctrl + L

Most Recent File: Y:\7488\7488 Correspondence\WBNM\C4.wbn

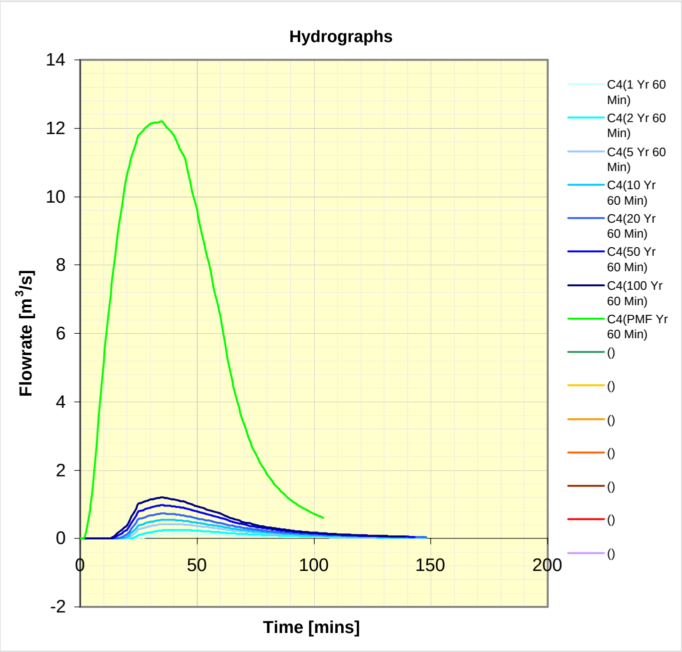
Location of WBNMRun.exe: C:\Documents and Settings\Peterg\My Documents\DRAINAGE\WBNM2007\WBNMrun.exe

8 Results

RESULTS FOR: Y:\7488\7488 Correspondence\WBNM\C4_Meta.out

Storm	1	2	3	4	5	6	7	8
	1 Yr 60 Min	2 Yr 60 Min	5 Yr 60 Min	10 Yr 60 Min	20 Yr 60 Min	50 Yr 60 Min	100 Yr 60 Min	PMF Yr 60 Min
Peak Flowrates at Subarea Outlet [Q m^3/s]								
C4	0.134	0.249	0.420	0.549	0.735	0.977	1.203	12.200

Inflow Peak									m^3/s
Outflow Peak									m^3/s
Inflow Volume									m^3
Max Vol Stored									m^3
Max Water Elev									m



iWBNM Lite

iWBNM Lite

1 Project Details

Project ID	SOUTHERN RIVER CELL 3A - Job No. 7488
Project Description	100 YEAR URBAN
Project Location	CATCHMENT C4

2 General Parameters

Lag Parameter (C)	1.6	
Stream Lag Factor	1	
Calculation Timestep	5	mins
Initial Loss	15.9	mm (swales capture)
Continuing Loss Rate	2.5	mm/hr

3 Rain Gauge Data

Choose Rain Gauge from Database

W_Perth

Add to Database: Name ☐ Zone ☐ Add

	2yr	50yr				
1 hr				F2	Ave Rain	
12 hr				F50	%Rough	
72 hr				G	MAF (0.0-1.0)	

4 Topology

Subarea	Name	Connects to	Area	Impervious
			ha	%
1	C4	SINK	10.48	80
2				
3				
4				
5				
6				
7				
8				
9				
10				
Total			10.5	80.0

5 Structure Data

Subarea	IWL	Storage_Fac	Type
C4	20	1	OUTLET

Weir	1	2
Diverts to Sub	sink	
Crest Elev [m]	21	
Length [m]	70	
Weir Coeff	2	
Disch-Factor	1	
Directed to	TOP	
Delay [mins]	0	

Pipe/Box	1	2	3
Diverts to Sub	SINK		
Invert [m]	20		
No. Barrels	1		
Ent. Type	1		
Dia/(Width)[mm]	300		
(Height)[mm]			
Disch-Factor	1		
Directed to	TOP		
Delay [mins]	0		

Elevation	Storage
m	m^3
20	0
20.2	522
20.4	1128
20.6	1819
20.8	2596
21	5000
21.2	10000
21.4	20000

6 Storm Data

Storm	ARI	Duration [mins]
1	100	10
2	100	15
3	100	30
4	100	60
5	100	360
6	100	720
7	100	1440
8	100	4320

7 Save & Run

Save & Run

Shortcut: Shift + Ctrl + L

Most Recent File: Y:\7488\7488 Correspondence\WBNM\c4.wbn

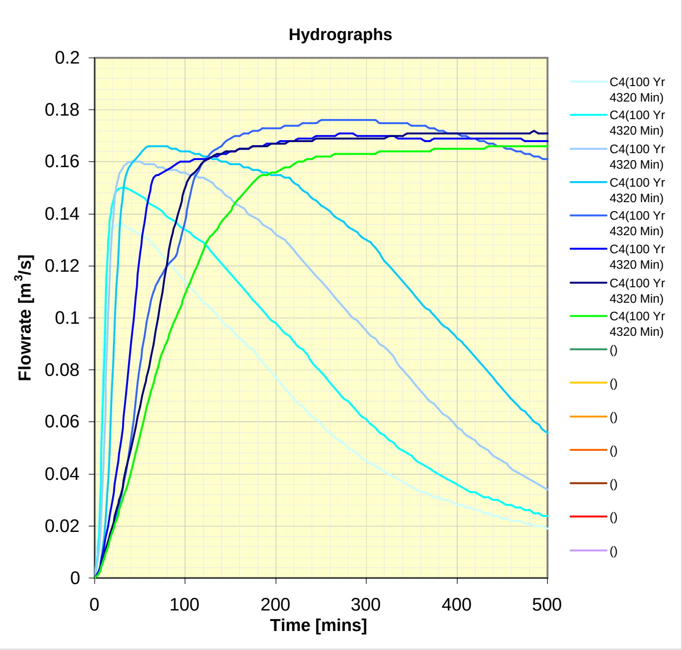
Location of WBNMRun.exe: C:\Documents and Settings\Peterg\My Documents\DRAINAGE\WBNM2007\WBNMrun.exe

8 Results

RESULTS FOR: Y:\7488\7488 Correspondence\WBNM\c4_Meta.out

Storm	1	2	3	4	5	6	7	8
	100 Yr 10 Min	100 Yr 15 Min	100 Yr 30 Mi	100 Yr 60 Min	100 Yr 360 Mi	100 Yr 720 Min	100 Yr 1440 Min	100 Yr 4320 Min
Peak Flowrates at Subarea Outlet [Q m^3/s]								
C4	0.136	0.150	0.160	0.166	0.176	0.171	0.172	0.166

Inflow Peak	3.134	3.319	3.004	2.596	1.159	1.201	0.808	0.375	m^3/s
Outflow Peak	0.136	0.150	0.160	0.166	0.176	0.171	0.172	0.166	m^3/s
Inflow Volume	2290	2779	3637	4471	7874	9594	12626	18044	m^3
Max Vol Stored	2051	2491	3242	3912	4919	4367	4450	3907	m^3
Max Water Elev	20.66	20.773	20.854	20.91	20.993	20.947	20.954	20.909	m



APPENDIX I
DRAINAGE DESIGN

LEGEND

▬ ▬ ▬ ▬	CATCHMENT BOUNDARY
— · — · —	SWALES (1 YEAR)
⊗	WATER GARDENS (1 YEAR)
🟪	LOCAL CATCHMENT BOUNDARIES
▭	PUBLIC OPEN SPACE
▨	DRAINAGE STORAGE (5 YEAR)
23.0	MIN. FILL LEVELS
19×58	MAX. GWL SPOT LEVELS
—19.0—	MAX. GWL CONTOURS
→	FLOW DIRECTION
-·-·-●	PIPE DRAIN & JUNCTION PIT
○	CCW WETLANDS
C4	CATCHMENT

NOTES:

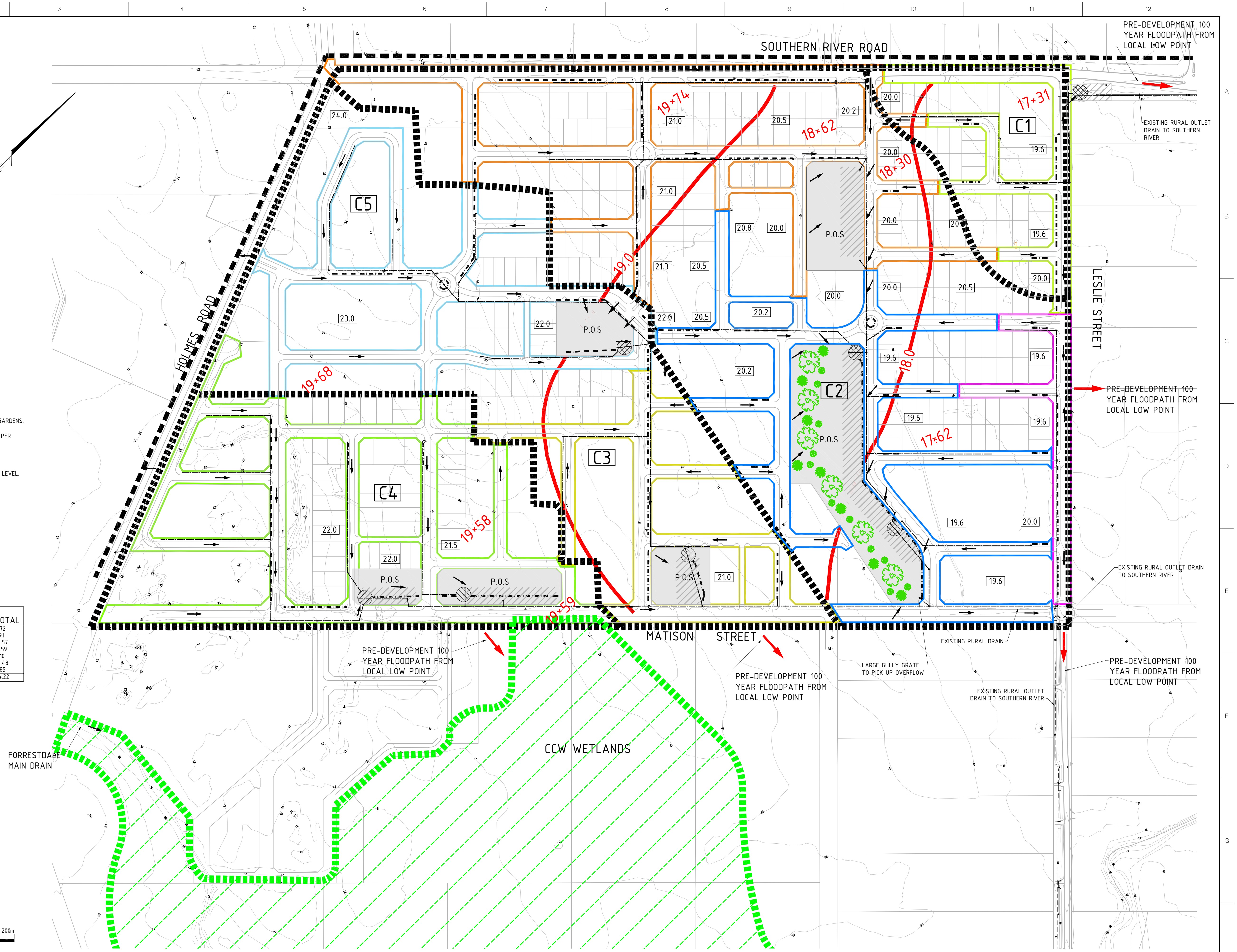
1. 1 IN 1 YEAR CONTAINED & INFILTRATED TO LOCAL SWALESOR WATER GARDENS.
2. 100 YEAR EVENT CONTAINED IN P.O.S & SWALE (OUTLET DESIGNED AS PER PRE-DEVELOPMENT FLOWS)
3. LOT/HOUSE DRAINAGE DISPOSED OF BY INFILTRATION ONSITE.
4. MIN CLEARANCE OF 1.5m BETWEEN AAMGL AND FINISHED LOT SURFACE LEVEL.

CATCHMENT KEY

🟩	A
🟪	B
🟦	C
🟧	D
🟨	E
🟩	F
🟦	G

CATCHMENT	ROAD RESERVE AREAS (Ha)	LOT AREAS (Ha)	TOTAL
C1-A	1.44	2.28	3.72
C2-B	0.92	0.99	1.91
C2-C	3.40	7.17	10.57
C2-D	3.90	7.69	11.59
C3-E	2.13	3.97	6.10
C4-F	3.86	6.62	10.48
C5-G	2.90	6.95	9.85
TOTAL	18.55	35.67	54.22

CATCHMENT	1 IN 5 YEAR AREA OF INUNDATION
C1	-
C2	8816m^2
C3 & C5	1346m^2
C4	3116m^2



EXISTING SERVICES - INFORMATION ON THESE DRAWINGS PURPORTING TO RELATE TO EXISTING SERVICES IS INDICATIVE ONLY AND MAY NOT BE COMPLETE REFER TO SPECIFICATION AND CLAUSE 12 OF AS4000

-40 0 40 80 120 160 200m
1:2000

REV	REVISION	DATE	APPROVED
B	1 IN 5 YEAR DRAINAGE STORAGE AMENDED		
A	ISSUED FOR APPROVAL		

CLIENT
WRF PROPERTY LTD

THE CIVIL GROUP
CONSULTING CIVIL ENGINEERS
38 Richardson Street West Perth WA 6005
Telephone: (08) 9481 4255
Facsimile: (08) 9481 3900

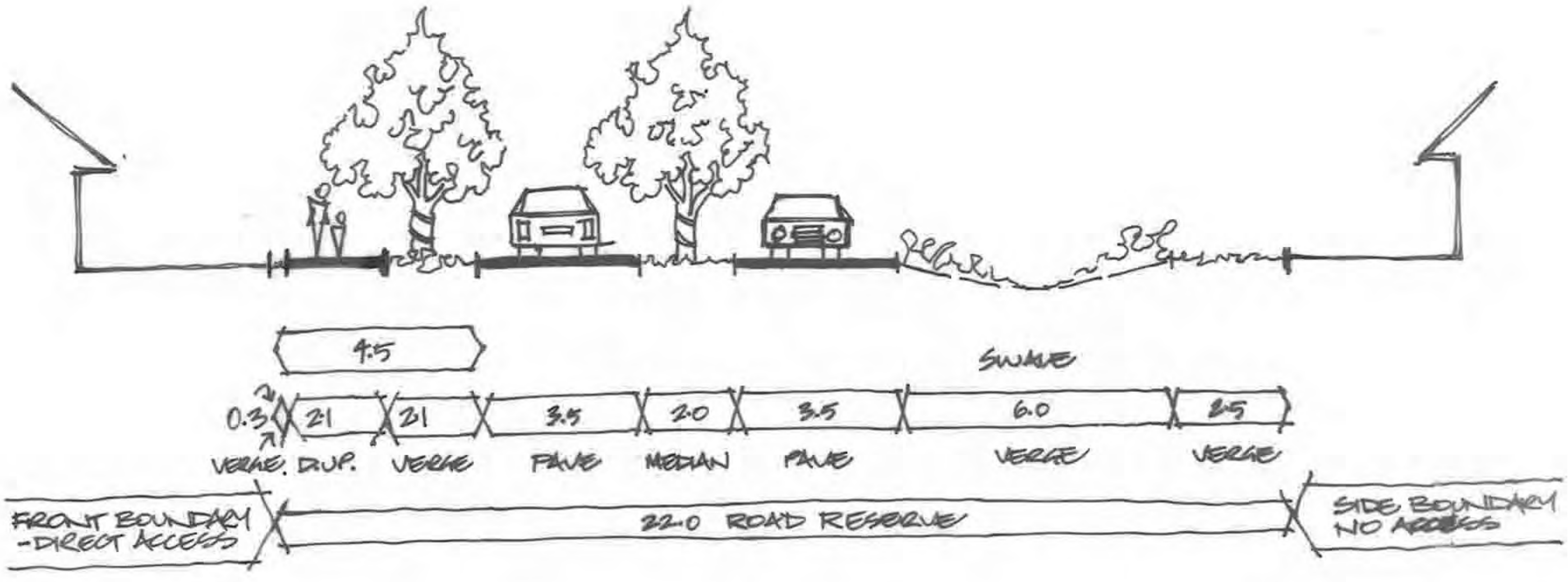
DRAWN L. Fisher
DESIGNED L. Fisher
CHECKED
APPROVED
DATE

TITLE
CELL 3A SOUTHERN RIVER
DRAINAGE CATCHMENT PLANNING FOR WRF LAND HOLDING

ORIGINAL SHEET SIZE A1
DO NOT SCALE
SCALE 1:2000
LEVEL DATUM : AHD
SHEET OF
DRAWING No 7488-33
REV B

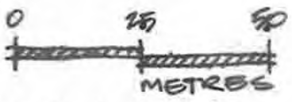
APPENDIX J

INDICATIVE LAYOUTS OF ROAD RESERVES WITH SWALES

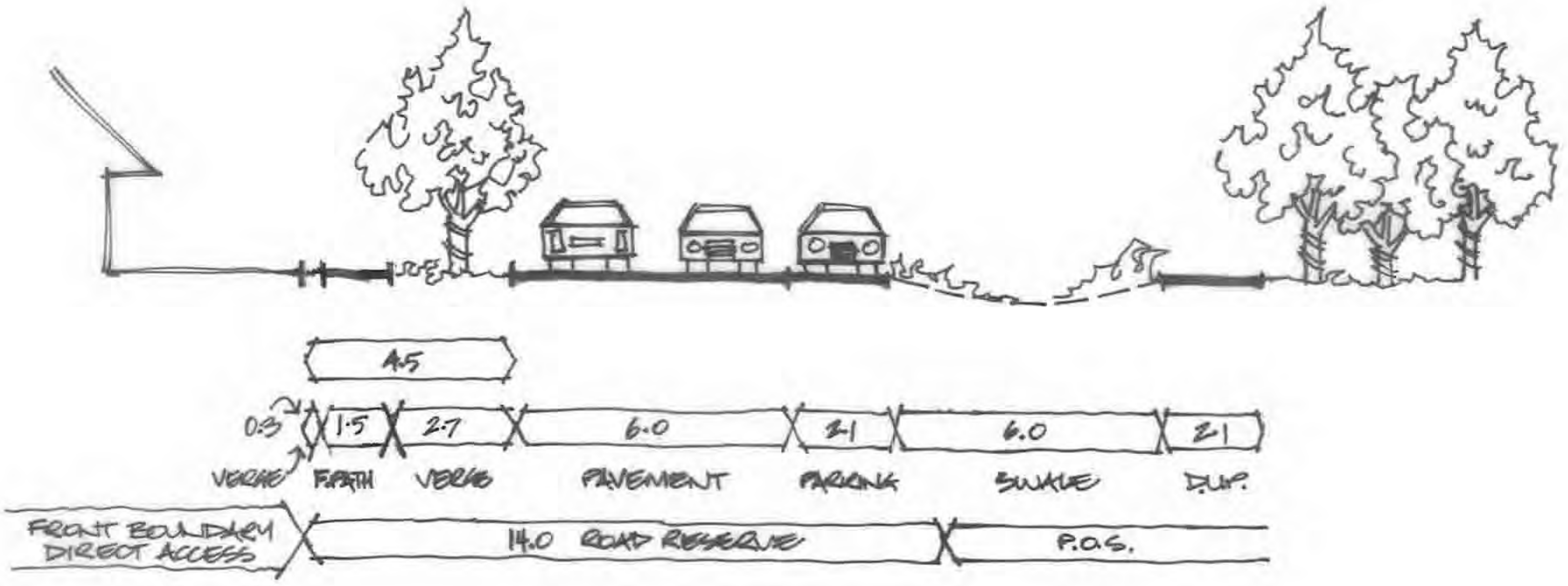


CONNECTOR ROAD WITH SWALE IN VERGE

CONCEPTUAL CROSS SECTION
SOUTHERN RIVER.



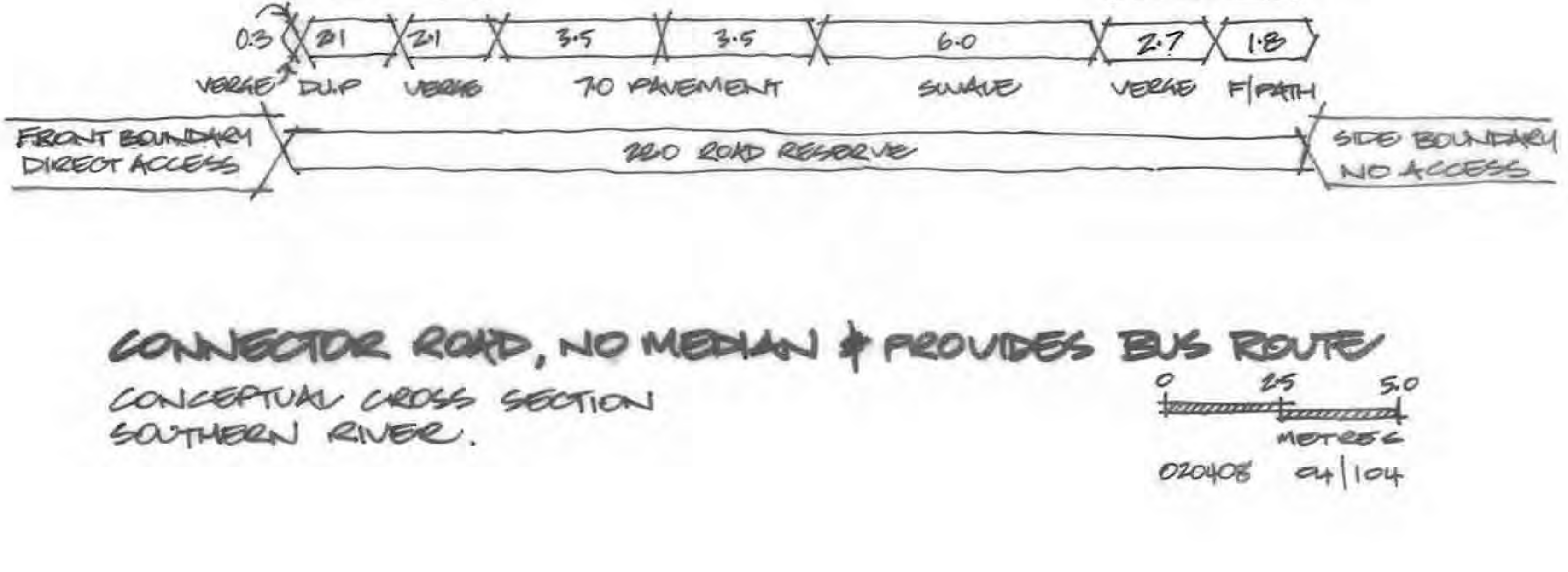
02.4.08 04|104



STANDARD ACCESS ST WITH SWALE/DUP. IN POS.

CONCEPTUAL CROSS SECTION
SOUTHERN RIVER.

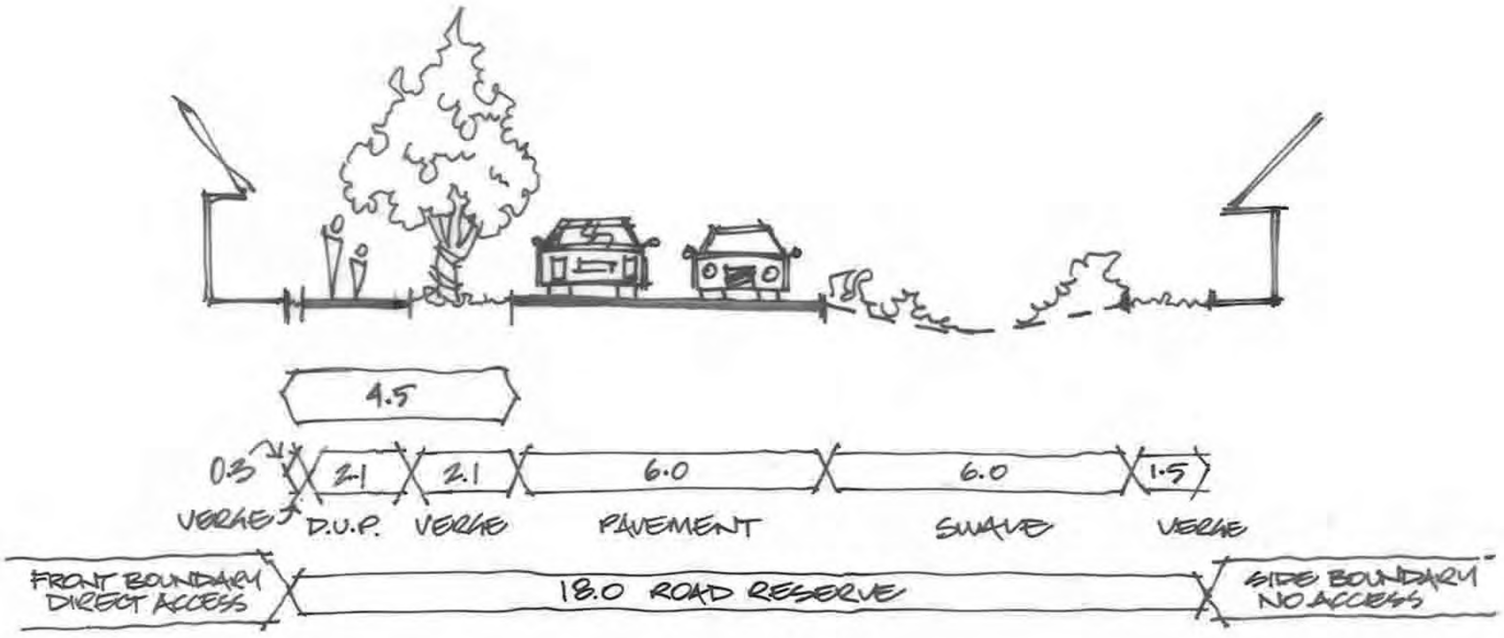
0 2.5 5.0
METRES
020408 04/104



CONNECTOR ROAD, NO MEDIAN & PROVIDES BUS ROUTE

CONCEPTUAL CROSS SECTION
SOUTHERN RIVER.

0 2.5 5.0
METRES
020408 04/104

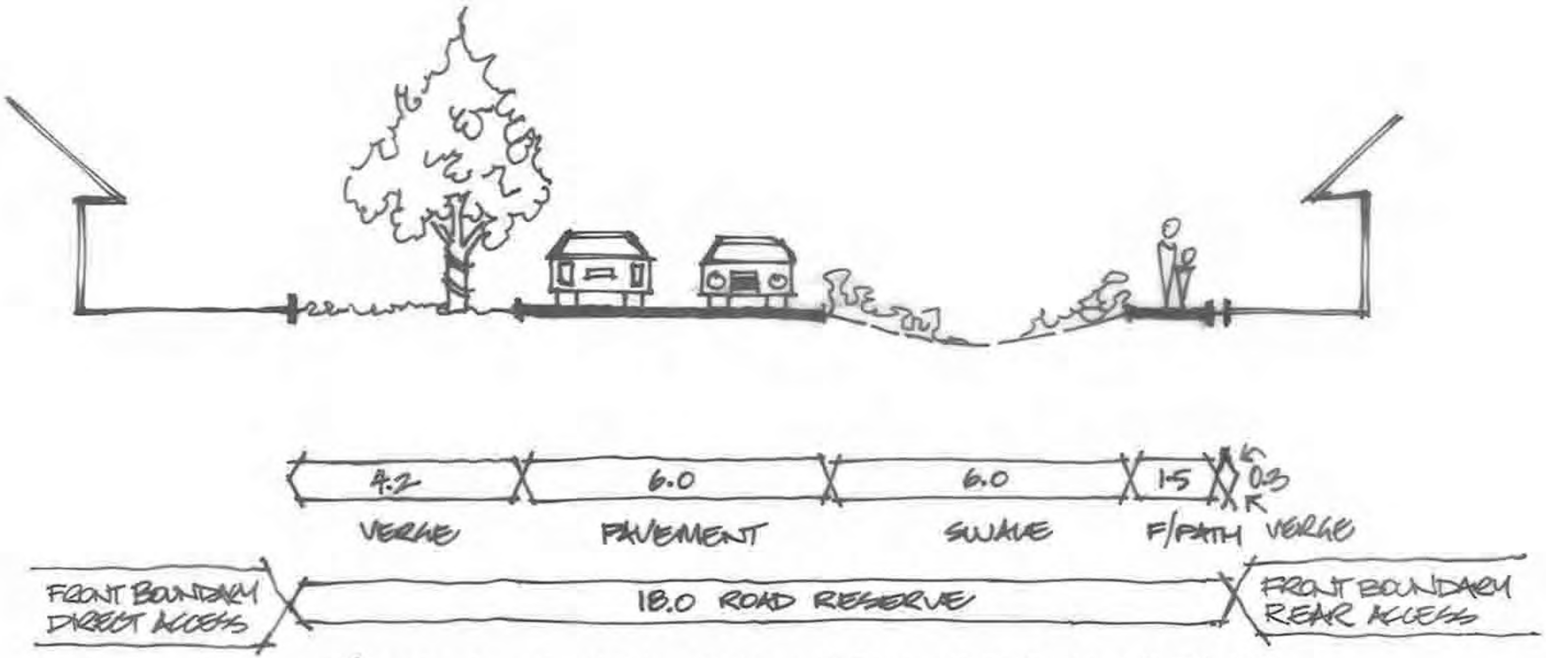


FRONT LOADED STANDARD ACCESS ST WITH SWALE SIDING LOTS.

CONCEPTUAL CROSS SECTION

SOUTHERN RIVER.

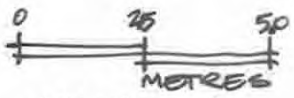
020408 04|104



* NOTE: 4.1m VERGE IS PERMISSABLE WITH TOTAL WIDTH 17.9m

REAR LOADED WITH FOOTPATH ABUTTING SWALE.

CONCEPTUAL CROSS SECTION
SOUTHERN RIVER.



020408 04/104

APPENDIX K
DETAILS OF MUSIC MODEL

APPENDIX K

MUSIC Modelling Report

This report has been included comply with the guidelines set out in Section 3 of the *Draft MUSIC Guidelines for Perth* (GHD, June 2006).

Model Version: 3.0.1

Start Date: 1 January 1975

End Date: 31 December 2000

Time Step: 6 minute interval

Data Source: Perth Airport data provided by MUSIC. Time step, start and end dates as per *Draft MUSIC guidelines for Perth* (GHD, 2006)

Catchment Data:

Catchments were modelled as pervious and impervious areas. The roof area was included in the pervious area as it is planned that roof runoff will be infiltrated on site. Water falling on domestic pavements is also assumed to infiltrate on site. This may slightly overestimate the amount of nutrients in the pervious area but this was considered to be a conservative approach.

The impervious area of the catchments was assumed to be equivalent to 60% of the road reserve area plus the commercial areas. The pervious area is equivalent to the residential area.

Catchment	Impervious Area (Ha)	Pervious Area (Ha)	Total (Ha)
C1	1.16	2.55	3.71
C2	5.31	21.38	26.69
C3	1.73	8.39	10.12
C4	1.76	8.33	10.09
C5	1.13	5.29	6.42

Node Assumptions:

Source node pollutant and runoff generation as per the guidelines (GHD, 2006). Pervious catchments were assumed to be sand and modelled as per Table 4 of the guidelines.

Treatment node parameters: as per guidelines.

Any potential problems related to the loss of flows from simulations through infiltration.

The swales in the road reserve will generally have nominally 600mm between the base or invert of the swale and the AAMGL. There are some situations where it will be greater than this. Swales are proposed to be 500mm to 600mm deep below the edge of road level, 1m base width and 1 in 6 side slopes. The vegetated detention basins in the POS are expected to have bases on or in the AAMGL. These basins were modelled as ponds in the model with a depth of 0.5 m below the outlet. This was undertaken because these structures are likely to be less linear than a swale and thus will have different hydraulic properties which are more similar to a pond than a linear swale system.

To model this, the swales were modelled under various scenarios to investigate the potential effects of high groundwater levels on infiltration. Modelling was undertaken with a range of infiltration rates between 0.36 and 3.6 mm/hr to reflect this. This range is equivalent to a system with a heavy clay to sandy clay base, or low infiltration rates due to high groundwater levels. It is likely that the base of the swales will be in materials ranging between sand and sandy clay, which would have an infiltration rate of 3.6 to 360 mm/hr, according to MUSIC.

Swales in C1 and C5 were modelled as bioretention systems, as it is likely that bioretention systems will be used in this area with the underdrain at AAMGL to control groundwater levels. These were also modelled with a range of infiltration rates between 0.36 and 18 mm/hr.

Even with all of the systems running with an infiltration rate of 0.36 mm/hr (equivalent to a heavy clay soil type), the system removed 85% of Phosphorus and 75% of Nitrogen, which is above the targets set by the ILWMP.

It is recognised that the basins in the POS may occasionally intersect the groundwater on the site. Swales in the north-eastern corner of the site, near the current chicken farm, will not be placed below AAMGL to limit the abstraction of nutrient rich groundwater from the site. Because of the placement of these structures, they will be above groundwater in summer and thus not receive any summer inflows. This design practice is being undertaken to minimise nuisance insect breeding on the site. Seepage is not considered to be an important part of the model, because it should be limited to periods of a few weeks when groundwater levels are at their highest.

Discussion of any potential problems related to the interaction of groundwater/surface water, including calculations, assumptions and potential inaccuracies.

The assumptions associated with infiltration in MUSIC are all very simple estimates of what may be the case. MUSIC does not model groundwater/surface water interactions and is thus simplification of what occurs on the Swan Coastal Plain.

Assuming that the bottoms of the POS swales are set at AAMGL, the swales may intercept groundwater for perhaps one week every second year. Assumptions that may be made are:

- that the groundwater level rises to an average of 5 cm above AAMGL over this period and the flow does not go significantly above the base of the channel (i.e. dh = 0.05 m);
- the soil at this level is a sandy clay with K = 18 mm/hr; and
- Swales are 30 m wide, there will be a total length of 1,700 m of swale in the POS. Half of this runs in direction normal to groundwater flow and half of it runs parallel to groundwater flow, a total of 865 m could intercept flow, and
- dx = 3 m or the width of the swale sides.

Using Darcy's equation:

$$\begin{aligned} Q &= K(dh/dx) \\ Q &= 0.018 *(0.05/3) \\ &= 0.003 \text{ m/hr} \\ &= 0.05 \text{ m/week} \end{aligned}$$

Given height of 5 cm and width of 865 m, the total area of flow would be 43.25 m^2. The total volume of water infiltrated would therefore be in the order of 2 kL over a week. This should be considered as an order of magnitude estimate, but it is not considered to be a significant volume, given the size of the catchment.

More accurate interception values can be modelled through the use of a groundwater model such as MODFLOW.

A description of any non structural treatment measures used

Non-structural treatment measures were not included.