ON SITE STORMWATER MANAGEMENT FOR INFILL DEVELOPMENT, CITY OF STIRLING

Jim Davies (PhD, FIEAust),
Marnie O'Donnell[1] (BSc Env, Grad Dip GIS),
Alex Rogers (BE (Env), MIEAust)

JDA Consultant Hydrologists, PO Box 117, Subiaco WA 6904
Tel: (618) 9388 2436 Fax: (618) 9381 9279 Email: jimjda@iinet.net.au

Jim Davies, Principal Hydrologist and Managing Director JDA has extensive experience in providing consultancy services in hydrology and water resources management. He was WA representative on the Institution of Engineers Australia (IEAust) National Committee on Water Engineering from 1994-2000, and is a current Member and past Chairman of the Hydrology & Water Resources Panel of IEAust (WA Division). Jim is a member of the Institute of Public Works Engineering (IPWEA), Australian Water Association (AWA), International Association of Hydrogeologists (IAH) and Environmental Consultants Association (ECA).

Marnie O'Donnell is a Hydrologist specialising in GIS analysis and spatial data interpretation. Marnie joined JDA in February 1999, as a Post Graduate in Geographical Information Systems obtained from Curtin University, following an undergraduate degree from Murdoch University in Environmental Science.

Alex Rogers is a Senior Hydrologist/Environmental Engineer at JDA, with 10 years experience in hydrology and water engineering. Alex has specific expertise in groundwater, infiltration and urban hydrology. He joined JDA in 1995, following 2 years experience with Water Authority (Groundwater and Environment Branch), and is a Member of the Institution of Engineers, Australia.

ABSTRACT

The paper details work-in-progress of the development of a comprehensive stormwater disposal standard (SDS) for private property sites within the City of Stirling. The SDS considers the impact of local ground conditions including soil types and groundwater level on infiltration rates, incorporates a review of best management practices, and provides compliance with relevant national and state standards. The paper discusses on site retention (OSR) as compared with on site detention (OSD) more commonly used in the eastern states of Australia.

1.0 INTRODUCTION

The City of Stirling covers an area of approximately 106 km^2, comprising over 30 suburbs (Figure 1). The trend for small lot residential subdivisions has led to a substantial increase in impervious areas, increasing runoff to the City's road drainage system that was not designed to accommodate flow from residential lots. The objective of the study is the development of a comprehensive stormwater disposal standard (SDS) for private property sites within the City of Stirling, using the following process:

- Summarise national and state standards/requirements for stormwater management
- Review various WA local authority on site drainage standards/approaches
- Identify zones of infiltration within the City of Stirling based on soil type and depth to groundwater
- Identify existing ground removal/backfilling and compaction areas likely to impact infiltration capacity
- Identify appropriate design average recurrence interval (ARI) for onsite retention (OSR)
- Develop a matrix for OSR storage volume calculation based on infiltration modelling
- Recommend appropriate Best Management Practices (BMPs) and associated products

The study resulted in a series of GIS produced maps of the City showing various attributes affecting stormwater, infiltration capacity including soil type and depth to water table.

This paper does not necessarily represent the views of the City of Stirling.

2.0 ENVIRONMENTAL FACTORS

2.1 Landforms and Soils

The city area comprises Quaternary deposits with an east-west transition from Pleistocene to the more recent Holocene, Figure 2 (Gozzard 1986). The transition is represented by Bassendean Sand in the east, Sand derived from Tamala Limestone and north-south band of Swamp Deposits in the centre, to the west Tamala Limestone and Safety Bay Sand along the coast. The swamp deposits are indicative of areas of high water table (i.e. wetlands including lakes).

2.2 Topography

There are two dominant north-south ridges (Figure 3), the western ridge approximately 2 km from the coastline rising from 10 m AHD to above 70 m AHD (generally through Carine, Karrinyup, Careniup, Doubleview, Wembley Downs) and the eastern ridge along the north east boundary with maximum height of 85 m AHD (generally through Balga, Careniup, Mirrabooka, Nollamara/Dianella and Yokine) – see Figure 1.

2.3 Groundwater Levels

The City of Stirling is located at the south western margin of the Gnangara Groundwater Mound. Groundwater flows to the west and south (Figure 4) towards the coast and Swan River.

The Perth Groundwater Atlas (WRC, 1997) shows maximum recorded groundwater contours based on maximum recorded levels of monitoring bores generally since 1975. Within the City, maximum groundwater contours vary from 34 m AHD in the north-east to 13 m AHD near the Swan River in the south, and 1 m AHD along the coast (Figure 4). Groundwater levels vary seasonally by approximately 1 to 2 m and have declined approximately 1m since 1975 associated with declining rainfall, although many local exceptions occur.

The accuracy of WRC's maximum groundwater level contours across the City of Stirling was assessed against DoE's superficial groundwater and surface monitoring sites long-term records.

DoE's monitoring water levels, absolute maximum on record, maximum since 1975, and calculated average annual maximum groundwater level (AAMGL) since 1975, are shown in Figure 5.

It appears that either not all DoE bores were used in the contouring of maximum groundwater levels, and/or a spatial interpolation technique may have been used in which integrity of the maximum value at the bore location may not have been maintained. That is, the contours do not conform to the data.

Depth to groundwater over the City is shown in Figure 4 calculated based on DOLA natural surface topographic contours (m AHD) sourced from the City of Stirling, and WRC's Groundwater Atlas (1997) maximum groundwater levels (m AHD), is shown in Figure 5. In summary the results show :

- The majority of the City has good clearance to maximum groundwater level (>10m).
- Approximately 24% of the City has low clearance (<2m) including a north-south coastal band approximately 1km inland from the coast, and larger areas north of Herdsman Lake (extending to Carine Swamps) and the south east corner of the Study Area adjacent to the City of Swan and Town of Vincent.

The depth to groundwater determined using these datasets is typically +/- 1.5 m. These inaccuracies and limitations are considered in the interpretation of modelling performed and the development of site specific groundwater investigation recommendations for the proposed on-site SDS.

2.4 Soil Permeability

For infiltration of rain or stormwater, a basic soil parameter is the soil permeability, otherwise called hydraulic conductivity. This is an intrinsic soil property expressing the rate of water movement under unit (1.0) gradient. This means x metres of head over x metres of soil (eg 1 m head over 1 m soil). It is generally high for sands and low for clays/peat. Typical values are 1 to100 m/d for sand, 0.001 m/d or less for clay/peat.

Estimation of soil permeability can be based on particle size distribution, field or laboratory permeability testing. No regional mapping of soil permeability is available. Figure 2 shows surface soil type, and provides the best readily available qualitative indication of vertical soil permeability (Kv).

Beneath the water table, horizontal soil permeability (Kh) can be estimated from mapping of transmissivity and saturated thickness as indicated on Figure 6, but this is not directly applicable to surface infiltration above the water table.

Zones of generalised vertical soil permeability (Kv), representative of natural surface conditions prior to any alteration of soil profiles by excavation, fill, compaction etc. are shown on Figure 2. These values are based on Kv = Kh ÷ 10. where Kh is taken from Figure 6.

Zones 1, 2, 3 & 4 indicated on Figure 2 are generalised and local variations will occur.

2.5 Infiltration Rate

In dry sandy soils the hydraulic gradient is unity (1.0) and therefore infiltration occurs at the vertical soil permeability rate (Kv). In dry clayey soils the hydraulic gradient exceeds unity and infiltration occurs at a rate greater than the vertical soil permeability rate. In ponded conditions, such as in sumps and soakwells where a depth of surface water may develop, the hydraulic gradient exceeds unity (> 1.0) and the infiltration rate exceeds the vertical soil permeability rate (Kv).

Where the water table is shallow the hydraulic gradient is significantly reduced below unity and the infiltration rate is correspondingly reduced in direct proportion to values well below Kv. Horizontal permeability Kh tends to dominate the process.

2.6 Implications for SDS

The combination of soil type and depth to water table affects the potential for stormwater to be infiltrated. Generally more permeable soils (such as sands and limestone) and deeper water table facilitate infiltration and require relatively small infiltration devices. Finer soils (clays) and peats with shallower water table have reduced infiltration rates and require significantly larger infiltration devices. This may make OSR impracticable.

3.0 REVIEW OF OSR/OSD STANDARDS

OSR has been practiced widely in Perth since the early days of settlement, and is the most common method of onsite storm water management in the city. OSD, with a low level outlet pipe, has rarely been used at all in Perth or the City, so far as we are aware, as the need has not yet been great enough to resort to it. This position is virtually the opposite to that of other major cities of Australia, where soil and water table conditions are not conducive to OSR, and OSD is the only option.

3.1 Building Code of Australia (BCA)

BCA performance requirements for roof and property drainage, which are mandatory, have primary reference to Standards Australia, National Plumbing and Drainage :

- AS/NZS 3500.3.2: Stormwater Drainage – Acceptable Solutions (1998)
  (superseded by AS/NZS 3500.3 Stormwater Drainage in 2003)

- AS/NZS 3500.5: Domestic Installations (2000) : Section 5 – Stormwater Drainage.

The Building Code of Australia (ABCB, 2004) contains no specific reference to OSR or OSD. Explanatory information states that where a stormwater drainage system is installed it must:

a) The position and manner of discharge of the stormwater drainage system must be to the satisfaction of the appropriate authority.

b) The stormwater drainage system must be designed so that any overflow during heavy rain periods is prevented from flowing back into the building.

3.2 Standards Australia (SA) – National Plumbing and Drainage

- **Roof drainage systems** are to be designed to 5 minute duration rainfall intensity for a minimum average recurrence interval (ARI) of 20 years where it is unlikely that adverse effects of stormwater flows would result in significant injury or damage to people or property. Where it is likely that adverse effects of stormwater flows would result in significant injury or damage to people or property a minimum 100 year ARI is recommended.
- **Surface drainage systems** are to be designed to dispose of stormwater flows with the concept of minor and major storms. Minor storms are to be contained within the drainage system, with major storms to overflow, as to not present a hazard to people or cause significant damage to property. Specific ARI's for major/minor storms are not specified, with allowance for determination of design criteria by the utility operator. With respect to runoff, roofed and unroofed impervious (paved) areas have coefficients of 1.0 and 0.9. Unroofed pervious areas runoff coefficients are to be nominated by utility network operators.
- **Subsoil drainage systems** are to be designed not to cause damage to buildings, by the removal of excess groundwater and reducing soil moisture levels.

Design rainfalls for 20 and 100 year ARI 5 minute duration are provided in the Standards via the Hydrometeorological Advisory Services of the Bureau of Meteorology. Australian Rainfall and Runoff (1987, since superseded by 2001) or other design rainfalls as provided by the network utility operator are considered appropriate by the Standard for surface drainage systems

No specific reference to on-site retention (OSR) is contained in either Standard. AS/NZS 3500.3 (2003) provides specific details of on-site stormwater detention (OSD) systems. General criteria for OSD in AS/NZS 3500.3 (2003) states harmless escape of overflows should be provided and any ponding is to be visible so fault can be noted. Ponding of overflow levels is required to be not less than 300 mm below any adjacent habitable floor levels of building and not less than 150 mm below non-habitable floor levels. However, no reference to specific design ARI in this regard is provided.

According to a Workshop Paper (O'Loughlin & Jones, 2003), the Australian Standards provide a platform from which designers or installers can depart if they "have confidence that better or more appropriate solutions can be adopted". Justifications are required if designers or installers choose to deviate from the standards. Deviations from standard specified Australian Rainfall Intensities (ARI's) however are not considered acceptable.

3.3 Engineers Australia (EA)

Engineers Australia has two industry publications related to flood and stormwater management : Australian Rainfall and Runoff (EA, 1997), and Australian Runoff Quality (EA, 2003).

Australian Rainfall and Runoff (1997) supersedes the earlier publication of Australian Rainfall and Runoff (1987). It contains Book VIII on Urban Stormwater Management, which is identical to Chapter 14 of the 1987 edition. This contains methods and concepts for stormwater management at the development scale but provides no information for OSR/OSD at lot scale.

EA (2003) in draft format provides an overview of current Best Management Practice in the management of urban stormwater in Australia, particularly with regard to stormwater quality. Some detail regarding the sizing of OSR/OSD systems is provided in Chapter 10 : Infiltration Systems through simplified conservative formula. EA (2003) refers the reader to more detailed mathematical modelling to provide better estimates of storage requirements.

Australian Runoff Quality (2003) provides no guidance on the ARI design storm event, time of concentration, or recommended runoff coefficient. Design ARI is stated to be the designer's responsibility, in consultation with Council.

3.4 Stormwater Industry Association (SIA)

No guidance is given for the design of OSR, although many newsletters refer to Water Sensitive Design and the desirability of storm water infiltration, where possible. Considerable attention has been given by the SIA to the application of OSD – particularly with respect to issues of licensing of designers/installers and maintenance.

The SIA website on stormwater management systems and techniques includes the following comments:

> *"The ongoing maintenance, access de-silting and surveillance of OSD systems on private property are acknowledged problems of OSD. Many structures have been found to have no access to carry out important maintenance and surveillance requirements.*
>
> *On-site-detention, which includes components of groundwater recharge, reuse storage and temporary flood storage can largely eliminate spills, reduce potable water consumption, release reservoir storage for environmental flow, naturalize storm discharge and preserve both the structure and habitat values of streams. The process of screening and settling of suspended solids in runoff before its release captures litter for disposal and retains sediment and detritus for use within the property.*
>
> *The benefits of OSD are:*
>
> - *it can be funded immediately (i.e. by the developer) and does not require any capital outlay for council;*
> - *it protects downstream properties from increase in flooding resulting from new developments. Thus it protects councils against claims for damage arising from increased runoff from new developments or redevelopments;*
> - *public land for larger detention basins may not be available adjacent to existing trunk drainage systems;*
> - *the cost of upgrading existing drainage systems is often beyond the financial means of councils;*
> - *the OSD system tackles the problem at its source, before the increased flows enter a council's drainage system;*
> - *some water quality improvements will also result from some deposition of coarse particles and the trapping of litter on outlet-protecting screens within OSD storages.*
>
> *The disadvantages of OSD are:*
>
> - *Regulations, criteria and design methods adopted by councils are often too simplistic and can therefore be unfair to developers)*
> - *Under some hydrological conditions, storages located in the lower parts of catchments can increase flow rates downstream due to delayed hydrographs.*
> - *Maintenance is a major problem, and OSD places a large administrative burden on councils and a possibly onerous duty on property owners.*
> - *OSD provides little scope for stormwater pollution reduction, especially for dissolved pollutants, and those attached to fine sediment particles.*
>
> *On-site stormwater detention systems were conceived to address the difficulty of coping with piecemeal developments and re-developments when it was technically and financially difficult to enlarge the capacities of established stormwater drainage systems. The OSD solution is to make those who are responsible for the increased runoff, and who are the beneficiaries of the change, to provide storages to maintain the status quo. "*

The SIA emphasis on OSD rather than OSR applicable to Australian cities other than Perth, is a natural reflection of SIA membership being centred in the eastern states.

3.5 A Manual for Managing Urban Stormwater Quality (WRC, 1998)

The document provides some examples of best management OSR and OSD practices, however these are provided at a regional scale rather than for individual lots. No specific reference appropriate design ARI or criteria are provided. The Department of Environment (DoE) are currently reviewing the manual. An interim position statement with regard to urban stormwater management was released February 2003 (WRC,2003), containing principles and objectives for stormwater management with a focus toward at-source controls. It did not contain any specific design information or criteria for OSD/OSR.

3.6 Urban Stormwater Management Manual (DoE, 2004)

The Manual recommends storage and stormwater reuse as high as possible in the catchment, and that stormwater detention should occur at source or on-site, to maintain as much as possible pre-urban levels of stormwater runoff. Little specific detail however regarding OSD/OSR and its design and implementation is provided. Chapters regarding specific BMP's, criteria, and application details are yet to be completed.

3.7 Local Government Guidelines for Subdivisional Development

The Institute of Municipal Engineering Australia (IMEA) Western Australia Division, produced a standard document detailing engineering requirements for subdivisional developments in W.A in 1998 (IMEA, 1998), Section 2.2 of which states all drainage designs for stormwater should comply with the following industry design requirements:

- Australian Rainfall and Runoff (Institute of Engineers Australia, 1987)
- Stormwater Drainage Design in Small Urban Catchments (Argue, ARRB Special Report No.34)
- Sub-Surface Drainage of Road Structures (Gerke, ARRB Special Report No.35)
- Water Sensitive Urban (Residential) Design Guidelines for the Perth Metropolitan Region (Whelans, 1993)
- A Manual for Managing Urban Stormwater Quality (WRC, 1998)

Catchment runoff coefficients are not listed in this document due to the variation of land, land use and soil types throughout W.A., however advice regarding design storms is provided. Local authority drainage networks are stated as required to be designed for 2 to 5 year ARI, except for arterial drains and compensating basins where 10 year ARI are stated to be used. Overland flow paths and storage facilities for flood flows are to be designed for a 100 year ARI storm event. Floor levels are recommended to be a minimum 300 mm above the 10 year ARI flood level. No specific reference to OSD/OSR at lot scale is provided.

3.8 Individual WA Local Government Policy for On-Site Stormwater Management

WA local government policy for on site stormwater management is summarised as follows:

- New developments and redevelopment sites are generally subject to councils on-site stormwater management polices. Retrofitting of existing development is not required.
- All City of Stirling neighbouring local authorities policies contain between 12 and 17 mm of runoff on-site. City of Stirling itself requires storage of 12.2 mm of rainfall, possibly derived from "½ inch" in imperial terms, equating to a 20 year ARI storm of 5 minutes duration.
- Soakwell capacity (m^3 requirements) are calculated as a product of depth x impervious area. For example, City of Stirling policy for an impervious area of 111 m^2 requires 1.36 m^3 storage which can be provided by a 1200 mm diameter and depth soakwell.
- Some local authorities allow for connection to their drainage network for areas with insufficient clearance to groundwater (eg City of Bayswater and City of Belmont near the Swan River), representing the delineation of zones with the local authority boundary for policy application.
- Some local authorities have different requirements based on land use (commercial/residential) or soil type (clay/sand). For example the City of Joondalup requires commercial property soakwell calculations to be based on 100 year ARI 24 hour duration storm event.
- Specific product recommendations are not stated by any of the local authorities. Four of the six neighbouring local authorities require concrete soakwells.
- A minority of the local authorities reviewed permit overflow systems to connect to the street drainage system (eg Town of Bassendean). Most authorities however require retention on site without connection.
- A number of councils have indicated they are currently in the process of reviewing their policies (eg City of Swan, City of Canning)

4.0 DESIGN ARI AND CRITICAL STORM DURATION

For city urban drainage design, prevention of inundation of private properties in storm events of 100 year ARI is appropriate, see for example EA (1987). OSR devices are traditionally designed for a lower ARI e.g. 20 year (see 3.8 above) with overflow to private property or road reserve in rarer events e.g. 100 year. This may be satisfactory if the peak overland flow has subsided at the time that the soakwell overtops.

The storm duration which gives rise to peak overland flows is probably shorter than the critical storm duration which causes OSR devices (mostly soakwells) to surcharge. This is because overland flow is directly related to peak flow generation, whereas OSR devices have a component of storage which tends to result in a longer storm producing the maximum water level and storage within the device.

It is suggested as a starting point soakwells should be designed for 30 minute storm duration, although shorter or longer storms may be critical. This needs to be verified by field studies of the performance of individual soakwells and their infiltration rates, in the same way stormwater detention basins are analysed for critical duration. Stormwater retention basins (sumps) typically have longer critical storm durations, 12 hours to 5 days.

5.0 OSR INFILTRATION MODELLING

5.1 Method

To investigate spatial variation within the City of infiltration potential, infiltration modelling is being performed for various site conditions (soil type, depth to groundwater etc) and various design storm events.

Two infiltration models are used, INFIL and MODRET. INFIL is used to model cases where a deep water table exists while MODRET is used to model areas of shallow water table. Both INFIL and MODRET use a design inflow hydrograph specified from the rainfall temporal patterns presented in AR&R (I.E.Aust, 1997) for various design storm frequencies and durations.

Infiltration scenarios modelled included:

- variation of depth to groundwater from 1 m to 20 m+
- various Kh, Kv
- design ARI's of 2, 20 and 100 year
- various soakwell capacities (900 mm dia, 1800 mm dia)

5.2 Modelling Results

Figure 7 shows the general shape of the relationship between impervious areas served by a soakwell and depth to water table, for specific Kv, Kh. The graph shows that for deep water table the required storage is independent of water table depth. In this region the required storage is related to soil permeability only. For shallow water table the line depends on depth to water table. Greater storage is required in this region which may be prohibitive.

This presentation of results for both shallow and deep water table cases to show the transition zone of governing equations has not been previously published.

Also shown on Figure 7 is the existing policy of 12.2 mm storage per impervious m^2 for 2 soakwell sizes.

6.0 DEVELOPMENT OF ON-SITE SDS

6.1 Scope of Application

Most road drainage in the City of Stirling does not allow for lot runoff, and is only designed to receive road runoff. Hence any additional impervious areas created during lot improvement, redevelopment, and/or subdivision has potential to lead to increased runoff to the road reserve and local authority and regional drainage systems. The following types of development within the City of Stirling are therefore proposed to be subject to the SDS :

- All new single dwellings
- Redevelopment lots (eg duplexes, triplexes, battle axe blocks), defined as lots which used to have or were originally zoned to have a lower density development than is proposed
- All commercial and industrial areas not located in industrial drainage scheme areas
- New subdivisions
- New ancillary structures, including swimming pools, tennis courts, carparks, garages, and sheds
- Redesign of the stormwater treatment or management of an existing development/dwelling
- Any alterations and additions which in the opinion of Council will result in an adverse impact on the capacity of the Councils stormwater drainage system.

Proposed exemptions to the SDS include :

- Building developments within Industrial drainage scheme areas
- Development in zones deemed by the City of Stirling as unable to infiltrate, and where in the opinion of Council discharge will not result in an adverse impact on the capacity of the Councils stormwater drainage system

The SDS will apply to all land within the City of Stirling local authority boundary.

6.2 Calculation of Storage Volume

Table 1 details an initial draft proforma for the calculation of on site storage requirements.

It should be noted that land filling and compaction may alter the soil condition and properties and the depth to groundwater from that shown in regional mapping (WRC,1997). This may result in different site storage volume requirements from those specified in Table 1 for various catchment infiltration zones, and site specific groundwater investigations for these development areas are recommended. Site specific groundwater investigations are also recommended for sites with low clearance to groundwater.

While use of rainwater tanks is encouraged by Council for non potable use applications, rainwater tanks do not substitute for the storage capacity required for on-site stormwater disposal. Innovative stormwater management systems including rainwater tanks may be considered by Council in some difficult cases to compensate for an inability to provide adequate on–site stormwater storage. JDA recommends such systems be considered on a case by case basis.

Table 1 : Proposed On Site Retention (OSR) Calculation Proforma

Development Name/Location :		
Development Type : (type list to be added)		
Catchment Infiltration Zone : (via Figure 3)	______	**A**
Estimated Depth to Maximum Groundwater Level : (via Figure 4)	______	
Has a Site Specific Groundwater Investigation Been Conducted (Yes/No) :	______	
If Yes to above, Calculated Depth to Maximum Groundwater Level based on Field Investigation (m) :	______	
Add check on compaction/fill		
Total Site Area (m^2) :	______	**B**
Total Equivalent Impervious Area (Roof, Driveway etc) Draining to On-Site Storage Facility (m^2) :	______	**C**
Site Storage Volume Required per m^2 EIA Based on Catchment Infiltration Zone (**A**) : Zone 1 = x.xxx m^3/m^2 Zone 2 = x.xxx m^3/m^2 Zone 3 = x.xxx m^3/m^2	______	**D**
On-Site Retention (OSR) Storage Requirement (m^3)		**CxD**

6.3 Maintenance

Regular maintenance of on-site stormwater systems will be required to maintain system performance, and is owner's responsibility. Maintenance should include clearing of accumulated debris, removal of sediment from base of soakwells/pit etc.

6.4 Information to be Submitted with Design

Plans to be submitted for on site stormwater disposal to Council for approval shall include :

- Proposed method of stormwater disposal, including product type
- Existing ground levels or contours
- Proposed level of paved or concreted areas
- Details of roof drainage disposal
- Calculation of required on site storage capacity
- Size and location of all on site storage and drainage system
- Location of overland flow paths
- Detail of access and maintenance facilities
- Site constraints such as trees, services or other structures that may affect the viability of the drainage or on site detention system.

7.0 REFERENCES

Australian/New Zealand Standard, Plumbing and Drainage, Part 3: Stormwater Drainage. AS/NZS 3500.3:2003.

Australian/New Zealand Standard, National Plumbing and Drainage, Part 5: Domestic Installations, Section 5, Stormwater Drainage. AS/NZS 3500.5:2000.

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (2000c) Australian Guidelines for Urban Stormwater Management, National Water Quality Management Strategy, 2000

Australian Building Code Board (2004) http://www.abcb.gov.au/

Arque J.R. (1986) Storm Drainage Design in Small Urban Catchments: A Handbook for Australian Practice, South Australian Institute of Technology.

City of Belmont (2002) Engineering Requirements and Design Guidelines.

City of Bunbury (2004) Local Planning Policy Stormwater Disposal from Private Properties & Connection to the City's Storm Water System.

City of Joondalup (2004) Approvals Fact Sheet, On Site Stormwater Drainage Requirements.

City of Joondalup (1998) Joondalup Development Design Specification JD5. Stormwater Drainage Design.

City of Mandurah (2004) City of Mandurah Development Guidelines.

City of Melville (2002) Policy No. T3 Drainage Easement.

City of Nedlands (2004) Street Drainage

City of South Perth (2002) Management Practice M415: Stormwater Drainage for Proposed Buildings.

City of Stirling (2004) Requirements for On-Site Drainage.

City of Subiaco (2004) Policy on Stormwater Disposal

City of Wanneroo (2003) Guidelines for Development and Subdivision of Land – Issue No.2 Development Design Specifications, WA Aus Spec #1.

City of Wanneroo (2004) Stormwater Runoff Information Sheet.

Davidson, W.A. (1995) Hydrogeology and Groundwater Resources of the Perth Region Western Australia, Dept. of Minerals and Energy, Bulletin 142

Department of Environment (2004) Stormwater Management Manual for Western Australia, February 2004

Gozzard J.R. (1986) Perth, Sheet 2034 II and part 2034 III and 2134 III. Perth Metropolitan Region Environmental Geology Series, GSWA.

Indian Ocean Climate Initiative (2002) Climate Variability and Change in South West Western Australia, Perth, September 2002.

Institution of Engineers Australia (1997) Australian Rainfall & Runoff Volume 1: A Guide to Flood Estimation

Institution of Engineers Australia (1987) Australian Rainfall & Runoff Volume 1: A Guide to Flood Estimation (Revised Edition).

Institution of Municipal Engineering Australia WA Division Inc. (1998) Local Government Guidelines for Subdivisional Development, Edition 1.

O'Loughlin G. and Jones R. (2003) Stemming the tide of stormwater. Excerpts for the Standards Australia & SIA workshop paper, Standards Australia web site, Australia. http://www.standards.org.au/STANDARDS/NEWSROOM/TAS/1999-05/T2005F03/T2005F03.HTM

Pezzaniti D., Argue J. and Johnston L. (2003) Detention/retention storages for peak flow reduction in urban catchments: Effects of spatial deployment of storages, Institution of Engineers Australia (2003) Australian Journal of Water Resources. Vol 7, No. 2.

Ryde City Council (2001), Stormwater Management Development Control Plan DCP No 41, August 2001

Shire of Swan (1991) Guidelines for Subdivision Development, Technical Services Department.

Town of Bassendean (2001) Standard Private Stormwater Connection to Council's Street Drainage System

Town of East Fremantle (1994) Council Policy for Drainage

Town of Victoria Park (2004) Requirements for On-Site Stormwater Drainage

Town of Vincent (2003) Requirements for On-Site drainage – Commercial Developments

Town of Vincent (2003) Policy Manual Technical Manual, Technical Services Engineering Policy No 2.2.16. Stormwater Drainage Connections.

Water and Rivers Commission (2003) Urban Stormwater Management in WA - Interim Position Statement Principles and Objectives February 2003 (Appendix A)

Water and Rivers Commission (1998) A Manual for Managing Urban Stormwater Quality in Western Australia. August 1998.

Water Corporation (1998) Urban Main Drainage Manual, Design & Construction Requirements for Urban Main Drains

Acknowledgements

JDA acknowledges the following City of Stirling representatives for their guidance and contribution toward the preparation of this document:

- Mike Grove (Senior Engineering Technical Officer)
- John Cameron (Manager Engineering Design)
- Andre Gillot (Principal Building Surveyor)
- Les Float (Principal Environmental Health Officer)