



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

Water monitoring guidelines for better urban water management strategies and plans

October 2012

Looking after all our water needs

Water monitoring guidelines for better urban water management strategies and plans

Looking after all our water needs

Department of Water
October 2012

Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone +61 8 6364 7600
Facsimile +61 8 6364 7601
National Relay Service 13 36 77
www.water.wa.gov.au

© Government of Western Australia 2012

October 2012

This work is copyright. You may download, display, print and reproduce this material in unaltered form only (retaining this notice) for your personal, non-commercial use or use within your organisation. Apart from any use as permitted under the *Copyright Act 1968*, all other rights are reserved. Requests and inquiries concerning reproduction and rights should be addressed to the Department of Water.

ISBN 978-1-921992-57-5 (print)

ISBN 978-1-921992-58-2 (online)

Acknowledgements

The Department of Water would like to thank all the organisations and individuals who made submissions on the *Draft water monitoring guidelines for better urban water management strategies and plans*. The technical assistance from staff across the department, including the regions, in providing responses to the submissions has made the completion of this publication possible.

For more information about this document contact:

Ken McIntosh
Urban Water Management Branch
Email: Ken.McIntosh@water.wa.gov.au
Telephone: 08 6364 6603
Facsimile: 08 6364 6516

This document may need to be reviewed on the basis of experience with its use, industry feedback, policy change, technical advances and changes to technical references.

Disclaimer

This document has been published by the Department of Water. Any representation, statement, opinion or advice expressed or implied in this publication is made in good faith and on the basis that the Department of Water and its employees are not liable for any damage or loss whatsoever which may occur as a result of action taken or not taken, as the case may be in respect of any representation, statement, opinion or advice referred to herein. Professional advice should be obtained before applying the information contained in this document to particular circumstances.

This publication is available at our website <www.water.wa.gov.au> or for those with special needs it can be made available in alternative formats such as audio, large print, or Braille.

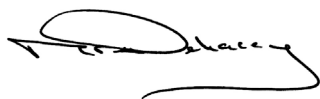
Foreword

The Department of Water developed these monitoring guidelines for surface water and groundwater systems to help the land development industry establish the necessary monitoring programs associated with urban development.

Integrated land and water planning is based on the principle of total water cycle management as outlined in the *State planning policy 2.9: water resources* (GWA 2006) and *Better urban water management* (WAPC 2008). These guidelines support the urban land development process and define what hydrological information to be collected and reported both before and after urbanisation. Addressing the requirements of these guidelines and incorporating them into the planning process is part of an integrated approach to land use planning and water management.

In the same way as *Better urban water management*, these guidelines acknowledge the need for a flexible approach to monitoring. The scale and detail of monitoring required will depend on the availability of existing data, the planned development's scale, local water values and the risk to local water resources.

Implementation of these guidelines will mean a more consistent approach to monitoring programs both pre- and post-development across Western Australia. The Department of Water will periodically review and update this document to reflect current issues.



Maree De Lacey
Director General
Department of Water

Contents

| | |
|--|-----|
| Foreword | iii |
| Summary | vii |
| Introduction..... | 1 |
| 1.1 Background and application..... | 2 |
| 2 Monitoring for urban development..... | 4 |
| 2.1 Objectives for monitoring | 4 |
| 2.2 Assessment requirements to support urban development monitoring | 4 |
| 2.3 Pre-development monitoring | 10 |
| 2.3.1 Regional water management strategy investigations..... | 11 |
| 2.3.2 District water management strategy investigations..... | 11 |
| 2.3.3 Local water management strategy investigations | 12 |
| 2.3.4 Subdivision – urban water management plan investigations | 13 |
| 2.4 Construction of subdivision | 13 |
| 2.5 Post-development monitoring | 14 |
| 3 Water aspects to be monitored..... | 16 |
| 3.1 Groundwater monitoring (levels and quality) | 16 |
| 3.2 Surface water flow monitoring..... | 17 |
| 3.3 Surface water quality monitoring..... | 18 |
| 3.4 Ecological water requirement..... | 19 |
| 4 Developing a monitoring program | 22 |
| 4.1 Setting monitoring program objectives..... | 22 |
| 4.2 Description of monitoring area | 23 |
| 4.3 Setting spatial boundaries..... | 23 |
| 4.4 Defining detail of monitoring..... | 23 |
| 4.5 Duration of monitoring | 23 |
| 4.6 Advice for selecting sampling sites | 24 |
| 4.6.1 Site selection and monitoring of the surface water | 24 |
| 4.6.2 Site selection and monitoring of the groundwater | 25 |
| 4.7 Sampling frequency..... | 26 |
| 4.8 Number of water quality samples and precision | 26 |
| 4.9 Selection of measurement parameters | 27 |
| 4.10 Data management | 29 |
| 4.11 Data preparation analysis and interpretation | 29 |
| 4.11.1 Data preparation | 29 |
| 4.11.2 Censored data | 30 |
| 4.11.3 Data integrity..... | 30 |
| 4.11.4 Data analysis and interpretation | 31 |
| 4.12 Reporting | 32 |
| 5 Recommendations..... | 34 |
| 5.1 Data storage in water information database (WIN)..... | 34 |
| Appendix A: Components of a monitoring program, monitoring requirements and responsibilities of involved parties | 36 |

| | |
|--|----|
| Appendix B: Water quality parameters and acceptable detection limits for surface and groundwater | 40 |
| Appendix C: ISO and AS standards for water quality monitoring..... | 43 |
| Appendix D: Selection of measurement parameters based on land use activities | 45 |
| Figure D1: Industrial land uses that may be impacting on groundwater systems, wetlands and surface water catchments..... | 45 |
| Figure D2: Rural land uses that may be impacting on groundwater systems, wetlands and surface water catchments..... | 46 |
| Figure D3: Urban land uses that may be impacting on groundwater systems, wetlands and surface water catchments..... | 47 |
| Shortened forms | 48 |
| Glossary | 49 |
| References | 51 |

Figures

| | |
|--|----|
| Figure 1 Integrating water planning with land planning processes | 2 |
| Figure 2 Process for determining ecological water requirements for water-dependent environments in urban areas | 21 |

Tables

| | |
|---|----|
| Table 1 Risks to/from water resource | 6 |
| Table 2 Risks to/from proposed urban development | 6 |
| Table 3 Planning decision..... | 8 |
| Table A1 Monitoring program summary | 36 |
| Table A2 Monitoring requirements and responsibilities of relevant parties | 39 |

Summary

The Department of Water developed these monitoring guidelines for surface water and groundwater systems to help urban land developers determine pre- and post-development monitoring requirements to support district water management strategies, local water management strategies or urban water management plans. These plans and strategies are prepared to meet the requirements of *State planning policy 2.9: water resources* (GWA 2006) as outlined in *Better urban water management* (WAPC 2008).

This document advises on setting monitoring objectives and developing a monitoring program. It also discusses data storage, data interpretation and reporting requirements. The scale of monitoring required for a proposed urban development will be influenced by the availability of existing data, the size of the planned development, local water values and the risk of degradation to local waters.

Establishing, operating and reporting on pre- and post- urban development water monitoring is the responsibility of developers. Monitoring undertaken by developers provides data and information for; urban development design, evaluation of designs so they can be continually improved, improving the cost effectiveness of designs and supporting the continued use of the “deemed to comply” approval approach. Relevant water data will lead to innovation and improved water management systems for future sustainable urban developments.

The state government has information that characterises water resources broadly at the regional scale for priority development areas. If no water data are available, developers may be required to undertake investigations, including water monitoring as early as the district planning stage to enable them to develop a district water management strategy.

This guideline recommends that pre-development monitoring timeframes for ecological, surface water and groundwater monitoring in ‘greenfield’ areas should be at least two full years.

Depending on the risks, site inspections for water management aspects should continue through the urban development construction phase

This guideline recommends that depending on the level of risk, post-development¹ monitoring should be for a minimum of three full years. If after 3 years there is no significant risk to the hydrological and/or hydrogeological condition of the area no further water monitoring needs to occur.

¹ Changes in the water quality parameters as a result of the development detected during the first three years of post-development monitoring, outside of trigger values set in the relevant water management strategy/plan, may require further action that could include further monitoring. Liaison is required with the local government, Swan River Trust, Department of Water and possibly Department of Environment and Conservation, depending on the situation.

The monitoring program should be regularly reviewed by the developer and, after consultation with the department and the local government, the program adjusted if required.

A summary of the requirements and responsibilities of different organisations for urban water monitoring is provided in Appendix A.

It is expected that an update to these guidelines will be published on the basis of feedback about their use, policy changes, technical advances, or changes to technical references.

Introduction

This document describes what should be considered when determining pre- and post- urban development water monitoring requirements, and at what stage in the planning process various water monitoring is required.

The objective of pre-development water resource monitoring is to characterise or define a site's hydrological conditions. Monitoring is thus required to help develop the future urban form and associated water management strategies. The strategies need to respond to the local hydrological conditions – to reduce risk to both water resources and the development. Monitoring in itself does not mitigate risk but informs the processes used to manage the risk; for example, catchment flood analysis, catchment management, site modelling, water management facility design, etc.

Water-resource-related risks can be highly variable depending on site-specific characteristics and the proposed land use change and/or development proposed. Monitoring requirements cannot therefore be fixed and a flexible approach is required in relation to both the level of detail and timing.

In the context of urban land development, monitoring of water resources is generally undertaken to:

- establish pre-development conditions, including identifying issues that need to be addressed as part of the land development process
- identify and characterise surface water- and groundwater-dependent environments and ecosystems that need to be protected
- determine the post-development impact of the proposal including assessment against agreed levels of performance
- evaluate the performance of water management infrastructure, including water sensitive urban design best-management practices².

Urban development water monitoring programs can be highly variable. Their design depends on local conditions, the program's objectives and the elements of the water environment that require assessment. To support the land development process, these guidelines provide developers with information to help determine their monitoring requirements. The guidelines promote a more consistent approach to establishing pre- and post-development monitoring programs for surface water and groundwater.

² Details for best management practices (BMP) monitoring is not covered in this guideline.

Monitoring to develop scientific understanding of BMP performance and/or assessment of the effects of urbanisation at the catchment scale are not within the scope of this document.

1.1 Background and application

State planning policy 2.9: water resources (GWA 2006) outlines the requirements for the protection and management of water resources as part of the planning and urban development approvals system. Implementation of this policy is supported by *Better urban water management* (WAPC 2008) (BUWM). BUWM outlines the broad water management information requirements at each planning stage and provides guidance on the preparation of regional, district and local water management strategies and urban water management plans.

One of the founding principles of BUWM is that land use decision-making for each planning stage should be based on an appropriate level of information. In most instances, on-site monitoring will be required to identify and characterise the key aspects of the water environment. This information is used to develop the appropriate water management strategy for that stage of the process.

BUWM describes the requirements for monitoring at the district, local and subdivisional planning stages (see Figure 1).

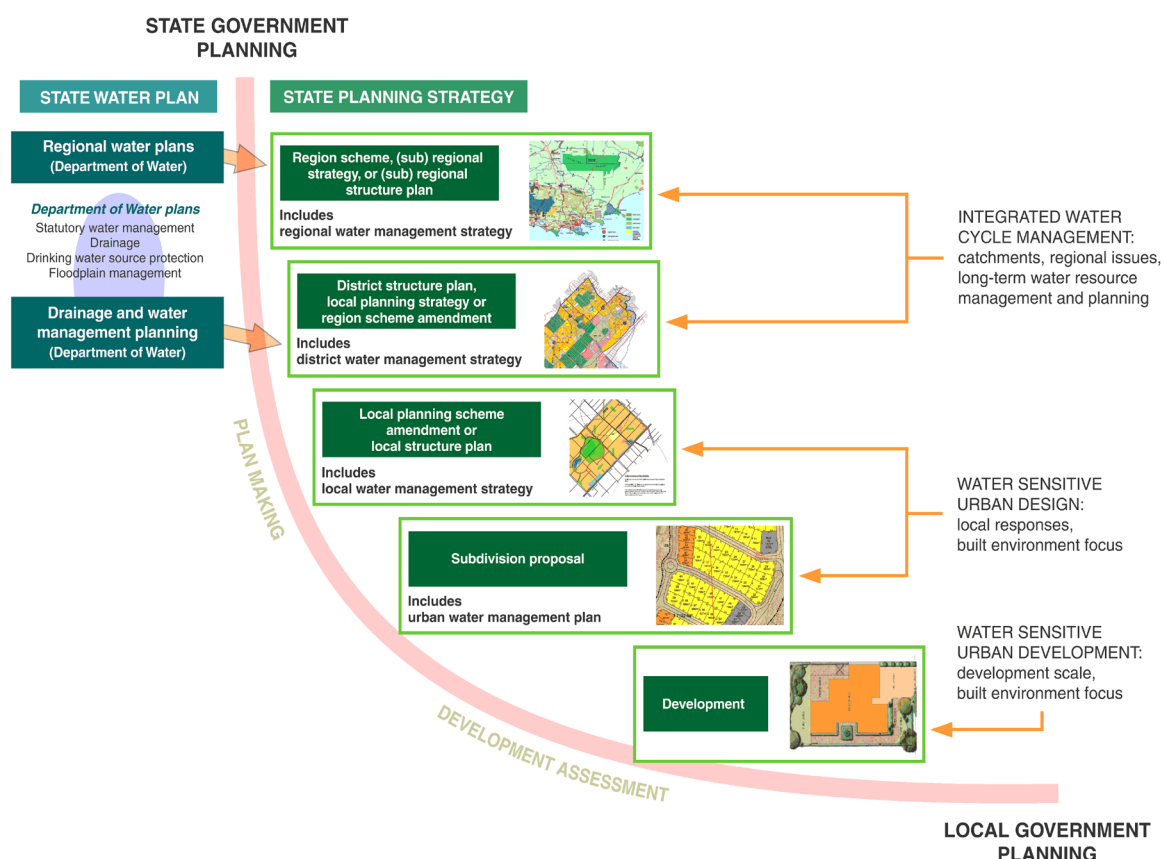


Figure 1 Integrating water planning with land planning processes

This guideline should be read together with other guidelines for surface water and groundwater sampling programs previously prepared by the Department of Water, listed below:

- *Groundwater sampling and analysis – a field guide*, Geoscience Australia record 2009/27 (Commonwealth of Australia 2009)
- *Operational policy no. 5.12 – hydrogeological reporting associated with a groundwater well licence* (DoW 2009a)
- *Ecological water requirements for Lefroy Brook*³ (DoW 2009b)
- *Water quality monitoring program design: a guideline to the development of surface water quality monitoring programs* (DoW 2008a)
- *Field sampling guidelines: a guideline for field sampling for surface water quality monitoring programs* (DoW 2008b)
- *Surface water sampling methods and analysis – technical appendices: standard operating procedures for water sampling – methods and analysis* (DoW 2008c)
- *Groundwater measurement: hydrologic measurement process*⁴ (DoW 2008d)
- *Water quality protection note 30: groundwater monitoring bores* (DoW 2006)
- *Minimum construction requirements for water bores in Australia* (Land and Water Biodiversity Committee 2003).

This document does not address the monitoring or information required for issues such as contaminated sites, dewatering or management of acid sulfate soils.

These issues must be considered in designing the monitoring program. Developers should refer to the Department of Environment and Conservation (DEC) website for additional information including;

- <<http://www.dec.wa.gov.au/>>
- *ASS4 – Managing urban development in acid sulfate soil areas*
- the acid sulfate soils guideline series
<<http://www.dec.wa.gov.au/content/category/31/790/1653/>>

³ At the time of publication of this water monitoring guideline, this document is the best example of an EWR determination.

⁴ This document is not available online but can be obtained from the department on request. To obtain this document, please email <stormwater@water.wa.gov.au>.

2 Monitoring for urban development

The Department of Water recommends that developers undertake pre- development water monitoring to characterise the site's local hydrology and hydrogeology. This will enable continuous improvement to the design of cost effective and sustainable urban landscapes.

Currently there is limited information on the performance of urban landscapes designed employing water sensitive urban design (WSUD) principles and water quality treatment structural controls under Western Australian conditions. Post development monitoring undertaken by developers also supports the continued use of the "deemed to comply" approval approach.

Post development monitoring data collected enables developers, local government and the department to have a better understanding of the performance of WSUD structural controls in developments and should lead to future improvements and innovation. Also as information is analysed, refinements to regulatory criteria requirements for development approval may be made.

BUWM notes that the water resource monitoring information required for each development stage is different. In general, more detailed information is expected as planning progresses through the district, local and then subdivision stages.

2.1 Objectives for monitoring

Objectives for water resource monitoring to support urban development are to:

1. Establish pre-development water quality data so that the objectives for water sensitive urban design identified in BUWM (WAPC 2008) can be implemented.
2. Establish baseline hydrological and hydrogeological data for pre-development conditions.
3. Enable an assessment of any impact of a development on the area's hydrology and hydrogeology.

Generally no monitoring is required during the construction period. However, developers should carry out appropriate site inspections to minimise the impact of construction activities on the area's hydrology and hydrogeology.

2.2 Assessment requirements to support urban development monitoring

Monitoring is required to help develop the proposed urban form and associated water management strategies, and to reduce risk to the development and the water environment. Monitoring in itself does not mitigate risk but informs the processes used to manage identified risks.

Potential water-resource-related risks can be highly variable depending on site-specific characteristics and the proposed land use change or urban development. Therefore, monitoring requirements cannot be fixed and a flexible approach is required in relation to both the level of detail and timing.

The following three steps have been provided to help developers assess the potential risks, determine the monitoring needs and identify the appropriate level of data required to support each planning stage.

Step 1 – Assessing risks

Risks may be present to/from water resources (see Table 1 for examples) and to/from the proposed urban development (see Table 2 for examples). Risks may vary from site to site due to:

- soil type and topography
- variation in rainfall regimes – this may result in extended areas of inundation, increasing the flood risk to the proposed urban development
- sub-strata conditions – high groundwater levels may increase the risk of impacts on road bases, foundations and other urban infrastructure
- the type of proposed land use change – this may increase the risk of the water resource becoming contaminated
- increases in impervious area – this may result in increased runoff from a catchment which raises the flood risk.

Table 1 Risks to/from water resource

| Water resource | Potential risks (examples only) |
|-----------------------|--|
| Surface water | Flooding (floodway/fringe) ¹ – consider water quantity ² |
| | Inundation (self-contained catchment) ¹ – consider water quantity ² |
| | Changing seasonal trends of the water-dependent ecosystem (e.g. waterway, wetlands) ¹ consider water quantity ² and quality ³ |
| | Impact on recreational uses and cultural sites – consider water quality ³ |
| | Polluting fit-for-purpose water supply – consider water quality ³ |
| | Polluting public drinking water areas – as required to satisfy WQPN ⁴ and/or DWSPP ⁵ |
| Groundwater | Impact on seasonal trends of groundwater-dependent ecosystem e.g. CC/EPP wetlands) ¹ – consider seasonal watertable level/quality trends ⁶ |
| | Changing seasonal trends of watertable ¹ – consider seasonal watertable level/quality trends ⁶ |
| | Polluting fit-for-purpose water supply – consider water quality ³ |
| | Polluting public drinking water supply – as required to satisfy WQPN ⁴ and/or DWSPP ⁵ |

¹ These aspects are likely to need some level of modelling. As the area's constraints increase (e.g. surface/groundwater interactions, level low-lying areas with poor drainage, self-contained catchments, etc.) the model complexity is likely to increase, which will require a longer term and more detailed level of monitoring data to enable appropriate model development and calibration.

² Can be used to proof up/calibrate models and/or methods used to predict catchment flow events.

³ Allows existing situation to be considered when setting trigger values and enables the risk associated with mobilising groundwater (e.g. risk of releasing acidity due to ASS/ferrolysis and/or mobilising legacy pollution from past land use).

⁴ WQPN – water quality protection notes.

⁵ DWSPP – drinking water supply protection plans.

⁶ Helps to determine an acceptable controlled groundwater level.

Table 2 Risks to/from proposed urban development

| Water resource | Potential risks (examples only) |
|------------------------|--|
| Development stormwater | Increased flooding/inundation of receiving environment ¹ – consider water quantity ² |
| | Mobilisation of contaminants from land use activities into receiving surface water and/or groundwater – consider water flow and quality ³ |
| Groundwater | Reduced infrastructure stability due to high watertable levels ¹ – consider water quantity |
| | Increased post-development watertable levels ¹ – consider water quantity ² |
| | Mobilisation of legacy pollution through subsoil systems – consider water quality ³ |

¹ These aspects are likely to need some level of modelling. As the area's constraints increase (e.g. surface/groundwater interactions, level low-lying areas with poor drainage, self-contained catchments, etc.) the model complexity is likely to increase, which will require a longer term and more detailed level of monitoring data to enable appropriate model development and calibration.

² Due to increased surface water runoff and groundwater recharge identified pre-development, vertical and horizontal separations are likely to change. In cases where the separations were relatively close to permissible minimums the post-development changes need to be modelled to ensure water management strategies are appropriately investigated.

³ As the pollution risk from land use practices (e.g. industry estates) and the risk of legacy pollution being released (e.g. groundwater via subsoil systems) increases, the need for water quality treatment increases to ensure set trigger values are not exceeded.

As the number or level of risks increases, the level of water management is likely to increase. This may require more water quality and/or water quantity monitoring, depending on the type of risk and management actions proposed.

Before identifying monitoring requirements, an assessment of the risk is required. This can be undertaken by investigating existing water resource conditions – location of waterways, wetlands, areas of inundation, groundwater and surface water use, sub-strata, geology, historical events, anecdotal evidence, etc. Analysis of site conditions together with the proposed land use change (type, density, location in the landscape, proximity to existing and other likely urban development) will determine the number, type and level of risks.

After the type and level of risk has been assessed, the water information and monitoring required to support the identification of appropriate management responses can be determined.

Step 2 – Assessing monitoring needs

Before developing a monitoring program a review of existing data should be undertaken. This review should consider the frequency, detail and accuracy of the existing data against what is required to support the design and management processes used to control the risk; for example, catchment analysis, modelling, water management strategy design, etc.

Where additional monitoring is required, it should be noted that monitoring is an iterative process. Data should be periodically analysed to ensure what is being collected is relevant. This may result in needing to modify the monitoring program to make it more appropriate and/or efficient.

There may be situations where existing data is sufficient to support management of the risk, either completely or in relation to the planning question being asked.

Step 3 – Assessing monitoring requirements for planning stages

To determine what level of information is required at each planning stage, the planning decision needs to be considered in relation to the risk to water resource management and the purpose of the planning document (see Table 3).

To ensure the planning process is not held up due to lack of required information or data, it is important to assess at each planning stage what data is required to inform the decision and what data will be required to inform the next decision, thereby allowing any required monitoring and associated studies to be conducted in a timely manner.

Table 3 Planning decision

| Planning decision | Planning document | Document purpose | Notes |
|--|---|--|---|
| What are likely areas for land use change in the future that impact the use and management of water resources? | Regional water management strategy (RWMS) | Identifies areas for future land use change and potential water resource management impacts. | Monitoring by developers should not be required to support this planning decision, provided sufficient regional information exists. Where additional information is required this will be identified for future studies in later planning stages. |
| Is this area capable of supporting the proposed development and if so, what areas are required to be set aside for water management? | District water management strategy (DWMS) | Demonstrates area is capable of supporting the change in land use and identifies land areas required for water management. | Depending on the risks and available data some new site investigations may be required to inform the existing available information: <ul style="list-style-type: none"> • seasonal groundwater-level trends to better define risks of waterlogging or risks to groundwater-dependent ecosystems (GDEs) • surface-water-level trends to investigate water-dependent environment (WDE) requirements and/or validate flood mapping models. |

| Planning decision | Planning document | Document purpose | Notes |
|---|--|--|--|
| How will the proposed development structure address water use and management? | Local water management strategy (LWMS) | Demonstrates how urban, commercial or industrial structure will address water use and management and identifies existing and required water management infrastructure, including detailed land requirements. | <p>Depending on the risks and existing data the following monitoring may be required:</p> <ul style="list-style-type: none"> Seasonal groundwater-level trends to develop an understanding of groundwater levels and/or identify GDE requirements to prove existing vertical separations and identify appropriate management strategies. Groundwater quality to ensure management strategies account for the risk of increasing the mobilisation of legacy pollutants and appropriate trigger values can be determined for post-development. Surface water quality and flows to develop an understanding of annual fluxes in volumes and quality; help develop the water balance, drainage design and trigger values; and to investigate GDE requirements and/or validate inundation/flood mapping models to prove horizontal separations (such that the proposed development is not at risk and WDEs are not adversely impacted). Surface water quality trends to prove proposed management strategies do not adversely impact WDEs and to allow appropriate trigger values to be determined for post-development monitoring. |
| How will the proposed development use and manage water? | Urban water management plan (UWMP) | Demonstrates how the proposal complies with LWMS and how the final urban, commercial or industrial form and infrastructure will use and manage water. | <p>Additional monitoring may be required to enable detailed design of water management strategies and facilities. Additional data may be required to refine water quality trigger values for post-development.</p> |

| Planning decision | Planning document | Document purpose | Notes |
|--|--|--|---|
| Have conditions specified in the UWMP been implemented and can the development be handed over to the local government. | UWMP – clearance of subdivision conditions | Demonstrates the final urban, commercial or industrial form and infrastructure appropriately manages surface water (including stormwater) and groundwater, as per the 'deemed to comply' approach. | Post-development monitoring should include data collection that provides surety to the local government and the department that the constructed water management facilities operate as expected in terms of water quantity and quality. This may include: <ul style="list-style-type: none">• groundwater levels to check predicted post-development rises and/or the operation of subsoil systems• groundwater quality• surface water flows, levels and qualities discharging from small, minor and major infrastructure systems• surface water flows, levels and qualities at the upstream and downstream development boundary where waterways pass through the developed area. |

2.3 Pre-development monitoring

Site-specific monitoring to establish a pre-development baseline is required to ensure:

- the impact of urbanisation on the site's water resources can be identified later
- engineering and management decisions can be made about drainage design, urban form and construction methodologies.

Pre-development monitoring is the developer's responsibility. Subdivision and/or development applications under the *Planning and Development Act 2007*, where no district or local water management strategies have been prepared previously, may require up to two full years of site-specific ecological, surface water and groundwater monitoring before the land is developed. This will depend on the potential risks of proposed development (Tables 1 and 2).

Data obtained during the district and local planning stages before subdivision approval should be periodically reviewed along with other available longer-term datasets (e.g. Department of Water long-term bores) to determine whether adjustments to the monitoring program are required.

If hydrological information is already available to support the development, developers should consult the relevant Department of Water regional office to ensure the information provides sufficient site-specific pre-development data and to identify data gaps that need to be addressed by new monitoring.

2.3.1 Regional water management strategy investigations

Regional surface water and groundwater investigations⁵, including mapping of the catchment and regionally significant water-dependent environments (WDEs)⁶, are undertaken on a priority basis by the relevant state government agency (Department of Water and DEC respectively).

Conducting a regional water management strategy investigation in urban areas is not usually the responsibility of the developers as it precedes the land zoning process.

Regional water management strategy groundwater investigations should consider the range of groundwater levels likely to result from climate scenarios, including wet, long-term average and dry sequences. In some areas, a reduction in rainfall combined with increased potential evaporation is expected to result in reduced runoff or recharge to aquifers. In other areas, increased extreme rainfall events are likely to result in more flash flooding. It should be noted that even with the drying climate in south-west Western Australia, peak events are still expected to be similar.

For guidance on expected climate change scenarios and their impact on rainfall, refer to the most recent federal or state government endorsed publications (e.g. *Climate change in Australia*, CSIRO & Bureau of Meteorology 2007).

2.3.2 District water management strategy investigations

District-level information may be available from the Department of Water to aid decisions on land use changes in priority development areas. This information may be in drainage and water management plans prepared by the department for selected areas. Where a drainage water and management plan or other district-level information is not available, site investigations will need to be undertaken by developers to characterise the baseline hydrological conditions. The requirement for further investigation at this stage depends on whether the land developers can prove (with the existing information) that the land can support the development or not.

If a developer is required to conduct a district monitoring program it should build on any available information and fill knowledge gaps about water resources at the district scale. It is not possible to stipulate the exact nature and extent of monitoring required at the district level, because the information needed will depend on the site's specific issues and the level and type of intervention proposed for the urban development. As the district stage of urban development, site investigations may be required to demonstrate that the land has the capability to support the proposed development and identify risks. For further details see the three-step process in Section 2.2.

Site investigations should be sufficient to characterise the hydrological conditions at the 'district' scale and identify the critical ecosystems to be protected. These may

⁵ The Department of Water does not usually carry out regional groundwater quality monitoring except for strategic planning, water source protection areas or in areas prone to saltwater intrusion (e.g. coastal areas and along the Swan and Canning rivers).

⁶ WDEs refer to surface water and groundwater-dependent environments/ecosystems throughout the document.

include wetlands, waterways, significant vegetation, water source protection areas and coastal dune areas. Other important elements that may require investigation include areas with high groundwater, existing or potential soil or groundwater contamination, as well as acid sulfate soils (although they are not covered by this guideline) or high levels of nutrients. It is recommended that developers discuss the requirements for district-level information with the appropriate regional office of the Department of Water and local government.

Where applicable, developers are encouraged to use the outputs from the department's regional-scale surface water and groundwater hydrogeological models to help identify site risks and develop a suitable monitoring program.

2.3.3 Local water management strategy investigations

A local monitoring program should build on regional and district information to define in more detail the site characteristics such as soils, geology, hydrogeology and groundwater. At this stage of development, monitoring is required to demonstrate the land is capable of supporting the proposed development and set the development boundary line. A local-scale pre-development monitoring program should include:

- *For groundwater:* bores located so as to improve district groundwater level and quality information at the local scale. Areas of focus should include significant environmental assets, upstream and downstream site boundaries, and areas of existing or potential contamination. Consideration should be given to areas where:
 - geotechnical investigations are required
 - soils have low permeability or high hydraulic gradients
 - soil types are heterogeneous
 - environmental water requirements need to be considered (see Section 3.4).
- *For surface water:* monitoring of inlet and outlet flow points of the development area (including drains) and any waterbodies within the development area. If there are any conservation value wetlands with the potential to be affected by the proposed development, monitoring requirements for the wetland including hydrological buffers should be discussed with DEC. Data for both quantity and quality are required.
- *For WDEs and remnant vegetation:* A local-scale monitoring program should also take into account the potential for impacts on waterways and wetlands and their buffers, conservation areas, marine ecosystems, natural areas such as karst and significant ecosystems and species. Hydrological buffer monitoring requirements for wetlands should be discussed with DEC⁷. This is particularly

⁷ DEC considers providing advice when there are likely to be significant impacts in relation to DEC-managed areas, regionally significant ecosystems, native vegetation and significant biodiversity values including threatened species and ecological communities. Sources of advice on the protection of local environmental values include the Environmental Protection Authority's *Guidance statement no. 33 – environmental guidance for planning and development and local governments*.

important where significant environmental assets such as conservation value wetlands have the potential to be affected by the proposed development.

Any proposed changes to the hydrological regime should be consistent with the report *Ecological water requirements for Lefroy Brook* (DoW 2009b), which is an example of an ecological water requirement (EWR) determination that includes a diagrammatic representation of the proportional abstraction of daily flows method.

Monitoring to inform the local stage of the planning process is required to provide 'proof of concept' for how the structure plan will manage water. For example, monitoring should be done to determine groundwater levels and surface water/ groundwater interaction where groundwater levels are close to the surface. While a commitment can be made that future monitoring will be undertaken to inform the development of an urban water management plan, the majority of monitoring should have been completed, evaluated and reported to the local government and the Department of Water at the local stage.

2.3.4 Subdivision - urban water management plan investigations

At this stage of development, it is necessary to demonstrate how the proposal complies with the local water management strategy and how the final urban form and infrastructure will use and manage water. If enough information has been gathered as part of district and local planning, additional monitoring may not be required to support the preparation of urban water management plans.

In some circumstances additional or ongoing monitoring may be required to enable detailed design of water management strategies and/or refine water quality trigger values for post-development.

The urban water management plan should:

- summarise and report the findings of all pre-development monitoring
- identify any ongoing monitoring requirements during construction, if required, and
- document a post-development monitoring plan, including the timing of commencement and the monitoring schedule.

A continued approach to monitoring through all development stages and post-development will make the comparison to post-development data easier and the identification of the cause of any impacts more certain.

2.4 Construction of subdivision

While it is not expected that water monitoring be continued between the pre- and post-development periods, some monitoring may be required to ensure the relevant local government approval requirements are being met and appropriate earthwork and building practices are being employed, especially where sensitive environments may be affected.

Visual inspection may be needed to confirm that appropriate management systems for dust, erosion, sediments, hydrocarbons, stormwater and other potential pollutants

are functioning correctly and in accordance with relevant approvals (i.e. dewatering licence) and local government guidelines/requirements. Where inspections identify that management systems may not be functioning correctly, the relevant government agencies should be notified with earthworks and building practices suspended until appropriate action is taken to remediate and ensure these systems are operating correctly. Short-term detailed water sampling and monitoring may then be appropriate to identify the cause, risk and appropriate management action. Visual inspection and any necessary remedial actions are the responsibility of the developers.

2.5 Post-development monitoring

The objective of post-development monitoring is to demonstrate that there are no directly attributable significant impacts from the new urban development on water resources. Post-development monitoring should be undertaken for a period consistent with local government handover requirements to assure the Department of Water and the local government that there won't be any ongoing water management issues directly related to urbanisation and thus the responsibility of developer to remedy.

This guideline recommends that post-development monitoring should be for a minimum of three full years depending on the level of risk. If Step 2 has determined that there is no risk to the hydrological and/or hydrogeological condition of the area no further monitoring needs to occur. Post-development monitoring should occur on a staged basis, with the required monitoring for each subdivision starting when the last lot in the subdivision is completed.

Once post-development monitoring has demonstrated that the final urban form and infrastructure can manage surface water (including stormwater) and groundwater consistent with the urban water management plan, no further monitoring is required. Most changes in surface water flows and groundwater levels due to urbanisation – in areas of shallow groundwater where the watertable is controlled by drainage – usually occur within the first two years. However, any urbanisation effect on water quality may take much longer to detect or stabilise and could take about 10 years. Therefore, in the case of urban developments that pose a significant risk to the water quality of water resources, a longer period of post-development monitoring may be required.

If post-development monitoring detects changes in the water quality parameters as a result of the development, which are outside of the trigger values set in the relevant water management strategy/plan, these should be investigated. If a suitable explanation cannot be found, additional sampling and analyses may be required to determine the cause of this variation. Liaison should occur with the local government, Department of Water, Swan River Trust (in the Swan-Canning catchment) and possibly Department of Environment and Conservation, depending on the situation. A follow-up appropriate management response may be required. Post-development monitoring results should be analysed along with pre-development baseline data for

comparisons to determine whether the development's design objectives and criteria are being met.

The developer's responsibility for monitoring will cease when the 'deemed to comply' approach has been demonstrated to the local government and the Department of Water.

3 Water aspects to be monitored

It is not possible to prescribe one standard monitoring program design (i.e. number of bores/samples required, frequency of sampling, location of sampling site, bore size and depth) for all urban development areas in the state. The design will depend on the site's particular characteristics and the nature and likely impact of the proposed development on water resources and the environment. It is recommended that a qualified hydrologist/hydrogeologist design the program and that discussions occur with the Department of Water.

Monitoring is required to provide an appropriate level of understanding to support planning for the relevant stage of the development. Monitoring data are required to provide appropriate knowledge of:

- groundwater levels and quality
- surface water flows
- surface water quality
- EWRs, where necessary.

All methods and equipment used in water quality sampling should meet the relevant standard under Standards Australia (AS) and/or the International Organisation for Standardisation (ISO): see Australian/New Zealand AS/NZS 5667.1:1998: *Water quality – sampling – guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples*.

3.1 Groundwater monitoring (levels and quality)

Groundwater has a three-dimensional distribution within a geologic framework and is characterised by contrasting aquifer and geologic features, limited accessibility (i.e. groundwater can only be sampled through an existing or newly drilled well), and differences in rates of movement through different geological or soil layers.

Groundwater bores should be monitored at enough locations to determine standing water levels, direction of flow, and water quality. Consideration should also be given to identifying saltwater intrusion in coastal areas. Developers should also consider the need for separate bores screened at different intervals if an aquitard is present at the site. Selection of bore locations should consider the ability to support post-development monitoring and it is recommended they be placed in future public areas if known and retained through the subdivision construction phase, if possible. It is therefore desirable that discussions occur with the relevant local authority during selection of bore locations to ensure best placement for their perpetual use.

Developers need to be aware of groundwater abstraction (e.g. pumping for water supply, irrigation, dewatering for development) and existing sumps that collect surface water runoff. The developer's monitoring program design needs to consider changes and fluctuations in water level and chemistry caused by existing groundwater use or recharge.

In proclaimed groundwater areas, if developers need to construct monitoring bores, a licence must first be obtained from the Department of Water under Section 26D of the *Rights in Water and Irrigation Act 1914*. The drilling of a bore and the associated disturbance to the surrounding area must also comply with the state's *Aboriginal Heritage Act 1972* and the Commonwealth's *Aboriginal and Torres Strait Islander Heritage Protection Act 1984*. Developers should note that there are permits and licences that need to be obtained depending on the relevant monitoring site/s. An atlas identifying proclaimed groundwater areas is available on the Department of Water's website.

Groundwater-level measurements⁸ are the main source of information about aquifers and are used to determine how any proposed development may affect groundwater recharge, storage and discharge (Taylor & Alley 2001).

Developers can monitor groundwater levels through periodic or continuous measurements. Periodic groundwater-level measurements are those made at scheduled intervals. In areas of significant water demand, high watertable or where there are significant groundwater-dependent environments, monitoring is generally recommended at a minimum of monthly intervals.

Continuous monitoring involves the installation of automatic water-level sensing and recording instruments (known as water-level data loggers) that can be programmed to measure water levels at a specific frequency. Continuous monitoring provides the highest-level resolution of water-level measurement and is a more accurate reflection of true water-level fluctuation in aquifers (Kern & Johnson 2009).

The design and implementation of a groundwater-quality monitoring program should be based on a thorough understanding of the unique hydrogeological characteristics of the local aquifers and of the groundwater flow system under investigation. The development's previous land uses, potential contaminant sources and proposed urban form must also be considered when designing the monitoring program.

3.2 Surface water flow monitoring

Most urban development areas will not require significant additional surface water flow monitoring. However, if a development risks affecting either the quality or quantity of surface water resources, and insufficient data are available to quantify and manage that risk, then additional flow monitoring will be required.

Additional surface water flow monitoring sites should be used to determine the site's water balance including its inflow and outflow, detention or retention of storage, and flows to or from WDEs. This is particularly important in catchments where significant changes in flow volumes, nutrients and any contaminants could be expected post-development and which would need to be managed.

⁸ In some areas, it is desirable for the development to increase groundwater levels to benefit groundwater-dependent ecosystems. Stormwater systems designed in accordance with water sensitive urban design guidelines and the *Stormwater management manual for WA* maximise the opportunity for aquifer recharge and a potential increase in aquifer storage and hence water available for later extraction and use.

Correct site selection is critical to obtaining accurate flow data. The primary criterion is a site where a consistent relationship between water level and flow rate is known or can be established. This usually requires a site that has low flow-velocity at the level recorder and an increase in water gradient downstream of the measurement site. A site will not be appropriate if it is:

- affected by backwater conditions from obstructions, debris or sediment from hundreds of metres downstream
- in drains with minimal gradient (longitudinal slopes)
- in tidally affected waterways
- where pumping occurs, and pumping records are not available.

All sites will need a means of converting water height to flow via rating curve development or by using total flow and velocity loggers⁹. The accuracy of the flow data can be improved by manual discharge measurements (gauging) over a range of flow rates.

If data loggers are required it is recommended they are set to record water levels at five-minute intervals to ensure that peak water levels are recorded in flash storm events. Data from dataloggers should be downloaded with a frequency that coincides with the frequency of manual monitoring in the area.

Existing and new surface flow monitoring data is useful to calibrate and validate surface water models for a development area. If this is an objective, then concurrent rainfall data is required for the area. This information could be gained either from a Bureau of Meteorology data station (if close enough) or ideally from an in situ rain gauge.

3.3 Surface water quality monitoring

Many small urban development areas will not require significant additional surface water quality monitoring. However, if there is a risk the development may affect the quality of surface water resources, and insufficient data are available to quantify and manage that risk, then additional surface water quality monitoring will be required.

The location of sites for surface water quality monitoring should allow capture of information on the spatial variability of surface water quality for the relevant development scale. Generally surface water quality monitoring by periodic grab sampling is sufficient. Where more detailed information is required, auto sampler and data loggers can be used. Surface water quality monitoring should be conducted in the same, or as close as possible to, surface water flow facilities – where weirs and alike are used. This should still be conducted in line with the other guiding documents on surface water monitoring, as mentioned in Section 1.1.

⁹ Velocity loggers are only needed in sites with significant rain/creeks/waterways.

When using auto samplers, the department recommends the sampler be located at the development site's outlet. The sampler may be connected to a flow meter so that sampling frequency can be related to flow volume, stream height or time.

Surface water grab sampling¹⁰ allows measurement of a wide range of variables across the development area. The spatial distribution of sampling sites should include the development's outlet and major inflow points to enable identification of sources of contaminants from contributing subcatchments.

In catchments where significant changes in flow volumes and quality post-development are considered likely, it is important that surface water flow and quality monitoring sites measure both water entering into and discharging from the proposed development areas. This is especially important in terms of WDEs (see Section 3.4).

Monitoring can be by opportunistic sampling at various selected sites. For example, monitoring the water quality flow into and out of a detention area and at various manholes is practical, during or after a storm event.

Where applicable, developers should design their monitoring plan to consider water quality objectives or targets for the local catchment improvement plan (WQIP) for that region. Objectives and targets may be defined by an approved water quality improvement plan (e.g. the *Peel-Harvey*, *Geographe Bay* or *Southern River Catchment WQIPs*), regional water plan, drainage and water management plan, or district water management strategy.

In the absence of defined water quality objectives for a local catchment, stormwater to be discharged to the Swan-Canning river system, its tributaries or drains should not exceed the trigger values applying to typical slightly–moderately disturbed systems (for lowland rivers in south-west Australia) cited in the *Australian and New Zealand guidelines for fresh and marine water quality* (ANZECC & ARMCANZ, 2000a) and the long-term nutrient targets in the *Healthy rivers action plan* (SRT 2008).

If the development proposal includes damming, dewatering, redirection of waterways or drainage or similar actions, DEC should be consulted to ensure the appropriate level of water monitoring immediately upstream of the development is being undertaken.

3.4 Ecological water requirement

The requirement for monitoring of 'ecological health and hydrogeological regime of WDEs' at the district-level scale is in accordance with BUWM. Water management plans and strategies should identify WDEs (e.g. wetlands, watercourses, estuaries) and regionally significant vegetation/habitat to be protected.

WDEs require specific water regimes to survive. These water regimes are referred to as the ecological water requirements (EWRs). Pre-development annual discharge

¹⁰ Surface water grab sampling is recommended for wetlands, as well as outlet and inflow points.

volume and peak flow should be maintained after the development, unless otherwise established through determination of EWRs for sensitive environments.

A useful example of an EWR determination is the document *Ecological water requirements for Lefroy Brook* (DoW 2009b). This document includes a helpful diagrammatic representation of the proportional abstraction of daily flows method and will help developers, their consultants and regulatory personnel with the process for determining and evaluating EWRs for WDEs in urban areas. Developers will be required to determine EWRs where they propose to change the water regime of a WDE within the subject land, or in adjacent and downstream areas.

While it is preferable to avoid direct, indirect and cumulative impacts that may alter the water regime of WDEs, it is recognised that in some cases modification to the existing water regime will be inevitable. Where discharge volume and peak flow to sensitive environments may potentially be affected by a development, the developer should specify that the timeframes and nature of the monitoring are adequate to provide a 'feedback loop' and allow for adaptive management of the sensitive environment. This type of monitoring should include not only discharge, flow and quality but also monitoring of the ecological values the EWR is designed to protect (e.g. fish passage).

At the regional and district level, not all identified WDE sites will be subject to site-specific investigations and surveys. DEC generally does not identify wetlands except through specific mapping exercises. These are undertaken in some regions of the state to provide a mechanism for ensuring wetland types and extents are located, and can be incorporated adequately into management activities and state planning. A number of wetland datasets are available on the DEC website at: <http://www.dec.wa.gov.au/content/view/5317/1556/>.

It should also be recognised that significant impacts on regionally significant natural areas and biodiversity values will not be acceptable in the absence of a relevant approval. Relevant approvals are those that may be required under the *Environment Protection and Biodiversity Act 1999* (Cwlth), and the environmental impact assessment under Part IV and permits for clearing of native vegetation under Part V Division 2 of the *Environmental Protection Act 1986* (WA).

Any regional or district-scale WDE sites with significant conservation value located within the proposed land development boundary should be included as part of local-scale EWR assessments. Where the relevant sensitive receiving environments are in the Swan River Trust Development Control Area, any change is to be negotiated with the Swan River Trust.

The monitoring of WDEs should encompass a multi-disciplinary approach. To understand changes in WDEs and ensure their protection, there is a need to integrate surface water and groundwater level and quality monitoring with ecological vegetation condition assessments. Vegetation condition measurement is conducted at the same time of year to assess the health of water-dependent vegetation. The annual monitoring enables assessment of short-term changes in the vegetation while the accumulated longer-term data allows the tracking of changes that may occur in

the vegetation community (Goodreid 2008). There is a significant relationship between vegetation condition, groundwater-level trends and EWRs. For a detailed explanation of the vegetation monitoring program, refer to Froend and Loomes (2006) and Loomes et al. (2007).

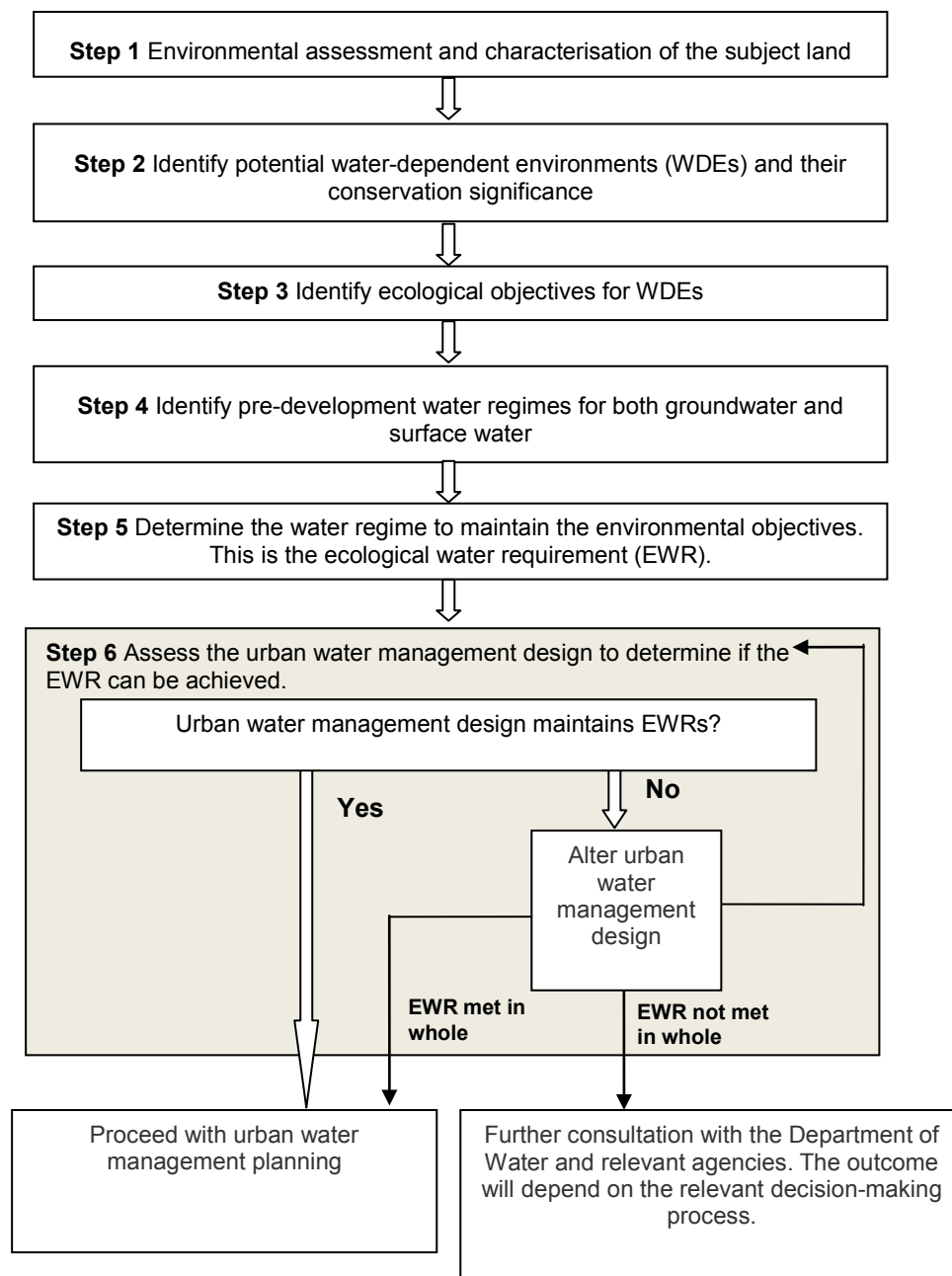


Figure 2 Process for determining ecological water requirements for water-dependent environments in urban areas

The detail and length of time for WDE water monitoring is to be negotiated with the Department of Water and DEC and should be in accordance with the urban water management plan.

4 Developing a monitoring program

This is a fundamental stage to ensure that sampling and analysis programs are cost effective and meet the monitoring objectives. It takes place before sample collection starts, and should involve interaction with the end-users of the information.

Developers should review the data and program design periodically as the monitoring proceeds and discuss any issues and need for amendment with the Department of Water as required.

The monitoring program should be documented in a sampling and analysis plan (SAP). A proposed post-development monitoring program is usually included in an urban water management plan, which is reviewed by the Department of Water. The design of a monitoring plan should involve the components outlined in the following sections.

4.1 Setting monitoring program objectives

The overarching objective of the total urban development water monitoring program should be to:

1. Collect or review sufficient baseline data to establish pre-development hydrogeological conditions including water levels and flow, water quality and temporal and seasonal variability (for both surface water and groundwater).
2. Inspect or audit the impact of the development during construction.
3. Enable assessment of the post-development performance of the urban development against local water management objectives, in line with the 'deem to comply' approach.

To achieve these objectives, the monitoring program may include, but not be limited to the need to:

- define soil strata and site characteristics using bores or test pits
- establish typical seasonal hydrographs of surface water flows, levels and quality
- establish the hydraulic gradient and transmissivity of the aquifer (for groundwater)
- assess background groundwater quality conditions
- record velocity and level, as well as volume of flow for surface water
- describe the performance of existing drainage and catchment activities
- define the connectivity between surface water and groundwater
- identify the potential effect of urban development on wetlands
- identify the potential effect of urban development on water flows and quality in receiving waterways or the groundwater, and/or
- identify the potential effects of urban development on other water sensitive environments, including waterways, conservation areas, marine ecosystems and significant ecosystems.

4.2 Description of monitoring area

The monitoring program should include a description of the monitoring area as follows:

- definition of extent of the area
- a summary of the environmental conditions and processes (including human activities) that may affect water quantity and quality
- meteorological, hydrological and hydrogeological information
- a summary of the local water values including actual and potential uses of water, and the requirements of ecosystems and assets.

4.3 Setting spatial boundaries

The spatial boundaries of the monitoring program should relate to the proposed development area and its surrounding hydrological catchment – both groundwater and surface water catchments. In most cases the monitoring catchment area will be larger than the development area.

The developer should demonstrate that the sampling sites are a true representation of the study area, both in the number of sites and their location.

When setting the spatial boundary, the monitoring of ‘upstream inputs’ to the study area must be considered, along with the impact of neighbouring developments and the potential impact on downstream catchment areas.

4.4 Defining detail of monitoring

When developing the program’s detail, several factors need to be considered:

- accuracy, reliability and validity of the proposed measurements
- the cost of data collection at the various scales versus the benefit derived from the data
- spatial uniformity and temporal range of the data
- risks to water resources.

It is essential to choose the appropriate detail relevant to the planning decision being made and size of the development (e.g. district, local or urban water management plan).

4.5 Duration of monitoring

The recommended standard timeframe for surface water and groundwater monitoring for pre-development investigations in ‘greenfield’ areas may be up to two full years before site works begin. See Section 2.3. Duration of monitoring could be less if there is a strong long-term record.

The recommended standard timeframe for surface water and groundwater monitoring for post-development investigations in 'greenfield' areas should be three years after site works have been completed. See Section 2.5.

4.6 Advice for selecting sampling sites

4.6.1 Site selection and monitoring of the surface water

Site selection should be consistent with the *Australian guidelines for water quality monitoring and reporting* (Australian Government 2000b), the ISO and AS (see Appendix C: ISO and AS standards for water quality monitoring). Selection of surface sampling sites requires consideration of the following factors (but may depend on the scale of the study as defined in Section 4.4):

- size/scale of the development and level of planning decision
- local hydrology and geology
- health and safety needs for field staff
- monitoring objectives
- knowledge of the catchment and its water systems (e.g. records of activities in the whole catchment including previous land use and prior monitoring, aerial photographs, development plans, and environmental assets)
- uses of the water including impact on the downstream environment
- any previous or potential future discharges of contaminants/wastes into or out of the system; for example, farm pesticide mixing and application areas, wastewater treatment plants and infiltration areas
- spatial and temporal variability of the measurement parameters
- presence of established monitoring facilities – rated waterway control structures or cross-sections
- the need for monitoring near potentially contaminating activities including artificially fertilised parks/gardens, farm pesticide mixing and application areas, wastewater treatment plants and infiltration areas
- the potential for sampling sites to be protected during the course of subdivision and development works should also be considered when selecting sites (these can then be used for post-development monitoring).

In choosing the location of the surface water sampling sites, some practical considerations are:

- a site at the lower side or outlet of the catchment, and/or sites where flow leaves the study area
- sites where any significant flow enters the study area
- sites immediately upstream of a waterway confluence or a wetland

- monitoring sites should be in flowing water and not backwater affected from downstream.

4.6.2 Site selection and monitoring of the groundwater

Site selection and monitoring of the groundwater bores should be consistent with Water quality protection note 30: *Groundwater monitoring bores* (DOW 2006) and AS/ NZS 5667.11:1998: *Water quality – sampling – guidance on sampling of groundwater* (see Appendix C: ISO and AS standards for water quality monitoring) and the *Australian guidelines for water quality monitoring and reporting* (Australian Government 2000a).

Groundwater sites should be selected based on the following criteria (but may depend on the scale and purpose of the study as defined in Section 4.4):

- Bores should be located across the development area at a spacing that allows effective determination of groundwater levels and its variability.
- If the developers intend using the superficial aquifer as a water resource, deeper bores should be used to determine the impact of pumping on lower aquifers depending on site and aquitard characteristics.
- Depth of bores should be at least 3 m below the minimum recorded groundwater level (GWL). However, in dealing with perched systems (i.e. clay or aquitard layers) that may affect groundwater flow, paired piezometers may be required. If the developers intend using the superficial aquifer as a water resource, deeper bores should be used to determine the impact on lower aquifers.
- Typical monitoring bore layouts should have bores located up-gradient, centrally and down-gradient, to determine the groundwater flow paths.
- Internal diameters of the bore casing should not be less than 50¹¹ mm to allow water quality sample collection.
- Screening of bores for urban development purposes will generally be in the upper few metres of the aquifer, with the bottom of the screen being at least 3 m below the expected minimum recorded GWL. The top of the screen should be close enough to the ground surface to allow for drawdown induced by pumping. Deeper aquifers will need to be screened from the base of the relevant pervious layer.
- Soil strata and bore construction log must be recorded for each bore.

Some practical considerations for selecting bore sites are:

- the potential for damage and vandalism (bores should have appropriate protective head locks)
- safe access under all conditions

¹¹ If smaller-diameter bores fitted with special sampling equipment are proposed, it must be discussed with the Department of Water regional office before installation.

-
- ability to accurately identify them so they can be sampled by different parties (global positioning system readings will ensure accurate recording of the site locations).

4.7 Sampling frequency

The monitoring program's objectives and the development site's potential risks to water quality dictate the basis for determining the optimum sampling frequency. Sampling for stormwater flows, surface water baseflows and groundwater may all require different frequencies.

For example, short-duration intense rainfall events that generate rapid runoff can have a dramatic impact on water quality at a local scale. Infrequent long-duration events that generate large volumes of runoff also affect water quality. Both types of occurrences may be missed by sampling using a fixed time-interval. Rapid changes in flow can profoundly affect the concentrations of measurement parameters and therefore the representativeness of sampling (Australian Government 2000a).

The sampling frequency also depends on the development area, its specific characteristics and the water resources. For characterising water quality over a long period (e.g. over a year in a river), an interval of one month between sampling is generally acceptable, whereas for contamination-control purposes weekly sampling may be necessary.

Groundwater levels should first be monitored on a monthly¹² and then on a quarterly basis as appropriate. Groundwater quality parameters should initially be measured quarterly (typically in January, April, July and October). The frequency of sampling should be reviewed at the end of the first year and adjusted if necessary. For more details on the frequency of sampling see Table A4, Appendix A.

4.8 Number of water quality samples and precision

Developers should consider the required precision and accuracy (quality control) at the sampling program's planning stage. After the initial three to four months of the monitoring, the sampling program should be validated or amended based on the amount of variability in the initial data. The program protocol should include independent checking of results and making of decisions to re-sample outside the normal program of sampling (i.e. irregular results should be verified not discarded). The number of samples required ultimately will depend on the study's timeline as well as its objective, the development site's potential risks and required level of quality control.

When collecting water samples for detailed chemical analysis, since contamination or errors may occur at any point between sample collection and final analysis, every monitoring program should include an approach to minimise contamination or errors

¹² While the frequency of the monitoring for groundwater levels is recommended to be on a monthly basis, local government authorities may request a higher monitoring frequency depending on the local conditions.

to ensure data integrity. Depending on the risks the monitoring program should have some additional samples such as blank samples and replicate samples. These are described below.

Replicate samples: two or more samples taken from the same site sequentially, using the same process. If any natural variations in the environment or the sampling method occur, these can be highlighted by replicate sampling.

Field blank samples: these contain de-ionised water which is exposed to the sampling environment at each sampling site and handled in the same manner as the real sample (e.g. preserved, filtered). These blanks provide information on contamination resulting from the handling technique and from exposure to the atmosphere.

4.9 Selection of measurement parameters

The choice of measurement parameters (physical and chemical) will depend on the environmental values and potential use assigned to the water resource (sustaining ecosystems, drinking water, recreation, industry, agriculture, aquaculture). The measurement parameters can differ geographically and temporally (Australian Government 2000a). Sample analyses should be conducted by a National Association of Testing Authorities (NATA) accredited lab as per *Operational policy 5.12* and *Water quality monitoring program design* (DoW 2009a).

The best way to decide on the appropriate parameters is to carefully consider the land uses (current and previous) within the catchment. The diagrams in Appendix D have been designed to guide what parameters to consider for measurement, relevant to the existing land use activities occurring throughout the catchment (DoW 2008a). Of note is that previous land use activities that may have contributed to observed water quality/quantity – such as earthworks, construction of drains, piggeries, chicken farms, turf farms or market gardens – should also be identified and their risk to water quality factored into the monitoring regime. The potential risk to sensitive receiving environments should also be considered when determining the appropriate parameters to be monitored.

Parameters appropriate for water quality monitoring should meet the following two general criteria:

1. A parameter should be considered for monitoring because it fulfils any or all of the following:

- is potentially harmful to human health, aquatic species, livestock and beneficial plants; that is, above concentrations recommended in Chapter 4, ANZECC guidelines (Australian Government 2000a)
- is of interest in surface water and may be transported from groundwater to surface water systems; for example, nitrogen species ammonia, nitrite and nitrate
- is an important ‘support variable’ for interpreting the results of physical and chemical measurements; for example, temperature and major ion balance

-
- is mobile in the environment.

2. Analysis of the chosen parameter should be cost effective by using well-established analytical methods at appropriate minimum detection and reporting levels necessary to achieve the study's objectives.

- Physical measurement parameters include flow, temperature, electrical conductivity, suspended solids, turbidity and colour. Chemical measurement parameters include pH, alkalinity, hardness, salinity, biochemical oxygen demand, dissolved oxygen and total organic carbon. In addition, other water chemistry parameters may include specific major anions and cations, and nutrient species (phosphate, nitrate, nitrite, ammonia, silica).

Based on the above criteria and site risks, the following general groups of parameters should be considered for water quality monitoring programs:

- field measurements (temperature, pH, electrical conductivity, dissolved oxygen¹³, depth-to-water or flow)
- total suspended solids (TSS) (TSS measurement is only required for surface water)
- total nitrogen (TN) and total Kjeldahl nitrogen (TKN)
- ammonia (NH₃)
- nitrate (NO₃) and nitrite (NO₂)
- total phosphorus (TP)
- orthophosphate¹⁴ PO₄³⁻

The following group of elements should be considered on a less regular basis for a water quality monitoring program:

- heavy metals including aluminium (Al), arsenic (As), boron (B), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), manganese (Mg), mercury (Hg), molybdenum (Mo), nickel (Ni), selenium (Se), zinc (Zn)
- major anions [chloride (Cl), sulfate (SO₄) and alkalinity]
- major cations [calcium (Ca), magnesium (Mg), sodium (Na), potassium (K) and acidity]
- hydrocarbons¹⁵.

¹³ As dissolved oxygen in groundwater is difficult to measure in the field and difficult to interpret (no guideline for dissolved oxygen in groundwater), the preferred parameter is redox potential (Eh, or ORP) which can be field measured and used as an indication of denitrification potential.

¹⁴ Orthophosphate is the predominant form of phosphorus taken up by plants. With the chemical formula PO₄³⁻ it is the simplest of the phosphates and is therefore often referred to as phosphate. The terms soluble reactive phosphorus (SRP) and filterable reactive phosphorus (FRP) may be used interchangeably. Both are defined according to the analytical procedure by which they are determined rather than the actual species of phosphorus present, however, most if not all of the SRP consists of orthophosphate. SRP (and FRP) is therefore considered to be a measure of orthophosphate (American Public Health Association (APHA) section 4500-P).

For a comprehensive list of parameters, see Appendix A.

4.10 Data management

Data management is the developer's responsibility. All data and reports (hard copy and electronic version) should be sent to the relevant local and state government agency¹⁶ and the Department of Water at the completion of the pre- and post-development monitoring stages. The department will archive these data and reports, and copies will only be made available to other parties with the developer's consent.

Data can be validated and uploaded to the department's water information system (WIN). For details see Section 5.1.

4.11 Data preparation analysis and interpretation

Data analysis and interpretation is the developer's responsibility. Monitoring results should be interpreted as they are collected and at various stages throughout the planning and development process to inform proposed design and management actions. If there are any issues, confirm by further monitoring before reporting to the Department of Water and undertaking remedial measures.

4.11.1 Data preparation

Water quality data obtained from laboratory and field studies should be summarised in a form that can easily be interpreted. It is best to check the data are acceptable by field and laboratory quality assurance/quality control (QA/QC) criteria, and that it is rounded off to the appropriate number of significant figures.

Analytical data should be tabulated into spreadsheets for easy analysis. Physical measurements should be tabulated in a form that permits ready comparisons with chemical and biological data for the same sites. The choice of formats for these is reasonably intuitive. Graphical presentations of the basic data are also useful for displaying differences. Any anomalous data should be provided with explanatory comments including the validation measures taken.

Before more comprehensive analysis, the data values must be given a preliminary examination to check their integrity before further analysis. Data that are missing or below detection limits (so-called 'censored' data) will need to be considered, as will obvious outliers that might be attributable to experimental or transcription errors (Chapter 6, ANZECC guidelines, Australian Government 2000b).

¹⁵ Hydrocarbons will only be analysed if the site is near a petroleum-based industry or a light industry.

¹⁶ Where the monitoring is conducted adjacent to significant wetlands (e.g. conservation category wetlands, or those of international importance and listed under the Ramsar Convention, or those of national importance and listed under the *Directory of important wetlands in Australia*), the data should also be submitted to DEC due to its responsibilities in respect of such areas.

4.11.2 Censored data

In some circumstances the level of contaminants in water may be below the detection limit of the instrument and/or the method. Laboratory analysis may therefore not detect contaminants in samples. Rather than concluding that the particular contaminant does not exist in a water sample, the developer should record the observation as 'below detection limit' (BDL). Appendix B summarises the detection limits recommended by the Department of Water.

There is no universally accepted method of dealing with data BDL during statistical analysis. Some common approaches include:

- treat the observation as 'missing'
- treat the observation as zero
- use the numerical value of the detection limit
- use the numerical value of half the detection limit.

Routine water quality parameters (means, percentiles etc.) should be computed using the full dataset with BDL data replaced by either the detection limit or half the detection limit. When a significant proportion of the dataset (e.g. >25 per cent) is BDL and there is a significant risk that the contaminant could be an issue:

- some form of inferential analysis (e.g. confidence intervals or hypothesis testing) should be carried out
- advanced statistical skills should be sought.

If only a small proportion of the dataset is BDL and has been replaced by a numerical surrogate, it is best to perform any statistical analysis twice: once using zero and once using the detection limit (or half the detection limit) as the replacement value. If results from the two analyses differ markedly, the developer should investigate more sophisticated statistical methods of dealing with censored observations (e.g. software packages LIMDEP by Econometric Software and SHAZAM by the University of British Columbia). If the results do not differ markedly, the censored observations probably have little influence on the analysis (Chapter 6, ANZECC guidelines, Australian Government 2000b).

4.11.3 Data integrity

Losses, reduced quality or errors of data can occur at different stages including:

- the time of collection not recorded
- in transit, if inappropriate sample preservation techniques used
- in the laboratory during sample preparation and analysis
- during recording of results, electronic manipulation and processing
- during analysis, interpretation and reporting.

Once data certification is completed by the laboratory, 'contamination' of results can still occur. An appropriate level of screening should be undertaken to ensure errors

related to data manipulations (transcribing, transposing rows and columns, editing, recording, and conversion of units) are corrected before data interpretation.

Discarding the extreme observations or ‘outliers’ from the dataset could introduce bias into subsequent analyses. On the balance of probabilities, an observation beyond three standard deviations from the mean is likely to be ‘anomalous’. Such observations need to be highlighted for follow-up investigation to identify causes (e.g. recording error, laboratory error, abnormal physical conditions during sampling or contaminations). Reasons for the anomalous results should be sought, and if they cannot be attributed to a nearby land use activity, another sample should be taken and analysed as soon as possible. It is important, however, to note that where a clear reason is identified, anomalous results may be discarded. Simple descriptive statistical measures and graphical techniques, combined with the developer’s knowledge of the system under investigation, are very valuable tools for identifying outliers.

Only the most extreme observations (e.g. those that are four or more standard deviations from the mean) can be excluded from the dataset (Chapter 6, ANZECC guidelines, Australian Government 2000b). However, extreme observations are common with hydrological data – especially stream or drain flows from peak storm events – and should not be excluded when using statistical methods.

4.11.4 Data analysis and interpretation

Developers should identify suitable methods of analysis that will help the interpretation of results. In analysing and interpreting the data, they should consider the following:

- preliminary data analysis over time as data are collected to ensure quality and relevance
- checking if the preliminary interpretation of data fulfils the monitoring program’s objectives
- if the study was redesigned at any time, checking that new or additional data have been collected, and the data re-analysed
- applying data reduction methods (graphical, numerical and tabular summaries)
- identifying ‘anomalous’ observations and investigating the reason/s
- collating the results of the analysis into a concise summary
- assessing the statistical output carefully and providing a non-technical interpretation such as high, low, median readings, standard deviation and trend lines
- benchmarking data against guideline criteria¹⁷ to sustain local environmental values (Chapter 4, ANZECC guidelines, Australian Government 2000b).

¹⁷ There are no groundwater-specific guidelines, therefore surface water guidelines are usually used for groundwater data comparison.

In the absence of defined water quality objectives for a local catchment, data collected within the Swan-Canning catchment should be benchmarked against the trigger values applying to typical slightly–moderately disturbed systems (for lowland rivers in south-west Australia) cited in the *Australian and New Zealand guidelines for fresh and marine water quality* (Australian Government 2000b) and the long-term nutrient targets in the *Healthy rivers action plan* (SRT 2008).

Periodic data analysis and interpretation should be viewed as an integral component of the urban development monitoring process. Periodic reviews should be made of:

- measurement scales
- frequency of data collection
- number of replicates/duplicate samples
- spatial and temporal coverage.

If any significant change in the water quality parameters (as a result of the development) – outside of the trigger values set in the relevant water management strategy/plan – are detected during the first three years post-development, a management response and reporting to the relevant local government and the Department of Water will be required. The management response could include:

- additional sampling and analysis
- identification of the cause of the change
- measures undertaken to retrofit/manage the issue
- evaluation of the effectiveness of management actions undertaken.

After the data analysis, the results for each parameter should be collated and summarised. The results should be interpreted in the context of the monitoring program's objectives. Values of parameters before and after the urban development that differ significantly need to be investigated and interpreted to determine if the water management strategy is effective or requires change.

Once the data interpretation is complete, the information should be written up into a report and submitted to the Department of Water and the relevant local government (see Section 4.12).

If monitoring or data analysis discovers any source of significant environmental or water management concern, it must be brought to the immediate attention of the relevant agencies, as set out in the appropriate water management strategy/plan, to determine if any management actions will be required.

4.12 Reporting

Reporting the outcomes of pre-development monitoring should be via the appropriate water management strategy/plan.

Post-development monitoring should be reported at the completion of the study period, in a form agreed to by all parties (as mentioned in Section 4.11).

The developer should review all data annually and advise the Department of Water and the local government if the data show any sources of concern.

The report submitted to the department and the local government should contain the following essential components:

- an introduction, outlining previous studies in the area or related studies, and delineating the study objectives
- a summary of the technical findings in relation to the monitoring objectives – in words that managers unfamiliar with technical detail can understand
- outline of the duration, nature and extent of the monitoring undertaken and compare the findings against the agreed monitoring design objectives
- experimental detail, describing the study location and study design, including descriptions of methods of sampling and analysis
- results – descriptive and detailed presentation of results, sometimes in combination with the discussion section
- tabulated results should be reported against the relevant trigger values and targets, with exceedences clearly highlighted
- discussion of the results including data interpretation and implications for management
- conclusions drawn from the results
- recommendations for future work
- reference details for literature cited in the report
- appendices, providing laboratory reports, data tables or other information that is too detailed or distracting to be included in the main body of the report
- if there is a need for further monitoring beyond three years
- the need for any remedial action or change to water management plans.

The monitoring report should include, but not be limited to: all the results, lab certificates and QA/QC information, lithology/ geophysical logs and methodology related information identified as part of the SAP.

5 Recommendations

5.1 Data storage in water information database (WIN)

The Department of Water encourages proponents to store all monitoring data in the WIN database. Data stored in WIN is collected from a variety of surface water and groundwater monitoring sites throughout the state and includes water quality, rainfall, flows and water levels.

However, doing so is voluntary because the department can only offer this service on a fee-for-service basis. If proponents wish their data to be stored in WIN they should contact a WIN officer¹⁸ to discuss the process and obtain a schedule of fees. The department recommends that before a developer/consultant initiates a sampling program they should contact the department to organise a training session on the field collection of data¹⁹ and data documentation and submission for WIN. Data not conforming to WIN requirements will not be added to the main database.

By providing data to WIN, developers will be contributing to a wide range of site information and performance data of water management systems to enable all stakeholders to refine designs and criteria for future urban developments.

The quality of data entered into WIN is important. The department provides water data to the Bureau of Meteorology for inclusion in its AWRIS system in accordance with the Regulations for the *Commonwealth Water Act 2007*.

Further information on the types of data the department supplies to the Bureau of Meteorology can be found on the bureau's website:

<<http://www.bom.gov.au/water/regulations/index.shtml>>

Additional information on the development of the AWRIS system is also available on the bureau's website:

<<http://www.bom.gov.au/water/about/wip/awris.shtml>>.

The advantages of storing data in WIN include:

- The data collected is validated, stored, referenced and protected with a strong emphasis on quality assurance.
- The collection and storing of data in WIN can help with assessing the performance of water quality improvement infrastructures over longer periods of time. Better understanding of these infrastructures' performance will enable their design to be improved, therefore reducing the cost of future instalments.
- The stored data is readily available to the public on request.

¹⁸ dain@water.wa.gov.au

Contact WIN officer through Department of Water reception: 6364 6587

¹⁹ Water Science Branch

- If there is a change of consultant and/or land ownership, the data stored in WIN will remain readily available to the new consultant and/or land owners.
- If the data is archived in WIN as an area is developed, then future developments may be able to use existing monitoring data from an adjacent development. This could potentially enable developers and their consultants to spend less time and money on monitoring.

For specifications of data requirements and formats for submission of groundwater and surface water resource information in electronic format, see 'WIN sample management forms' (these can be obtained from a Department of Water WIN officer).

Appendix A: Components of a monitoring program, monitoring requirements and responsibilities of involved parties

Table A1 Monitoring program summary

| Monitoring | Sites | Frequency | Parameters |
|----------------------------------|--|---|--|
| Groundwater ²⁰ | Network of monitoring bores ²¹ to provide suitable spatial representation of study area | Monthly | Standing water level ²² |
| | | Quarterly (i.e. January, April, July, October); may be site-specific. | Water quality <i>in situ</i> : temperature, pH, DO, EC, depth-to-water. The appropriate parameters should be selected based on the land use near the site. For details see <i>Section 4.9: Selection of measurement parameters</i> . |
| | | The frequency and parameters should be reviewed at the end of the first year and adjusted if necessary. | At a minimum the following parameters should be measured: Unfiltered sample: acidity/alkalinity, TN, TKN, ammonia, heavy metals. Filtered sample: nitrate/nitrite, TP orthophosphate. The following group of elements should be considered at the start of project and on a less regular basis for a water quality monitoring program (see Appendix B for a comprehensive list of parameters): <i>In situ</i> parameters (above) <i>nutrients</i> heavy metals ²³ major anions (Cl, SO ₄ , and alkalinity) major cations (Ca, Mg, Na, K and acidity) hydrocarbons ²⁴ |

²⁰ For specifications and Australian Standard see *Minimum construction requirements for water bores in Australia* (Land and Water Biodiversity Committee 2003).

²¹ Appropriate spacings for bores should be based on level of investigation. Frequency of the bores should increase as development planning proceeds.

²² Developers should locate bores using GPS (with AMG coordinates) and arrange survey level of the top of bores (AHD) to allow mapping and data interpretation.

²³ Aluminium, arsenic, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, zinc.

²⁴ Hydrocarbons will only be analysed for if the site is in vicinity of a petroleum based industry or a light industry.

| Monitoring | Sites | Frequency | Parameters |
|----------------------------|--|--|--|
| Surface water | Development inflow and outflow ²⁵ locations as a minimum | Site-specific, could be weekly during winter and less frequent depending on the flow. | Flows ²⁶ Water levels |
| | | Continuous | Water level and flow volume. |
| | Key drainage pathways (where development may impact on drain or waterway). | Fortnightly | Water quality (same as groundwater). Once-off snapshot at surface water sites within catchment (usually September): a single sample for: <i>In situ</i> parameters (same as groundwater) <i>nutrients</i> heavy metals ²⁷ major anions (Cl, SO ₄ , and alkalinity) major cations (Ca, Mg, Na, K and acidity) hydrocarbons |
| Surface water (cont.) | Inflow and outflow of detention storages | Fortnightly water quality grab samples while flowing, to be reviewed after the first year of monitoring. The monitoring to be continued if water quality declines. | The appropriate parameters should be selected based on the land use near the site. For details see <i>Section 4.9: Selection of measurement parameters</i> . At a minimum the following parameters should be measured: <i>In situ</i> : temperature, pH, DO, EC. Unfiltered sample: TSS, TN, TKN, ammonia, heavy metals. Filtered sample: nitrate/nitrite, TP, orthophosphate. |
| Water-dependent ecosystems | Representative transects | Annual | Water-dependent flora and fauna ²⁸ |
| | District: representative sites should be chosen based on Department of Water and DEC advice ²⁹ . Local: significant sites as per Department of Water and DEC advice. | Monthly (Developers should demonstrate there is not a significant fluctuation ³⁰ in groundwater levels within a month; otherwise they should increase the monitoring frequency). | Groundwater level |

²⁵ It is not expected for every development to have two 'inflow' and 'outflow' gauging stations. This will depend on factors such as the level of risk (see the three-step process in Section 2.1).

²⁶ If used, loggers should be set to record surface water levels at five-minute intervals to ensure that peak water levels are recorded in flash storm events.

²⁷ Aluminium, arsenic, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, zinc.

²⁸ DEC has responsibilities to regulate the clearing of native vegetation, and the definition of clearing includes substantial damage caused by flooding and draining, as well as direct removal.

²⁹ DEC aims to provide advice particularly where there is potential for a significant impact on DEC-managed areas, the conservation estate and regionally significant natural areas, ecosystems and/or species.

³⁰ Fluctuations are considered significant when they are in orders of magnitude or appear as outliers.

| Monitoring | Sites | Frequency | Parameters |
|------------|--|---|--|
| | <p>District: representative sites should be chosen based on Department of Water and DEC advice.</p> <p>Local: significant sites as per Department of Water and DEC advice.</p> | <p>Site-specific, could be monthly for the first year. The frequency should be reviewed at the end of the first year and adjusted if necessary.</p> | <p>Groundwater quality</p> <p>The appropriate parameters should be selected based on the land use near the site. For details see <i>Section 4.9: Selection of measurement parameters</i>.</p> <p>At a minimum the following parameters should be measured:</p> <p><i>In situ</i>: temperature, pH, DO, EC.</p> <p>Unfiltered sample: pH, EC, TN, TKN, ammonia, heavy metals.</p> <p>Filtered sample: nitrate/nitrite, TP, orthophosphate.</p> |
| | Wetlands | Monthly | <p>Water level (install gauge boards where water levels need to be accurately controlled, e.g. Ministerial conditions setting operating levels, vegetation submergence criteria).</p> <p>Groundwater levels should be measured upstream and downstream of the wetland at the same time as wetland water levels to establish the wetland hydrology and the relationship between the groundwater and surface water. <i>In situ</i>: temperature, pH, DO, EC.</p> <p>At annual peak, nutrients as above.</p> <p>Once-off at each site (at peak on normal year), a single sample for:</p> <p><i>In situ</i> parameters (same as groundwater)</p> <p><i>nutrients</i></p> <p>heavy metals³¹</p> <p>major anions (Cl, SO₄, and alkalinity)</p> <p>major cations (Ca, Mg, Na, K and acidity)</p> <p><i>hydrocarbons</i></p> |

³¹ Aluminium, arsenic, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, zinc.

Table A2 Monitoring requirements and responsibilities of relevant parties

| Responsible party | Timing | Monitoring requirement |
|---------------------|---|---|
| Developers | Pre-development: up to two full years ³² | <p>Monitor key criteria for maintenance of hydrologic regimes, and environmental values.</p> <p>Monitor local superficial aquifer groundwater levels.</p> <p>Monitor flow and water quality (including nutrients, TSS and gross pollutants) at the local and district level. The program should address critical outflow points, appropriate frequency (regular intervals and continuous). The monitoring should be able to provide appropriate data to assess the impacts of development on pre-development environment.</p> <p>Undertake two snapshot sampling programs³³ per year (in winter and spring) within developments and wetlands.</p> |
| | Construction or Intervening period | <p>While it is not expected that extensive monitoring should continue between the pre- and post-development periods, some monitoring is likely to be required to ensure that appropriate building practices are being employed and that no dust or water containing sediment leaves the site and enters the drainage system and waterways.</p> <p>Additional ecological monitoring of regionally significant conservation assets may also be required to ensure these environments are not impacted by construction activities.</p> |
| | Post-development Minimum of three full years depending on the level of risk | <p>Monitor key criteria for maintenance of hydrologic regimes, and environmental values.</p> <p>Monitor local superficial aquifer groundwater levels.</p> <p>Monitor flow and water quality (including nutrients, TSS, litter, hydrocarbons, heavy metals, sediments and organic material) at the local and district level. The program should address critical outflow points, appropriate frequency (regular intervals and continuous). The monitoring should be able to provide appropriate data to assess the impacts of development on the environment.</p> <p>Undertake two snapshot sampling programs per year (in winter and spring) within developments and wetlands.</p> <p>Monitor performance (water quality and quantity) of new drainage systems.</p> |
| Department of Water | Ongoing ³⁴ | <p>Monitor regional surface water flows and quality where established networks exist.</p> <p>Monitor confined aquifer groundwater levels and regional superficial aquifer groundwater levels and quality (where applicable).</p> <p>Monitor surface water quality and flows at strategic locations in main drains and waterways.</p> |

³² Pre-development refers to the hydrologic and hydraulic condition of a site immediately before any development or construction begins.

³³ This is the regular sampling program within the development to measure current and recent peak flows and levels and current water quality parameters. This includes monthly levels in wetlands.

³⁴ Department of Water expects to continue to monitor water attributes on a regional scale and will consider new work at the same scale; however, all the department's undertakings are subject to funding availability or sponsorship by the developer.

Appendix B: Water quality parameters and acceptable detection limits for surface and groundwater

Standard sample bottle: unfiltered [1000 mL capacity]

Total other parameters (unfiltered)

| Parameter | Detection limit ³⁵ (mg/L) |
|------------------------------|--------------------------------------|
| Acidity as CaCO ₃ | 1 |
| Alkalinity | 1 |
| TN (autoclave) | 0.025 |
| TP (autoclave) | 0.005 |
| TDS (evaporation) | 10 |
| TSS (NFR) ³⁶ | 1 |

Physical

| Parameter | Detection limit |
|--|-----------------|
| pH | - |
| Conductivity at 25°C (EC ³⁷) | 1 mS/m |

Dissolved other parameters (unfiltered)

| Parameter | Detection limit (mg/L) |
|------------------|---|
| Sulfate | 5mg/L as SO ₄ , 2 mg/L as SO ₄ -S |
| Fluoride | 0.2 mg/L |
| Chloride | 10 mg/L |
| SiO ₂ | 0.002 mg/L as SiO ₂ |
| Bromide | 0.01 or 0.05 |

³⁵ These are the recommended detection limits based on methods used by National Measurement Institute (NMI) laboratories. NMI is a division within the Department of Innovation, Industry, Science and Research.

³⁶ Non filterable residue (NFR) is another term for total suspended solid (TSS).

³⁷ Conductivity should not be recorded as EC but conductivity (compensated to 25°C) or conductivity (uncompensated). If the uncompensated conductivity is measured, the temperature of the sample medium should also be recorded.

Small bottle: field-filtered [250mL capacity]**Other dissolved parameters (field-filtered – 0.45 micron)**

| Parameter | Detection limit (mg/L) |
|---|------------------------|
| Ammonia (NH ₃ -N) | 0.010 |
| Nitrite (NO ₂ -N) | 0.01 |
| NO ₂ -N ⁺ NO ₃ -N (NO _x -N) {TON} | 0.01 |
| Soluble reactive phosphorous ³⁸ (PO ₄ -P, FRP and SRP) | 0.005 |
| Dissolved organic nitrogen | 0.025 |

Medium acid washed bottle: unfiltered [500mL capacity]**Dissolved metals (lab-filtered)**

| Parameter | Detection limit (mg/L) |
|----------------|------------------------|
| Aluminium [Al] | 0.005 |
| Calcium [Ca] | 0.005 |
| Iron [Fe] | 0.005 |
| Magnesium [Mg] | 0.005 |
| Manganese [Mn] | 0.001 |
| Potassium [K] | 0.02 |
| Sodium [Na] | 0.05 |

³⁸ Orthophosphate is the predominant form of phosphorus taken up by plants. With the chemical formula PO₄³⁻ it is the simplest of the phosphates and is therefore often referred to as phosphate. The terms soluble reactive phosphorus (SRP) and filterable reactive phosphorus (FRP) may be used interchangeably. Both are defined according to the analytical procedure by which they are determined rather than the actual species of phosphorus present, however, most if not all of the SRP consists of orthophosphate. SRP (and FRP) is therefore considered to be a measure of orthophosphate.

Total metals (unfiltered in acid washed bottle)

| Parameter | Detection limit (mg/L) |
|------------------|-------------------------------|
| Aluminium | 0.005 |
| Arsenic | 0.002 |
| Boron | 0.02 |
| Cadmium | 0.002 |
| Calcium | 0.005 |
| Chromium | 0.005 |
| Cobalt | 0.005 |
| Copper | 0.005 |
| Iron | 0.005 |
| Lead | 0.001 |
| Manganese | 0.001 |
| Magnesium | 0.005 |
| Mercury | 0.0001 |
| Molybdenum | 0.005 |
| Nickel | 0.005 |
| Selenium | 0.002 |
| Zinc | 0.005 |

Appendix C: ISO and AS standards for water quality monitoring

Standards Australia (AS) publications available online at:
<<http://infostore.saiglobal.com/store/>>.

They have also developed standards of relevance to the content of water-related databases, including:

1. AS 3778.1-2001: *Measurement of water flow in open channels – vocabulary and symbols*, identical to and has been reproduced from ISO 772:1996
2. AS/NZS 5667.1:1998: *Water quality – sampling – guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples*, provides general principles to be applied in the design of sampling programs, general guidance on sampling techniques and guidance on the procedures to be taken to preserve and transport samples for the physical, chemical and radiological analysis of waters and waste waters, including bottom sediment and sludges, for the purposes of process control, quality characterisation, identification of sources of pollution, compliance with water quality guidelines or standards, and other specific reasons.
3. AS/NZS 5667.10:1998: *Water quality – sampling – guidance on sampling of waste waters*, provides detailed guidance on the design of sampling programs, sampling techniques and the handling and preservation of samples of waste water. It is identical with and has been reproduced from ISO 5667-10:1992.
4. AS/NZS 5667.11:1998: *Water quality – sampling – guidance on sampling of groundwater*, part of ISO 5667 that provides guidance on the design of sampling programs, sampling techniques and the handling of water samples taken from groundwater for physical, chemical and microbiological assessment.
5. AS/NZS 5667.4:1998: *Water quality – sampling – guidance on sampling from lakes, natural and man-made*, provides detailed guidance on the design of sampling programs, sampling techniques and the handling and preservation of samples of water from natural and man-made lakes. It is technically equivalent to and has been reproduced from ISO 5667-4:1987.
6. AS/NZS 5667.6:1998: *Water quality – sampling – guidance on sampling of rivers and streams*, part of ISO 5667 that sets out the principles to be applied to the design of sampling programs, sampling techniques and the handling of water samples from rivers and streams for physical, chemical and microbiological assessment.
7. AS 2368-1990: *Test pumping of water wells*, relating to factors which need to be considered and the measurements which need to be made when designing and performing a pumping test. It details the types of pumping tests carried out for water supply purposes, in which water is abstracted from a well. The minimum set of data that needs to be collected before and during a pump test is defined, as presented in the suggested data forms.

8. AS 1726-1993: Geotechnical site investigations, which sets out minimum requirements for a geotechnical site investigation, as a component in the engineering design, construction, commissioning and operation of civil engineering and building works. Comprehensive appendices are provided dealing with preferred systems of geotechnical investigations and commonly considered laboratory tests. A typical project brief for a geotechnical site investigation is given and the commentary sets out guidelines on construction assessment, maintenance and evaluation of failures. First published as AS 1726-1975. Second edition (including Add. No.1-1978) 1981. Third edition 1993.

The International Organisation for Standardisation (ISO) publications, available online at <http://www.iso.org/iso/home.html>.

9. ISO 6107 series: *Water quality – vocabulary*, containing parts 1 to 9 and defines a list of terms used in certain fields of water quality characterisation.

10. ISO 8689-1:2000: *Water quality – biological classification of rivers – part 1: guidance on the interpretation of biological quality data from surveys of benthic macroinvertebrates*.

11. ISO 8689-2:2000: *Water quality – biological classification of rivers – part 2: guidance on the presentation of biological quality data from surveys of benthic macroinvertebrates*.

Appendix D: Selection of measurement parameters based on land use activities

Figure D1: Industrial land uses that may be impacting on groundwater systems, wetlands and surface water catchments

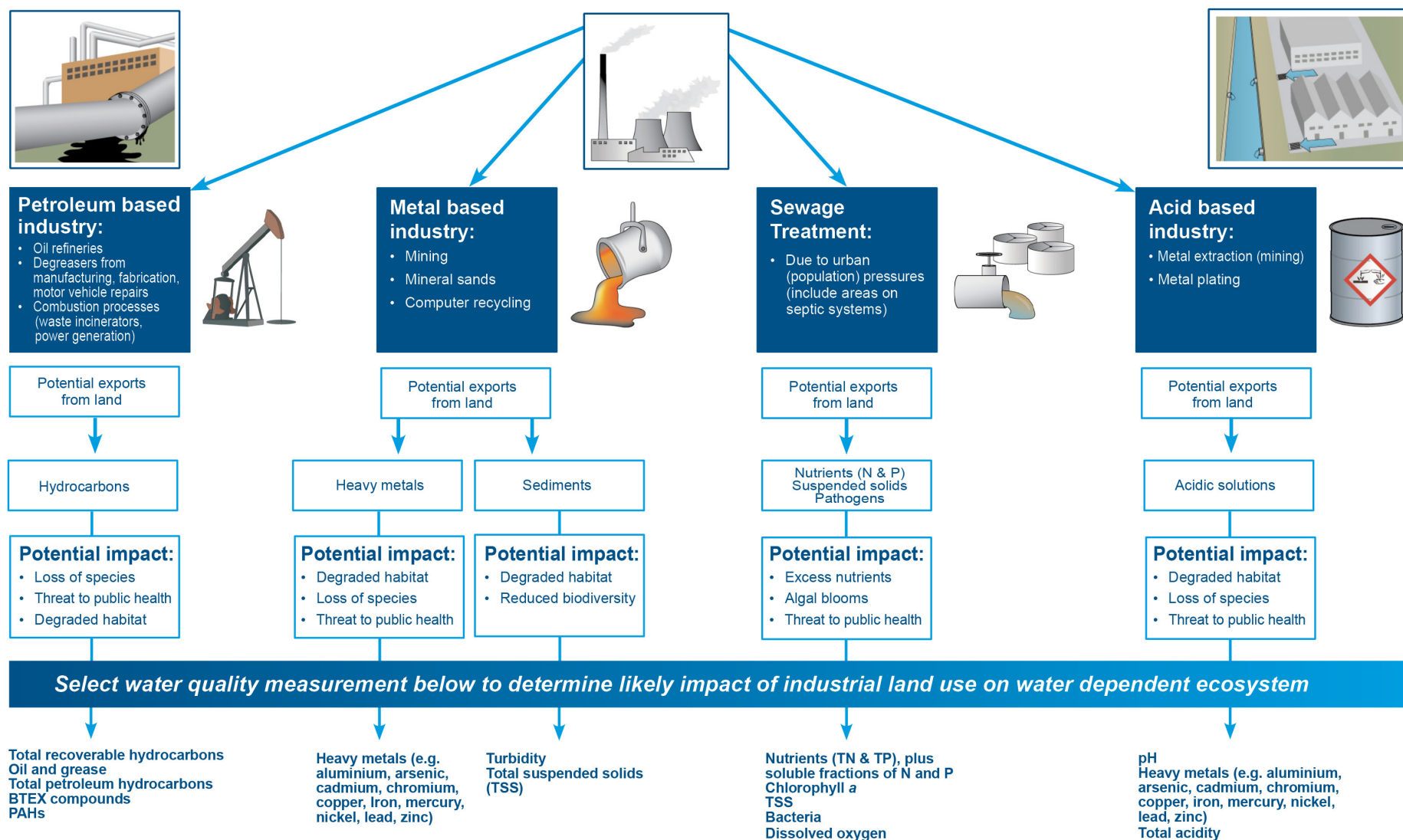


Figure D2: Rural land uses that may be impacting on groundwater systems, wetlands and surface water catchments

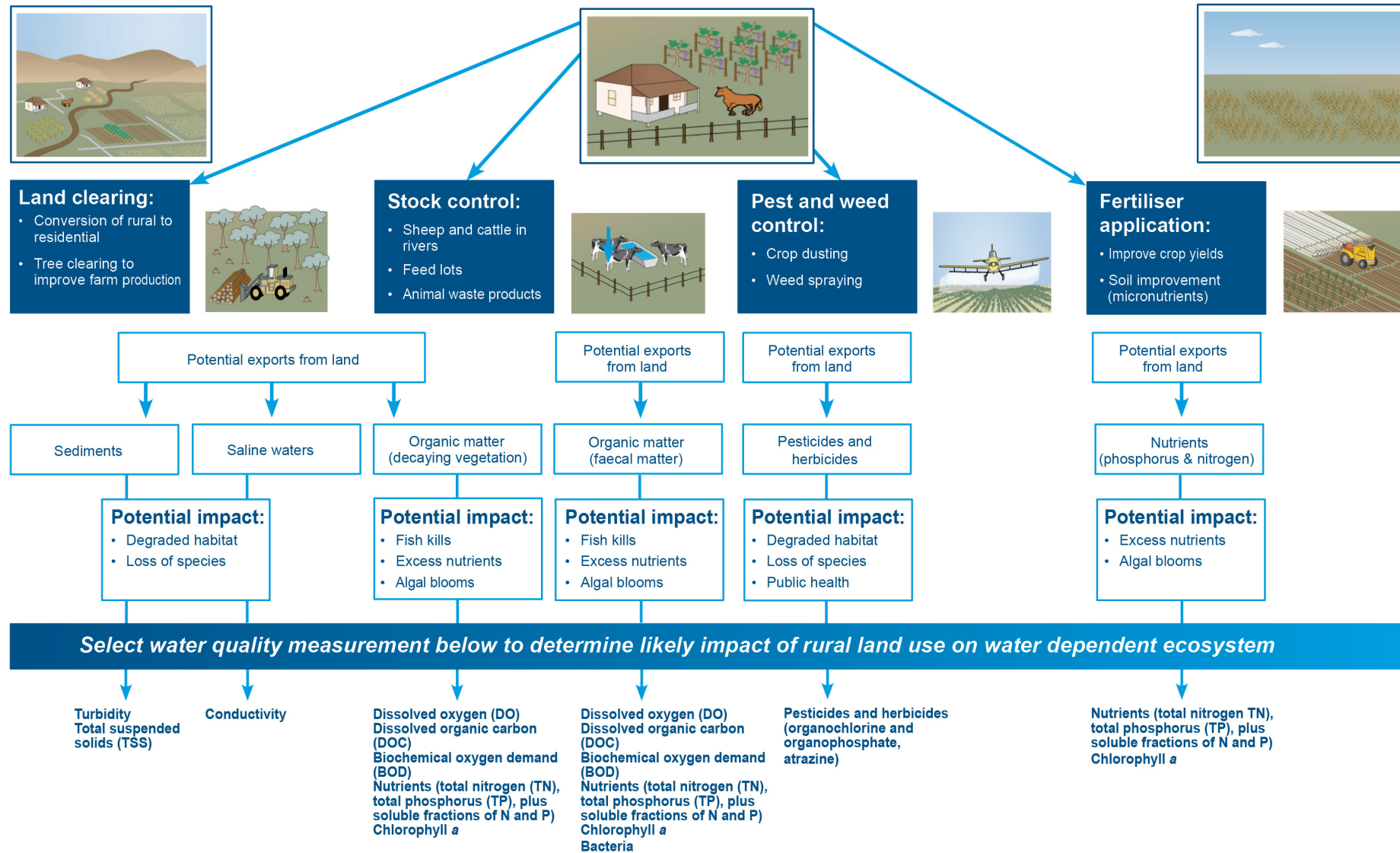
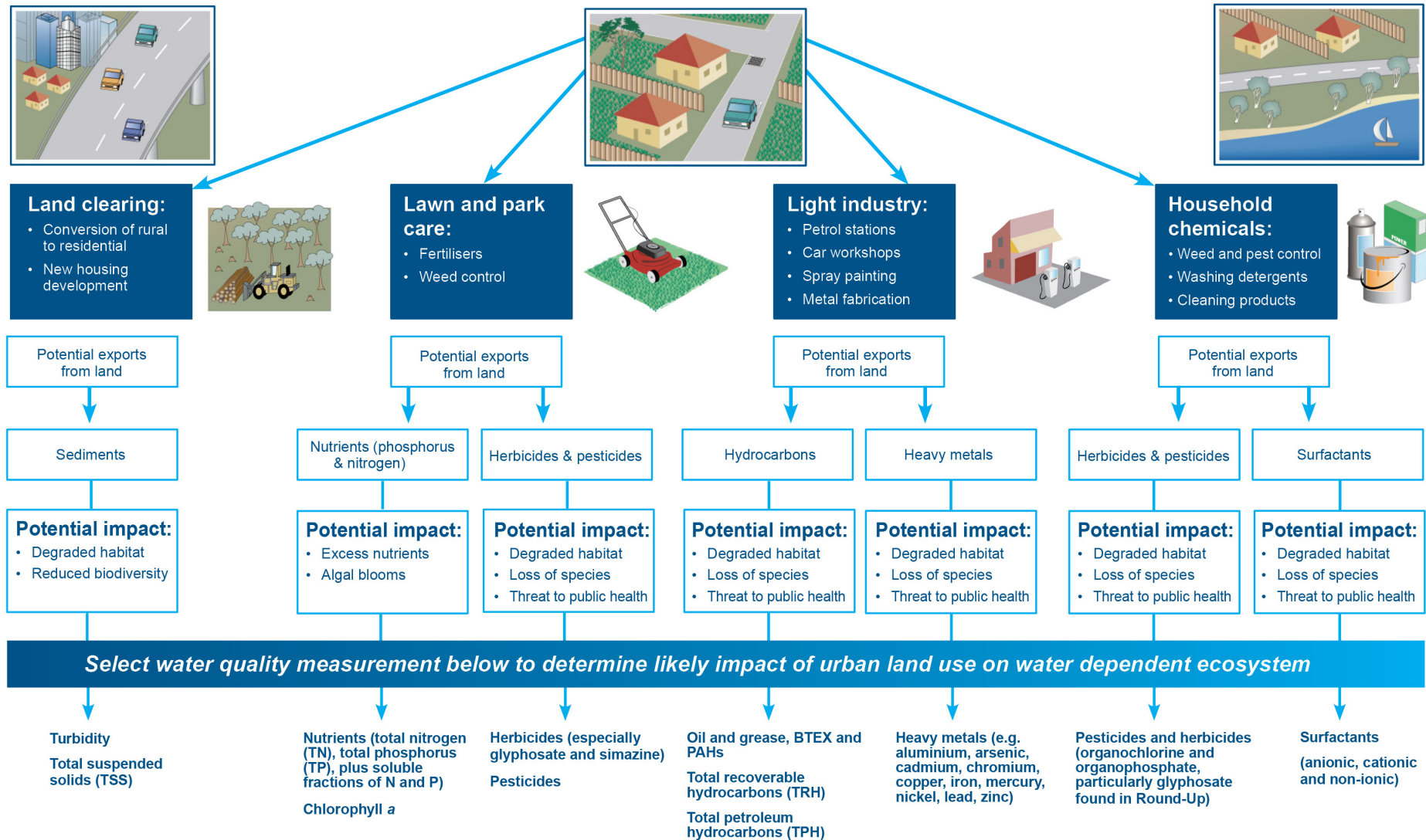


Figure D3: Urban land uses that may be impacting on groundwater systems, wetlands and surface water catchments



Shortened forms

| | |
|-------|--|
| ASS | Acid sulfate soils |
| BDL | below detection limit |
| BMP | best-management practice |
| BoM | Bureau of Meteorology |
| BUWM | <i>Better urban water management</i> (WAPC 2008) |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| DEC | Department of Environment and Conservation |
| DoW | Department of Water |
| EWR | ecological water requirement |
| GDE | groundwater-dependent ecosystems |
| GWA | Government of Western Australia |
| GWL | groundwater level |
| LWMS | local water management strategy |
| NATA | National Association of Testing Authorities |
| RWMS | regional water management strategy |
| SAP | sampling and analysis plan |
| SRT | Swan River Trust |
| TN | total nitrogen |
| UDIA | Urban Development Institute of Australia |
| UWMP | urban water management plan |
| WALGA | Western Australian Local Government Association |
| WAPC | Western Australian Planning Commission |
| WDE | water-dependent environment |
| WIN | water information network |
| WQIP | water quality improvement plan |
| WSUD | water sensitive urban design |

Glossary

Acid sulfate soil: The common name given to soils containing iron sulfides.

Application: A formal request made in accordance with regulations for a decision by a responsible authority.

Baseline data: Data representing the existing elements, characteristics and trends in an area to provide a measure against which progress can be assessed.

Best-management practices (BMPs): Devices, practices or methods for removing, reducing, retarding or preventing targeted stormwater runoff constituents, pollutants and contaminants from reaching receiving waters (Taylor & Wong 2002) and for reducing the volume of stormwater runoff.

Contaminated: In relation to land, water or a site, means having a substance present in or on that land, water or site at above background concentrations that presents, or has the potential to present, a risk of harm to human health, the environment or any environmental value.

District scale: Only the areas of proposed types of development, major 'constraint areas' (bushlands, waterways, wetland etc.) and major roads are identified.

Dewatering: Removing underground water to facilitate construction or other activity. It is often used as a safety measure in mining or as a preliminary step to resumption of development in an area (*Rights in Water and Irrigation Act 1914*).

Fit-for-purpose water resource: Water recycling adopts the concept of using water that is fit-for-purpose, whereby the quality of water is appropriate for the intended use.

Groundwater: Water found under the land surface that occupies pores and crevices of soil and rock.

Hydrogeology: The hydrological and geological science concerned with the occurrence, distribution, quality and movement of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.

Hydrology: The science of the behaviour of water in the atmosphere, on the surface of the earth and within the soil and underlying rocks. This includes the relationship between rainfall, runoff, infiltration and evaporation.

Local scale: The proposed density of development; the locations of all roads and local parks are clearly identified.

Monitoring: The collection of data by various methods for the purpose of understanding natural systems and features, evaluating the impacts of development proposals on such systems, and assessing the performance of mitigation measures.

Developers: Refers to land developers and consultants

Statutory referral: Planning and development proposal as required under the *Planning and Development Act 2005*.

Surface water: Water flowing or held in waterways or wetlands on the surface of the landscape.

Subdivision: The division of land into lots.

Subdivision scale (urban scale): The proposed cadastre; sizes of the blocks and public areas (such as parks) are specified.

Surface water: Water flowing or held in waterways or wetlands on the surface of the landscape.

Water-dependent ecosystems: Those parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence of water resources, including flowing or standing water and water within groundwater aquifers.

Water sensitive urban design (WSUD): A design philosophy that provides a framework for managing water-related issues in urban areas. WSUD incorporates the sustainable management and integration of stormwater, wastewater and water supply into urban design. WSUD principles include incorporating water resource management issues early in the land use planning process. WSUD can be applied at the lot, street, neighbourhood, catchment and regional scale.

References

- Australian Government 2000a, Australian and New Zealand guidelines for fresh and marine water quality accessed 9 February 2010 at:
http://www.mincos.gov.au/publications/australian_and_new_zealand_guidelines_for_fresh_and_marine_water_quality.
- 2000b, *Australian guidelines for water quality monitoring and reporting*; accessed 8 February 2010 at:
http://www.mincos.gov.au/publications/australian_guidelines_for_water_quality_monitoring_and_reporting <http://>.
- Baskaran, S, Feitz, AJ, de Caritat, P, Plazinska, A, Brodie, R, Coram, J & Ransley T 2009, *Groundwater sampling and analysis – a field guide*. Geoscience Australia record 2009/27.
- Commonwealth Scientific and Industrial Research Organisation & Australian Bureau of Meteorology 2007, *Climate change in Australia*, technical report. Commonwealth Scientific and Industrial Research Organisation, Canberra 148 pp.
- Department of Water 2006, *Water quality protection note 30: groundwater monitoring bores*; available from www.water.wa.gov.au/PublicationStore/first/59685.pdf.
- 2008a, *Water quality monitoring program design: a guideline to the development of surface water quality monitoring programs*. Department of Water, Perth.
- 2008b, *Field sampling guidelines: a guideline for field sampling for surface water quality monitoring programs*. Department of Water, Perth.
- 2008c, *Surface water sampling methods and analysis – technical appendices: Standard operating procedures for water sampling – methods and analysis*. Department of Water, Perth.
- 2008d, *Groundwater measurement: hydrologic measurement process*. Department of Water, Perth
- 2009a, *Operational policy no. 5.12 – Hydrogeological reporting associated with a groundwater well licence*. Department of Water, Perth
- 2009b, *Ecological water requirements for Lefroy Brook* Department of Water, Perth
- Froend, R & Loomes, R 2006, *Determination of ecological water requirements for wetland and terrestrial vegetation – southern Blackwood and eastern Scott coastal plain*; prepared for the Department of Environment, report no. 2005–07, Centre for Ecosystem Management, Edith Cowan University, Joondalup.
- Goodreid, A 2008, *South West groundwater areas monitoring program*. Water resource allocation planning series, report no. 34, Department of Water, Perth.
- Government of Western Australia 2006, *State planning policy 2.9: water resources*. Western Australian Planning Commission, Perth.
- 2007, *State water plan*. Department of Premier and Cabinet, Perth

- Kern, AM & Johnson, SL 2009, *Improved groundwater resource management through better groundwater monitoring – a review of groundwater monitoring*, Hydrogeology report series, HR268, Department of Water, Perth.
- Land and Water Biodiversity Committee 2003, *Minimum construction requirements for water bores in Australia*. Land and Water Biodiversity Committee.
- Loomes, R, Ogden, G, & Froend R 2007, *Selection and establishment of vegetation transects at groundwater-dependent ecosystem criteria sites in Bunbury, Busselton–Capel groundwater areas*, prepared for the Department of Environment, Centre for Ecosystem Management, Edith Cowan University, Joondalup.
- Swan River Trust 2008, *Healthy rivers action plan*, an action plan to improve water quality in the Swan Canning River system. Swan River Trust, Western Australia.
- Taylor, CJ & Alley, WM 2001, *Groundwater level monitoring and the importance of long-term water-level data: US Geological Survey Circular 1217*, 68 p., accessed 8 February 2010 at <<http://pubs.usgs.gov/circ/circ1217/>>.
- Western Australian Planning Commission 2008, *Better urban water management*, Western Australian Planning Commission, Perth, Western Australia.

Department of **Water**

168 St Georges Terrace, Perth, Western Australia

PO Box K822 Perth Western Australia 6842

Phone: 08 6364 7600

Fax: 08 6364 7601

www.water.wa.gov.au

8446 0 1012