City of Armadale water resource management for land development

A position paper

Prepared for the City of Armadale

By Essential Environmental

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GLOSSARY

Dampland – type of wetland, a seasonally **waterlogged** (damp) basin (Semeniuk, 1987)

Perched groundwater - water that sits above the regional or district scale groundwater table due to presence of an impermeable layer and therefore contains only locally infiltrated rain/run-off water

Sumpland – type of wetland, a seasonally **inundated** basin (Semeniuk, 1987)

The following terms are used to describe rainfall conditions for groundwater level analysis in section 5.2.2:

Average winter – winter during a year with approximately average total rainfall

Wet winter – winter during a year with total rainfall approximating to a 10% annual exceedance probability

The following terms are used in section 5 in relation to groundwater modelling:

Steady state – Steady state modelling assumes that the magnitude and direction of flow is constant with time throughout the entire domain. This does not mean that in a steady state system there is no movement, it simply means that the amount of water within the domain remains the same, and that the amount of water that flows into the system, is the same amount as flows out.

Dynamic – Dynamic modelling introduces spatial variability and a timestep to allow representation of spatially and temporally variable conditions such that both the magnitude and direction of flow can change over time.

1 INTRODUCTION AND BACKGROUND

1.1 Purpose

This position paper has been prepared to initiate and inform a process of consultation with stakeholders to establish a suite of water resource management and design criteria that are appropriate to the local environments prevalent in the City of Armadale; meet the amenity and safety expectations of a growing community; and are practical and achievable for developers.

With this position paper the City aims to set out its position on a number of significant water resource management issues that need to be addressed by development in the City and provide guidance on the expectations and objectives of the City. Key objectives for the City of Armadale that may be affected by water resource management issues are:

- Protection of public health and safety
- Maintenance of acceptable public amenity
- Management and maintenance of public infrastructure and assets
- Protection and management of sensitive environments

The City has taken a risk based approach to define the scope for this paper. The risk of issues arising that impact on the City's ability to meet its objectives is present throughout the City. However, it is important to note that many of the key risks are more prevalent in Swan Coastal Plain areas where the most significant development is occurring. As a consequence, this paper substantially focuses on these areas whilst including more limited consideration of the remainder of the City.

It is hoped that the paper will facilitate future consultation with developers and their technical consultants to facilitate the City's future development of water management guidelines for use when developing new greenfield and infill subdivisions in the City. This paper also considers the impacts of other land use changes but guidance for water management is generally aimed at urban development.

1.2 Background

Over the past few years, the City of Armadale has experienced rapid growth and development. During this time, three key water resource management issues have arisen as follows:

Loss of amenity caused by groundwater level rise following development – this has been the result in some Swan Coastal Plain locations where an 'infiltrate on site' drainage strategy has been employed without sufficient consideration of geotechnical and hydrogeological characteristics of the site.

Erosion and sedimentation caused by concentration of overland flowpaths – this has been the result in some areas of the Hills and foothills where clearing and subsequent development has been undertaken without proper provision for the resulting increase in overland flows and velocities.

Public health concerns as a result of increased mosquito populations and algal blooms – rapid development occurring in areas of shallow groundwater and significant nutrient loads released into the downstream environment have the potential to increase the risk of algal blooms. Development in areas adjacent to wetlands and waterbodies, particularly where they are degraded and have poor water quality increases the frequency of human contact with mosquitos which in turn increases the risk of exposure to mosquito borne diseases.

The City is committed to supporting and encouraging innovation but it is important to recognise that the City has a responsibility to: maintain amenity standards for the current and future community; manage and maintain public infrastructure and assets; and manage risks to public health and safety. In undertaking this role the City considers it necessary to receive sufficient technical detail to demonstrate that a proponent has undertaken sufficient monitoring and investigations to fully inform themselves of the prevalent site conditions and that modelling and design work has been undertaken in a technically rigorous way, including, where appropriate, inclusion of some margin of safety to deal with uncertainty.

This paper has been developed by the City to obtain input from key stakeholders including industry on likely requirements to enable clear and transparent decision-making on future urban water management strategies and plans.

1.3 The study area

Located approximately thirty kilometres south-east of the centre of Perth, the City of Armadale (the City) encompasses an area of approximately 560km^2 much of which is located on the Darling Scarp at elevations over 100 m AHD.

The City (Figure 1) is made up of three significant landform types each with their own environmental and community characteristics. These are: Hills; Foothills and Scarp; and Swan Coastal Plain; and they contain the following localities:

- Hills
  - Bedfordale
  - Ashendon
  - Lesley
  - Karragullen
  - Roleystone
- Foothills and Scarp
  - Armadale
  - Kelmscott
  - Mount Nasura
  - Mount Richon
  - Wungong east
- Swan Coastal Plain
  - Brookdale
  - Camillo
  - Champion Lakes
  - Forrestdale
  - Harrisdale
  - Haynes
  - Hilbert
  - Piara Waters
  - Seville Grove
  - Wungong west

1.4 Planning context

Planning in the City of Armadale is guided by the City's Town Planning Scheme No 4, Local Planning Policies and Local Planning Strategy.

The Metropolitan Redevelopment Authority (MRA) has planning control over areas of land within the City's boundaries through the Armadale Redevelopment Scheme and Wungong Urban Water Redevelopment Scheme, including the following precincts:

- Armadale Central - West of Commerce Avenue
- Kelmscott - portion bound by Albany Highway, Railway Avenue and Davis Road, including a southern part of Third Avenue
- Champion Lakes
- Champion Drive
- Forrestdale East

- Forrestdale West
- Wungong Urban - including Hilbert and Haynes, south of Armadale Road, east of Tonkin Hwy and south of Eighth and Roads.

The City of Armadale is one of the top three fastest growing local government areas in Western Australia and its City Centre is one of eight designated Strategic Metropolitan Centres in the State's Government's *SPP4.2: Activity Centres for Perth and Peel*, and *Directions 2031*.

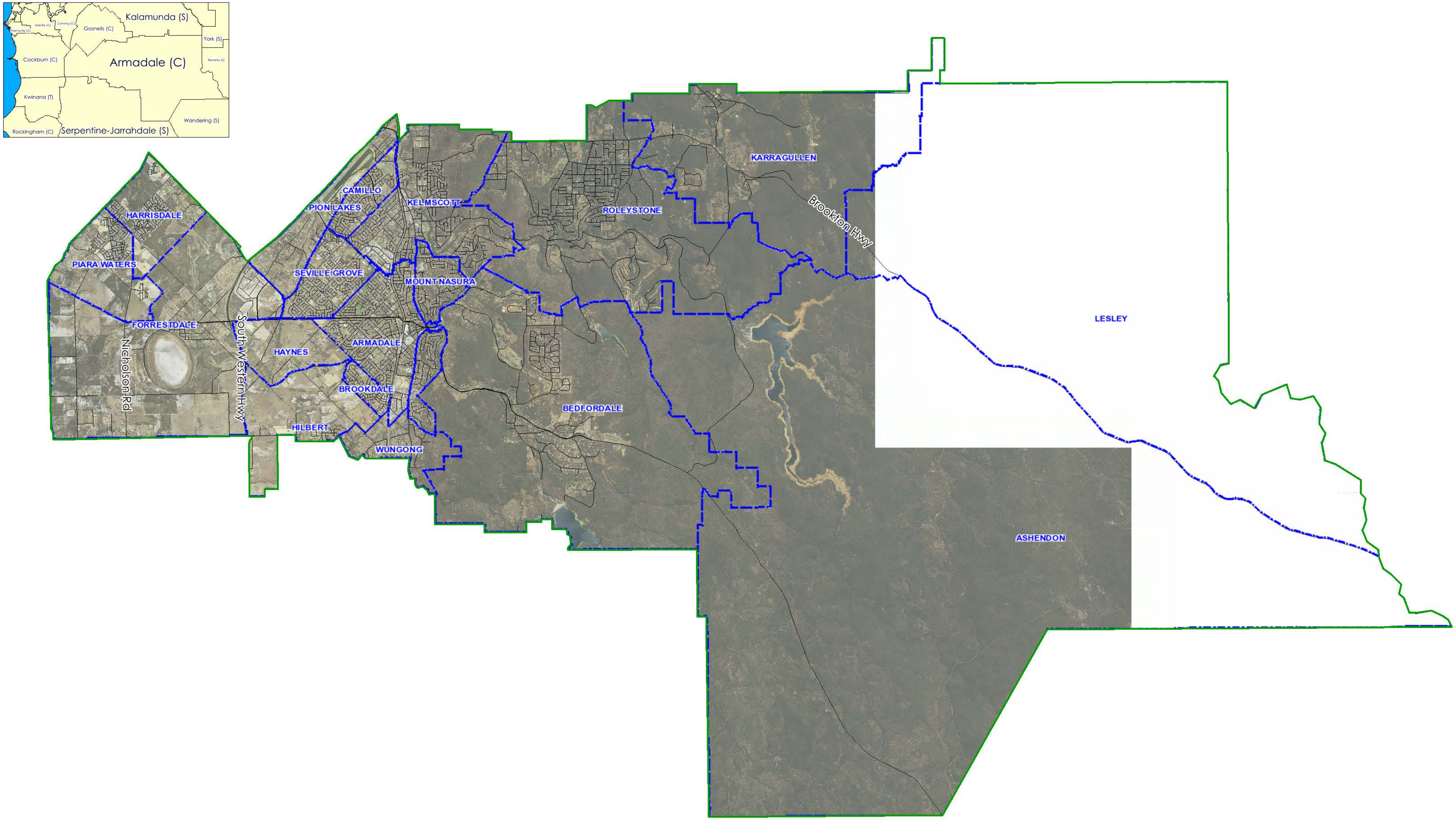
1.5 Principles for preparation of water management documents in the City of Armadale

The City of Armadale, in preparing this document have considered the key issues that are prevalent in the City and the principles that should be applied when preparing urban water management documents to address them. Core principles that the City wishes to promote include:

- **Consult early and often** – the City aims to provide an open and collaborative approach to the urban water management approvals process and encourages proponents to establish and maintain contact throughout the planning and design process.
- **Provide technical detail only when necessary** – the City wishes to set a high standard for technical investigation and assessment to provide confidence in engineering and landscape designs. The City does not wish to force proponents to undertake expensive studies for low risk sites. Where there is uncertainty about the necessary level of detail for a particular site, proponents are encouraged to seek clarification.

City of Armadale - water resource position paper
Figure 1 - Location

Legend
Road centrelines
City of Armadale boundary



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2 HYDROGEOLOGICAL CONTEXT OF ARMADALE

In considering the hydrogeology of Armadale it is useful to review its various landform groups since they are strongly indicative of the prevailing hydrogeological conditions. For the purposes of this document, the major landform groups considered are:

- Hills
- Foothills and Scarp
- Swan Coastal Plain

The hydrogeological conditions of each of these landform groups are described in below. Mapping of the environmental and land use characteristics of the City of Armadale is provided in Appendix 1 as follows:

- Topography
- Geology
- Acid sulfate soil risk
- Groundwater and wetlands
- Rivers and floodplain mapping
- Metropolitan Region Scheme
- Armadale and Wungong Redevelopment Scheme areas
- Contaminated sites

2.1 Hills

The hills area of the City includes the localities of Bedfordale, Ashendon, Lesley, Karragullen, and Roleystone. The area can mostly be described as varying from steeply to gently undulating, tending to becoming steeper in the west as the Scarp is approached. The land is largely forested with small semi-rural communities, some orchards and vineyards.

2.1.1 Landform geology and soils

The Armadale hills are largely formed of Granite, Laterite, Gravel and Gneiss with valley-fill deposits of clayey, sandy silts and clayey gravely sands.

2.1.2 Groundwater systems

Groundwater in the hills is inconsistently found in rock fractures and some small areas of alluvial or colluvial valley floors where they form small dampland or sumpland type wetlands. Seasonal groundwater springs from the fractured rocks are also not uncommon and contribute to streamflows.

For management purposes, the area is described as the Karri groundwater subarea. However the Department of Water does not actively manage the groundwater resources in this area.

Key threats to groundwater quality, and therefore downstream surface water quality, are nutrients from applied fertilisers and septic tanks.

2.1.3 Surface water systems

There are two major river systems which traverse the hills area of the City, these are:

- Canning River and its tributaries including:
    - Canning River East
    - Kangaroo Gully
    - Churchman Brook
    - Stony Brook
    - Wright Brook
- Wungong River and its tributaries including:
    - Neerigen Brook

The upper catchments of both of these systems are proclaimed public drinking water source water catchment areas terminating in the Canning, Wungong and Churchman Brook Dams.

Stream flow in the hills is formed by surface water runoff and some springs, with flows in the major dammed catchments heavily controlled downstream of the dams.

Key threats to surface water quality are erosion and sedimentation as well as nutrients present in both stormwater runoff and groundwater springs.

2.2 Foothills and Scarp

The steep incline of the Darling Scarp from Swan Coastal Plain to Hills begins in the most populated part of the City where development has been relatively unconstrained by water. This is a result of elevation providing separation from groundwater and well-defined incised watercourses providing well drained developable land. The localities of Armadale, Kelmscott, Mount Nasura, Mount Richon and Wungong east are included in the foothills and scarp area. Wungong west (as divided by the South Western Highway) is considered in the Swan Coastal Plain area discussed later.

2.2.1 Landform geology and soils

The foothills and scarp area of the City is an area of transition with the Darling Scarp rising sharply from approx. 35m AHD to 185m AHD over approximately two kilometres. The geology also transitions in this area from Granite, Laterite, Gravel and Gneiss with valley-fill deposits of clayey, sandy silts and clayey gravely sands of the hills, past the Darling Fault and on to the clayey sands overlain with sands of the Swan Coastal Plain.

2.2.2 Groundwater systems

Groundwater to the east of the Darling Fault, which broadly corresponds to the South Western Highway is described similarly to the hills where groundwater is inconsistently present in rock fractures and valley floors. The steep incline of the scarp and foothills also increases its scarcity.

To the west of the Darling Fault, at the base of the Darling Scarp, more consistent groundwater aquifers become present and are managed by the Department of Water in the City of Armadale subarea of the Perth groundwater area.

2.2.3 Surface water systems

The two river systems originating in the hills both pass through the foothills and scarp area with the Canning River flowing through Kelmscott and the Wungong River through Wungong east. Additionally, the major Wungong River tributary; Neerigen Brook passes through Armadale collecting much of the drainage from the urban area of the City. There are also many other minor watercourses which originate on the Scarp.

The Scarp and foothills watercourses tend to be quite deeply incised with narrow floodplains and as they progress into more heavily built up areas they become substantially linked to constructed urban drainage systems, and in many cases are piped in sections. The Canning River, as the largest watercourse in this area is an exception, remaining largely in a semi-natural state although its floodplain has largely been cleared.

As a result of the steepness of the landscape, increasing urbanisation and interaction with urban drainage, the key water quality threats in this area are erosion and sedimentation as well as nutrients and other contaminants from urban land uses.

2.3 Swan Coastal Plain

The localities of Brookdale, Camillo, Champion Lakes, Forrestdale, Harrisdale, Haynes, Hilbert, Piara Waters Seville Grove and Wungong west (as divided by the South Western Highway) are located in the relatively flat Swan Coastal Plain area of the City and are characterised by a strong presence of water in the landscape. There are numerous natural and man-made wetlands, lakes and waterways and groundwater is frequently shallow.

2.3.1 Landform geology and soils

The Swan Coastal Plain area of the City as described by its title is very flat and typically waterlogged with frequent wetlands, lakes, watercourses and drains. The soils are generally clayey sand overlain with sand which is itself interspersed with areas of clayey sands and sandy clays.

2.3.2 Groundwater systems

Groundwater resources in this part of the City are managed by the Department of Water in the City of Armadale groundwater subarea, except for western parts of Piara Waters and Forrestdale which are in the Wright and Forrestdale subareas of the Jandakot groundwater management area.

Groundwater is typically present in at least three aquifers which are (in order of increasing depth) Superficial, Leederville and Yarragadee. In many areas, in the presence of clayey substrata, there is local shallow perched groundwater which may or may not be seasonally connected to the district or regional scale superficial aquifer. This geotechnical and hydrological condition supports local wetlands and watercourses, particularly in the localities of Brookdale, Camillo, Champion Lakes Haynes, Hilbert, Seville Grove and Wungong to the east of the Wungong River (Figure 2). To the west of the Wungong River, wetlands and waterways are largely connected to and sustained by the regional superficial aquifer.

Water quality in the shallow groundwater aquifers of the Swan Coastal Plain is affected by nutrients and other contaminants which have accumulated over many years of agricultural land uses as well as more recently from urban and industrial areas.

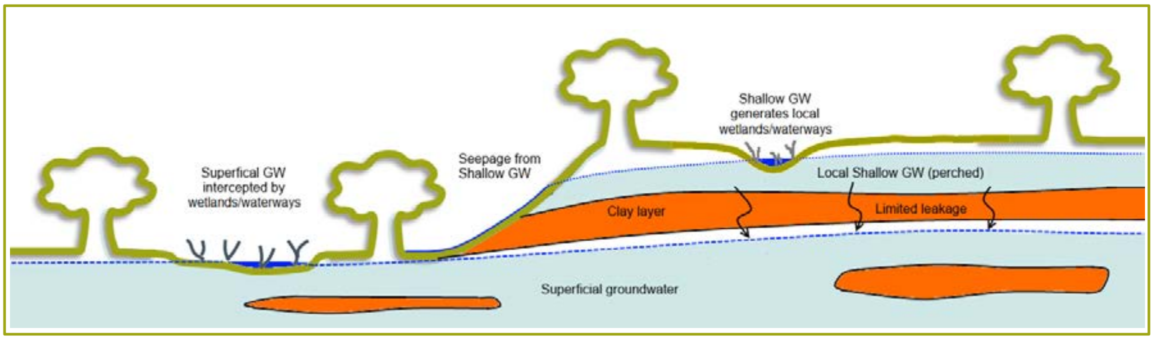


Figure 2: Representation of locally perched and regional superficial groundwater systems

2.3.3 Surface water systems

The Swan Coastal Plain area is dominated by extensive interconnected wetlands and waterways with the major features being Forrestdale Lake and the Southern and Wungong Rivers.

Floodplain mapping has been undertaken for the Wungong and Southern Rivers. By virtue of the flat, low-lying landscape and typically shallow groundwater system, surface water inundation can be extensive following large rainfall events and many wetland areas are almost continuously inundated throughout winter. Streams, with the exception of the downstream extents of the Wungong and Southern Rivers are ephemeral, being mostly dry throughout the summer months.

The numerous wetlands throughout the Swan Coastal Plain area have highly variable hydrological characteristics. In almost all cases the hydrological regime of a wetland is driven by a combination of surface and groundwater systems. However some may be predominantly groundwater dependent with only a minor surface water catchment, whilst others may be mainly surface water dependent.

The hydrological regime of a wetland, and as a result, the area where there is a high potential for development to impact on it (hydrological zone), is defined by:

- Topography and the defined surface water catchment
- Soils – both within the wetland and its catchment
- Groundwater regime – both locally perched and regional superficial groundwater systems
- Presence of natural or constructed drainage flows into or out of the wetland

Threats to the wetlands and watercourses of the Swan Coastal Plain include: nutrients and other contaminants in stormwater runoff from urban and agricultural land uses and impacts from the development. The most significant threats from development in these areas are:

- Changing hydrological regimes through construction of drainage systems and/or diversion of surface and groundwater catchment flows (increasing or decreasing inflows and/or outflows)
- Mobilisation of legacy nutrients from soils and shallow groundwater systems as a result of improved drainage.
- Exposure of acid sulfate soils .
- Sand drift from land clearing and/or construction activities.
- Erosion from changing water regimes.

3 WATER MANAGEMENT DOCUMENT REQUIREMENTS

The key documents for consideration of water resource management in developing parts of the City of Armadale are Local Water Management Strategies (LWMS's) and Urban Water Management Plans (UWMP's). Whilst District Water Management Strategies provide high level establishment of objectives and principles for water management and provide the necessary evidence of the land's capacity to be developed, it is these lower level documents that identify and test the way that development will proceed.

In reviewing LWMS's and UWMP's the City of Armadale have found that there are a number of specific items that are identified as required in *Better Urban Water Management* (WAPC 2008) where the level of detail that is provided is either insufficient or presented in a manner that is difficult to assess. This sometimes results in protracted consultation periods with numerous versions of reports being submitted for review. This is a continual drain on the City's stretched resources and leads to further delays to development. The City understands that this is frustrating for developers and wishes to provide additional guidance for proponents on what information is expected at each stage of development.

The City intends to use this paper to initiate a consultation process with developers and stakeholders. This process will be aimed at assisting the City to develop a suite of guidance material that provides an appropriate level of detail to facilitate and guide innovative water sensitive development in the City.

3.1 District water management strategies

DWMS's are provided to support region scheme amendments and district structure planning and are expected to demonstrate that the land can support the proposed land uses. A broad approach to technical information is generally applied and limited technical detail is expected except when significant site specific issues are present. There are few locations within the City of Armadale where DWMS's are expected and so this paper generally does not contain requirements for this stage of documentation.

3.2 Local water management strategies

LWMS's are provided to support local structure planning and are expected to identify how the proposed urban structure will address water use and management. The level of detail required is generally described as "proof of concept".

Table 1 identifies the work required to support the recommendations in an LWMS as defined in *Better Urban Water Management* (WAPC 2008) and expands on this with some specific requirements of the City of Armadale. Consideration has also been given to the requirements outlined in *Interim Guidelines for preparation of Local Water Management Strategies* (DoW, 2008).

For staged developments or structure plan areas with multiple landowners. The LWMS must provide sufficient detail to clearly articulate the interactions between various stages and/or landholdings such that individual UWMP's can be reasonably assessed and approved in isolation.

Where insufficient confidence is provided in relation to the interactions and interfaces between landholdings and/or development stages, additional detail, including design information outside the individual subdivision area, may be required in future UWMP's.

More detailed information on the requirements is contained in section 4.

3.3 Urban water management plans

UWMP's are provided to support subdivision and are expected to identify how the final urban form will use and manage water. The level of detail generally required is considered to be "detailed design"; however it is noted that the level of detail that is possible is dependent on whether subdivision approval has been granted.

Table 2 identifies the work required to support the recommendations in a UWMP as defined in *Better Urban Water Management* (WAPC 2008) and expands on this with some specific requirements of the City of Armadale. Consideration has also been given to the requirements in *Urban water management plans: Guidelines for preparing plans and for complying with subdivision conditions* (DoW, 2008).

Where UWMP's are lodged concurrently with the subdivision application the document is expected to provide sufficient detail to perform as the 'basis for design'. Thus, detailed engineering and landscape designs are not generally required.

Where UWMP's are lodged in response to a condition of subdivision, a greater level of detail is generally expected within the document which should also be supported by detailed engineering and landscape designs.

For staged developments or structure plan areas with multiple landowners. There is an expectation that the UWMP will comply with a previously approved LWMS.

Where insufficient confidence has been provided in a previously approved LWMS in relation to the interactions and interfaces between landholdings and/or development stages, additional detail, including design information outside the individual subdivision area, may be required in the UWMP.

Additional guidance on the requirements is provided in section 4.

Table 1: work required to support the recommendations in an LWMS

Work item	Guidance provided in *Better Urban Water Management*	City of Armadale requirements (where relevant)
Water balance modelling	• Identify pre- and post-development water balances to inform the assessment of options for reducing the need to import potable water through consideration of fit-for-purpose use (eg toilet flushing, laundry, hot water and ex-house). Consider approvals required to achieve desired options. For further guidance see *Developing Alternative Water Supplies in the Perth Metropolitan Area Series* (Water Corporation, 2007).	• Water balance modelling should also consider the impacts and influences of changing land use and water management practices on the local hydrogeology. This should include assessment of pre and post development: o Evapotranspiration o Groundwater recharge (including locally perched, superficial and deeper groundwater systems as relevant) o Runoff o Use of infiltration systems o Groundwater demand o Imported scheme water use, reuse and disposal
Water dependent ecosystems and ecological health	• Consider findings of district water management strategy (or DoW drainage and water management strategy) and provide more detailed assessment where necessary. • Show buffers of wetlands and waterways to be protected. • Continue monitoring of ecological health and hydrological regime of water dependent environments to be protected.	• Identify groundwater dependent remnant vegetation (i.e. Banksia woodland) for retention and protection. • Demonstration that the hydrology of the wetland or waterway is understood and quantification of how it will be affected by its relationship to changes in the surrounding land uses. • Demonstration that proposed buffers are consistent with appropriate management and rehabilitation of wetlands and waterways. For example: o Where revegetation of the buffer is proposed can it be delivered in a way that will achieve environmental objectives and be compatible with bushfire management requirements? o How will necessary surface water inflows be managed and maintained, noting that drainage infrastructure is often restricted within buffers?
Desktop historical land use assessment	• Discussion of previous land use and likely impacts on the quality of surface run-off and shallow groundwater, and how this will be addressed by the proposed system, including further site ground truthing. • Determine the areas of high-risk acid sulfate soils and potential acid sulfate soils depicted in *Planning Bulletin 64* (WAPC, 2003). Where these areas exist, identify an appropriate management strategy to address them.	• Demonstration that the potential impacts of historical land uses have been properly considered when developing the water management strategy. For example: o Where on-site infiltration of stormwater is proposed, can the extent to which soil-stored nutrients will be mobilised as a result be quantified? How will the potential impacts to baseline water quality be managed? o Where contamination is identified, does its management preclude or otherwise affect the preferred water management strategy? • Review of desktop geotechnical information detailing anticipated conditions to be investigated further in future.
Groundwater monitoring and modelling (primarily for high watertable areas)	• Identify the current state of the resource, including quality and levels. • Demonstrate that potential impacts to groundwater and water dependent environments to be protected are avoided or minimised. Demonstrate that any potential impacts will not have a significant environmental impact. • Assess potential for short-term mobilisation of nutrients and contaminants resulting from development works as well as long-term impacts on groundwater quality from development. Where necessary, identify pollutant pathways. • Demonstrate need for controlled groundwater levels or subsoil drainage where proposed, identifying likely change in groundwater levels. • Assess superficial/surficial groundwater quantity. • Explore potential for use of shallow groundwater for a non-potable source.	• Demonstration that the local hydrogeology is understood and quantification of how it will be affected by its relationship to changes in the surrounding land uses. For example: o Will the clearing and development of the land result in increasing groundwater levels due to lost evapotranspiration and increased recharge? – How will this be managed? • Demonstration that groundwater and surface water drainage systems and strategies have been developed with consideration of their inter-relationships. For example: o In areas of shallow groundwater, where on-site infiltration of stormwater is proposed, what impact will this strategy have on local and regional groundwater levels? o Where groundwater (subsoil) drainage is proposed, will water quality treatment be provided in combination with surface water drainage or as an entirely separate system? o Is the creation of new drains with inverts penetrating the groundwater level proposed and how

Work item	Guidance provided in *Better Urban Water Management*	City of Armadale requirements (where relevant)

Surface water modelling	• Floodplain and wetland modelling to determine minimum building levels, setbacks for development, and receiving water levels.
	• Flow monitoring of existing surface water streams to establish current requirement.
	• Identify how to manage post-development flows to meet catchment target flows.
	• Drainage modelling to determine the detailed land requirements and flood ways needed to cope with major and minor storms (1 in 1 year, 1 in 10 year and 1 in 100 year), based on the receiving environment's requirements.
	• Establish acceptability of location of surface water flow paths (streams) and floodwater storage areas (floodplains) in consultation with drainage service provider.
	• Identify and address potential impacts on surface water dependent ecosystems to be protected. Demonstrate that any potential impacts will not have a significant environmental impact.
		will the potential water resource (quality and quantity) impacts be managed?
		• Demonstration that groundwater and surface water drainage systems and strategies have been developed with consideration of their land requirements. For example:
		  o Where will water quality treatment be accommodated and is there sufficient space provided to achieve the desired urban form outcomes (including functional POS)?
		• Modelling assumptions and parameterisation should be clearly documented including the reasoning for selection of particular approaches and parameters. For example:
		  o The proportion of road reserves that are impervious and can be considered as directly contributing to a drainage system will vary according to: surrounding urban form, construction materials, kerbing, presence of footpaths on one or both sides or the presence of street trees or other vegetation. Parameterisation should consider and account for this variability such that a different parameter might be applied in the localities of Armadale, Wungong or Bedfordale.

Monitoring of flows in existing streams or drainage systems	• Identify the current quality of any surface water flows. • Identify current quantity of flows which will be required to establish pre-development requirements, ie 1 in 1 year flows.	• Monitoring requirements vary but generally it will be necessary to provide sufficient data to establish water quality and quantity under varying seasonal conditions and under current (predevelopment) land use conditions. • Where surrounding land uses or land management practices have changed, water quantity and quality data should be provided that reflects its current state, for example: o It is not considered adequate to provide water quality data that is 10 years old when the land use, or land management practices have changed more recently.

Table 2: work required to support the recommendations in a UWMP

Work item	Guidance provided in *Better Urban Water Management*	City of Armadale requirements (where relevant)
Water balance modelling		• Post development water balance modelling should be refined at UWMP stage to demonstrate the efficacy of proposed systems in managing the impacts and influences of changing land use and water management practices on the local hydrogeology.
Management of water dependent ecosystems	• Show buffers for wetlands and waterways to be protected. • Continue monitoring of ecological health and hydrological regime of water dependent ecosystems to be protected. • Reference to a detailed survey of flora and fauna undertaken at an appropriate time to support management requirements proposed in the local structure plan.	• It is expected that buffers will be consistent with those demonstrated within a previously approved LWMS. Where there are changes proposed justification must be provided including consideration of items discussed in Table 1.
Site investigations	• More detailed soil and site characteristics. • Further field investigations for contamination or acid sulfate soils where required, consistent with DEC guidelines.	• Detailed geotechnical investigations should be presented as a part of the UWMP including borehole construction, field and laboratory testing of site soils. • Where increased or improved understanding of the nature and/or extent of contamination results in a change to water management strategies it may be necessary to consider changes to the subdivision design and even in some cases to the structure plan and related LWMS to accommodate alternate or modified infrastructure. For example: o Avoidance of a contaminated part of a site may require that drainage or water quality treatment infrastructure needs to be accommodated within a widened road reserve or enlarged public open space.

Groundwater monitoring and modelling	• Identify nutrient levels and pollutant pathways relating to background levels and contamination/nutrient hot spots. • Map groundwater level contours – existing and proposed. • Identify floor level heights and fill requirements. • If proposed, outline subsoil drainage strategy, including avoidance and management of impacts on water dependent ecosystems and treatment of subsoil drainage water, prior to discharge to the surface water system. The subsoil drainage strategy should also address areas with nutrient-rich groundwater. • Identify groundwater recharge rates.	• In areas of shallow groundwater detailed analysis of post-development groundwater levels is necessary including consideration of seasonal, inter-annual and event based effects related to the selected surface and groundwater management strategies. For example: o Where subsoil drainage and/or on-site infiltration of stormwater is proposed what is the resulting variation of local groundwater levels under a range of seasonal, event based and climate conditions (wet winter, average winter and major/minor storm events). • Where fill is used to deal with adverse geotechnical or hydrological conditions consideration should be given to the provision of groundwater (subsoil) drainage to control post development groundwater level rise • Where groundwater (subsoil) drainage is necessary and soil-stored or groundwater nutrient levels are elevated compared to baseline levels in the receiving environment treatment will be necessary for discharges to the downstream environment irrespective of a dilution effect created by the infiltration of rainwater. • Designs for the surface and subsurface drainage system should be provided to support the UWMP. For staged developments; preliminary design drawings for the whole subdivision together with detailed designs for the first stage may be accepted. • Designs for water quality treatment systems should be provided to support the UWMP with sufficient detail to include soil media and planting requirements, erosion protection provisions, location and type of drainage inlets and outlets
Surface water modelling	• Demonstrate how post-development flows will meet catchment criteria. • Modelling of up to 1 in 1 year ARI event to determine capability for retention/detention and water quality treatment, where/if required. • Modelling of "minor" and "major" stormwater systems to identify and size flow paths (via pipes or overland flow) and required flood detention volumes. • Refinement of 1 in 100 year floodway if required.	
Conservation of drinking water	• Where non-potable water supply is proposed, detailed modelling of site water balance and demonstration of sustainable sources for non-potable, fit-for-purpose use (eg toilet flushing, laundry, hot water and ex-house). Any strategy should have the necessary approvals and agreements in place. • Alternative strategies to achieve water conservation, including agreements and implementation mechanisms and expected performance.	• Where non-potable water supply is proposed for irrigation of public open spaces the City will require demonstration that the water source is viable in the long term and can be sustained with reasonable levels of maintenance. For example: o Where groundwater is proposed, the City will require a groundwater license to be held and bore testing to be undertaken to demonstrate that sufficient yield can be achieved to satisfy the predicted demand. Suitable arrangement will need to be made to transfer this licence to the City at time of handover.

4 TAKING A RISK BASED APPROACH

In considering a risk based approach to water resource management in the City of Armadale, the following core objectives have been considered:

- Protection of public health and safety
- Maintenance of acceptable public amenity
- Management and maintenance of public infrastructure and assets
- Protection and management of sensitive environments

These objectives allow the definition of risks which can then be evaluated to set priorities for investigation and management in the various areas of the City. The key risks which have been identified are:

- Protection of public health and safety
  - Toxic algal blooms in wetlands or water bodies
  - Increased mosquito populations
  - Drowning
  - Road safety incidents (skids, washouts etc)
- Maintenance of acceptable public amenity
  - Loss of function or access to public areas (through flooding/inundation)
  - Aesthetic degradation of public areas
- Management and maintenance of public infrastructure and assets
  - Road surface or subgrade failure
  - Drainage system failure or blockage
  - Damage to other public assets or infrastructure
- Protection and management of sensitive environments
  - Toxic algal blooms in wetlands or water bodies
  - Drowning of vegetation & loss of refugia
  - Acid sulfate soil impacts
  - Hydrological regime change, particularly in relation to wetlands

The consideration of risks to and from the development should be a core component of water management strategies and plans at every stage of planning and design. The following sections explain what level of risk assessment the City expects to be undertaken at each stage.

4.1 District water management strategy

Risks to and from the development should be identified and ranked according to their site specific importance with greater focus on the greatest risks.

4.2 Local water management strategy

The description and understanding of risks should be refined with a detailed risk assessment undertaken for all medium or high risk items. Risk management strategies should be proposed, including consideration of the cumulative impacts or interaction between different management strategies. The risk assessment should include consideration of these interactions and establish appropriate priorities for the site.

For example; the use of infiltration systems may increase the risk of local groundwater level rise that could be offset through the use of subsoil drains, whilst the use of subsoil drains may increase the risk of mobilising legacy nutrients or other contaminants present in soils. A risk assessment may conclude that the use of subsoil drains presents an unreasonable risk to the downstream environment and therefore the use of infiltration systems might be limited.

It is considered acceptable at this stage to retain multiple options for risk management strategies, to be confirmed at the subsequent UWMP stage.

4.3 Urban water management plan

The risk assessment should be finalised to include the final suite of selected management strategies to address all identified high and medium risks together with associated actions for implementation.

5 INVESTIGATIONS, MODELLING AND ASSESSMENT

This section provides additional information on the City's expectations for investigations and technical information to support the preparation of LWMSs and UWMPs for structure planning and subdivision. The key areas are monitoring and investigations; and modelling and analysis.

5.1 Predevelopment monitoring and investigations

The key consideration for deciding the extent and duration of monitoring and investigation required to support planning and development is: *What is the question you are trying to answer?*

Monitoring and site investigations should always be targeted at addressing a specified problem. For instance, if the problem is shallow groundwater then the monitoring program should be targeted to understanding groundwater levels in particularly low-lying or vulnerable parts of the site. If the problem is around understanding a sensitive wetland then the monitoring program should be targeted to capture information about the wetland including both surface and groundwater inputs and outputs. Finally, in some circumstances monitoring may not be required, provided targeted site investigation is undertaken. For example; geotechnical investigations undertaken in winter can provide sufficient information to confirm the presence or absence of shallow groundwater and provide correlation to already available data.

The City of Armadale does not wish to cause unnecessary monitoring to be undertaken and early consultation is therefore recommended to assist with definition of monitoring and investigation work.

5.1.1 Hills, foothills and scarp

In the hills, foothills and scarp environments, the hydrogeological conditions generally do not require substantial monitoring to support development. In these areas, the question we are asking is generally:

What is the current state of the environment?

- In response to this, some understanding of local surface water flow and quality is necessary but can usually be determined to an acceptable standard using existing Department of Water data augmented with local snapshot sampling if required together with a simple hydrological assessment.
- Geotechnical investigations are always necessary to support subdivision and will generally provide some indication of the presence and depth of groundwater. Where groundwater is present, generally in the alluvial or colluvial valley floors of the hills area some assessment of winter groundwater level will be necessary.

In low lying areas of the foothills where groundwater approaches the surface, potentially indicated by the presence of wetlands, it is necessary to establish whether more extensive monitoring is required. In this case our first question is:

Is more detailed monitoring necessary?

- This should be determined by a preliminary review of available information supported by preliminary on-site investigations. This may be undertaken as a part of geotechnical investigations provided the fieldwork is carried out during winter.

Where winter groundwater is found within 3 m of the natural surface, additional groundwater investigations will be necessary as described in section 5.1.2 for Swan Coastal Plain areas.

5.1.2 Swan Coastal Plain

In low-lying shallow groundwater and clay soil environments such as those prevalent in the Swan Coastal Plain areas of the City there is a need to fully understand the seasonal, inter-annual and long term variability of the local groundwater system and in addition to the basic investigations outlined in section 5.1.1 above to establish the current state of the environment, the following questions will also need to be answered:

Does the local groundwater level reflect the district or regional scale superficial aquifer or is there a localised perching effect due to the presence of impermeable materials in the soil profile?

- Localised perching can be permanent or seasonal depending on the extent and level of the impermeable layer. It is critical to develop an understanding of the relationship between the local groundwater system and the geotechnical conditions.
- Local wetlands and waterways may be sustained by a local perched groundwater system or the district or regional scale superficial groundwater system
- Shallow perched groundwater systems are sensitive to changes to the pre-developed water balance, such as a focus on 'at source' infiltration, or importation of irrigation water.

How close to the natural surface does the pre-development groundwater rise during an average winter?

- These are the conditions that are likely to be experienced frequently and can impact on the amenity and liveability of the subdivision, in particular reducing the functionality of public open spaces as well as being potentially damaging to infrastructure.

How close to the natural surface does the groundwater rise during a wet winter?

- These are less frequent occurrences, and may not have occurred at all in recent history but it remains important to understand how groundwater will behave under them so that the urban form can be designed appropriately.

To answer these questions groundwater level monitoring needs to be undertaken and capture at least two winters locally so that this data can be correlated to the nearest available longer term record and the long term patterns can be understood.

Where there is a locally perched groundwater system it is important to consider the extent to which local groundwater levels may be disconnected from the regional groundwater system on a seasonal, annual or inter-annual basis. Monitoring programs should be tailored to include this consideration potentially through the use of paired deep and shallow bores.

Where subsoil drainage is likely to be used to manage a shallow groundwater system the following additional questions will need to be considered:

What level is acceptable for installation of subsurface drainage (CGL)?

- The definition of an acceptable CGL should be undertaken consistent with *Water resource considerations when controlling groundwater levels in urban development*

(DoW 2013) in consultation with the City of Armadale and for approval by the Department of Water in their role as water resource managers.

- This process generally considers the impact to the regional or district scale superficial aquifer and the wetlands and watercourses that it sustains and may require significant additional monitoring and investigation work.
- There is also a risk of impacts to local wetlands and watercourses as well as potential for significant groundwater export from locally perched systems and these effects need to be fully understood to be managed.

What is the potential water quality impact from groundwater that will be discharged from the subsoil drainage system?

- It is critical to gain an understanding of the in-situ soil and groundwater quality that will be mobilised by the system so that an appropriate level of treatment can be provided.
- Where historic land uses indicate a risk of contamination or there is a known contaminated site present within or in proximity to the site, additional investigations will be necessary.
- Additionally, it is necessary to understand the water quality in the receiving environment so that any impacts in the future can be properly identified and understood.

To answer these questions, surface water and groundwater quality information needs to be collected. The data must be sufficient to provide an understanding of seasonal trends and recent enough to capture the current status of the site and surrounding land uses. Generally this will require sampling to be undertaken on at least four to six occasions timed to provide at least one sample per season.

5.1.3 Minimum monitoring and investigation reporting requirements

As a minimum, it is expected that the following information (Table 3) is provided at each reporting stage. Information should be based on all available monitoring and site investigation data with assumptions and analytical methods clearly articulated.

Table 3: Minimum monitoring and investigation reporting requirements

Information requirement	Local water management strategy	Urban water management plan
Groundwater	• Depth to long term max (10-30 yrs) • Depth to recent max (2 yrs) • Seasonal & inter-annual ranges • Regional/district scale trends (10 yrs) • Gradient and direction of flow • Relationship to existing wetlands/waterways • Bore logs and monitoring data records • Desktop geotechnical information (mapping of impermeable substrata where available)	• Detailed site condition assessment at an appropriate investigation scale for the development. • Extent and nature of additional monitoring and investigation to be provided at UWMP stage should be discussed with the City prior to commencement. • Where a significant change in data or understanding is presented it may be necessary to consider changes to the proposed urban form in response.

Information requirement	Local water management strategy	Urban water management plan
Surface water	• Are water bodies, water courses and flow paths; ephemeral or permanent? • Catchment size, slope, land use, extent of clearing including off-site upstream catchment) • Baseflow estimation; recent (2 yrs) and longer term (10 yrs) • Major/minor event; flows levels and areas of inundation • Monitoring data records	• Detailed assessment of surface water flows and quality. • Extent and nature of additional monitoring and investigation to be provided at UWMP stage should be discussed with the City prior to commencement. • Where a significant change in data or understanding is presented it may be necessary to consider changes to the proposed urban form in response.
Wetlands	• Summer and winter water levels; recent (2 yrs) and longer term (10 yrs) • Underlying soil profile • Describe relationship to groundwater, surface water, soils and topography • Estimation of relative importance of above factors • Impacts of proposed land use and earthworks/infrastructure changes to all of above • Buffer size and delineation • Vegetation type and quality	• Detailed assessment of wetland values and hydrological conditions. • Where a significant change in data or understanding is presented it may be necessary to consider changes to the proposed urban form in response.
Water quality	• What is the background surface and groundwater water quality o Seasonal variations o Impacts of recent land use/management changes o Impacts of proposed land use and earthworks/infrastructure changes	• Refined assessment of LWMS analysis based on increased local scale information • Where a significant change in data or understanding is presented it may be necessary to consider changes to the proposed urban form in response.

5.2 Modelling and analysis

Modelling is required to demonstrate an understanding of the hydrogeological conditions of the site and surrounds, to support and inform the design of water management systems and to predict the impact of proposed land use changes on the environment. Critical considerations for modelling and analysis to support development are:

- What site characteristics and conditions are changing as a result of development?
- What are the risks associated with the likely changes?
- How will the risks be managed?

It is expected that modelling should incorporate both annual and event based analysis. Different modelling approaches, tools and methodologies should be applied that are best suited to the analysis that is required. This includes water balance, groundwater level, hydrological and hydraulic and water quality modelling (where proposed).

5.2.1 Seasonal water balance analysis

A seasonal site water balance based on a monthly timestep should be developed for every site in all areas of the City. The water balance should be initially developed at LWMS stage and reviewed/refined at the UWMP stage and should consider all of the relevant pre and post development fluxes of water (Figure 3) including:

- Abstraction
- Evapotranspiration
  - clearing and planting of deep rooted vegetation
  - increased impervious area and loss of evaporation from surface soils
- Shallow groundwater/soil storage (natural and in imported fill)
- Deeper aquifer recharge
- Runoff and drainage (use of on-site infiltration systems)
- Climate change (drying climate effects)

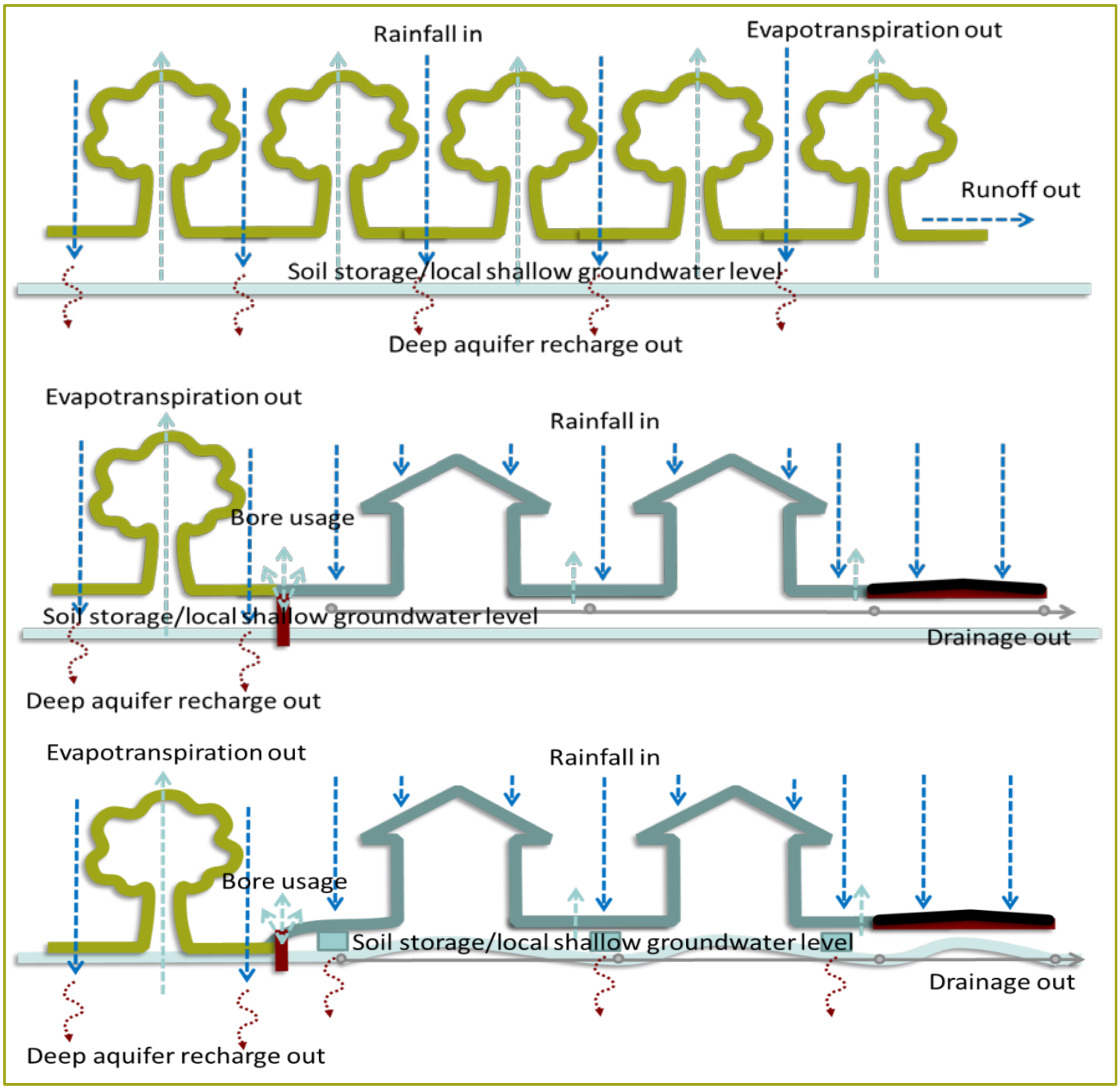


Figure 3: Representation of pre and post development annual site water balances

Seasonal water balance modelling should be used to provide an estimation of the hydrogeological changes that will occur following development and in particular should address the following questions:

- Will recharge substantially increase or decrease and what effect will this have on local groundwater levels (on the site and surrounding areas)?
- Will runoff substantially increase or decrease and what effects will this have, such as:
    - Will overland flow regimes transition from sheet flow to more channelised flow and result in increased erosion of the landscape?
    - Will environmental flows to downstream environments be changed resulting in ecological impacts?

Commonly, parameters applied to water balance analysis will not be the same as those used for event based modelling. For example; it is generally expected that the bulk annual volume of runoff will be a substantially lower proportion of total annual rainfall than the runoff parameter applied for event based analysis would imply.

The level of detail required should be based on the level of risk to the environment and urban form posed by the proposed changes.

Where substantial changes between the pre- and post-development water balance are predicted it may be necessary to consider an interim or 'partially-developed' scenario. Where a partially developed scenario is assessed it should be considered alongside the pre- and post-development scenarios (not replace them) such that the progressive changes in the water balance can be understood. For example; it may be reasonable to accept some limited inundation of specific areas of a development (such as raingardens) with the understanding that this will reduce over time.Where there is a potential risk to sensitive environments from climate change, the City is supportive of innovative approaches to adaptation including the potential for direction of groundwater and small rainfall event discharges to prevent drying-out of wetland habitats.

5.2.2 Groundwater level analysis

The City of Armadale is aware of a project currently being undertaken by WALGA and IPWEA to develop standardised criteria for groundwater separation distances and provide guidance to assist local government with the assessment of groundwater modelling and subsoil drainage designs. The City is supportive of this project and on its completion, the City will review the position stated within this paper and consider the adoption of the WALGA/IPWEA proposed approach.

Post development groundwater analysis should be undertaken for all Swan Coastal Plain and lower lying hills and foothills sites where shallow groundwater is known to be present, or where seasonal water balance analysis indicates increasing recharge or where subsurface drainage is proposed.

This analysis may, but does not necessarily, include the use of one or two dimensional modelling tools. However, it is necessary to include consideration of the spatial and temporal variability of groundwater level under a variety of seasonal, climatic and event based conditions (Figure 4).

The level of detail provided should be based on the level of risk to the environment and urban form posed by the proposed water management strategy.

The following factors may increase risks of impacts to the environment and urban form from groundwater level changes:

- Proximity of sensitive environments to urban form
- Clearing of vegetation
- Presence and depth of underlying impermeable surfaces

- Irrigation with imported water
- Groundwater abstraction
- Selection of drainage strategy (use of infiltration systems or not)
- Landform change (cut and fill)
- Climate variability

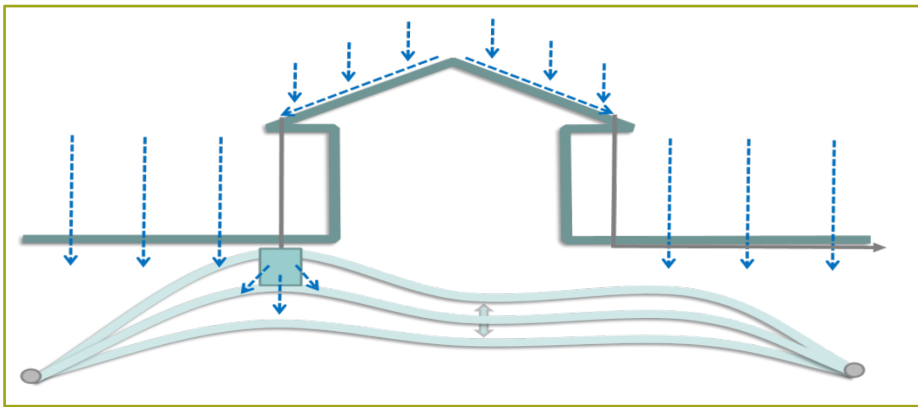


Figure 4: Representation of recharge and groundwater variability in a drained system

Detailed groundwater analysis is required to consider local groundwater conditions and design subsoil drainage systems (where proposed). Maximum groundwater level under a range of circumstances including both an 'average' and 'wet' winter should be assessed and discussed with the City for determination of the appropriate baseline for separation assessment purposes.

Where 2- or 3-dimensional groundwater modelling is undertaken the assessment should be undertaken consistent with the *Australian Groundwater Modelling Guidelines* (Barnett et al 2012).

Where dynamic 1-dimensional groundwater modelling is undertaken the assessment should include:

- Winter during a year with approximately average rainfall for the site – based on rainfall recorded at the Bureau of Meteorology site at Armadale; 2011 is a reasonable approximation for this condition.
- Winter during a year with rainfall of approximately the 10% annual exceedance probability– based on rainfall recorded at the Bureau of Meteorology site at Armadale; 1921 is a reasonable approximation for this condition.

Where steady state 1-dimensional modelling is undertaken, the assessment should include rainfall rates consistent with the 20, 10, and 5 % AEP rainfall events.

The following desirable separations from the phreatic crest between subsoil drainage lines may be applied in the City of Armadale (Figure 5):

- 500 mm to lots at the furthest point from subsoil drains (typically the back garden)
- 500 mm to passive open spaces at the furthest point from subsoil drains
- 750 mm to active (turfed) open spaces at the furthest point from subsoil drains
- 900 mm to oval's at the furthest point from subsoil drains

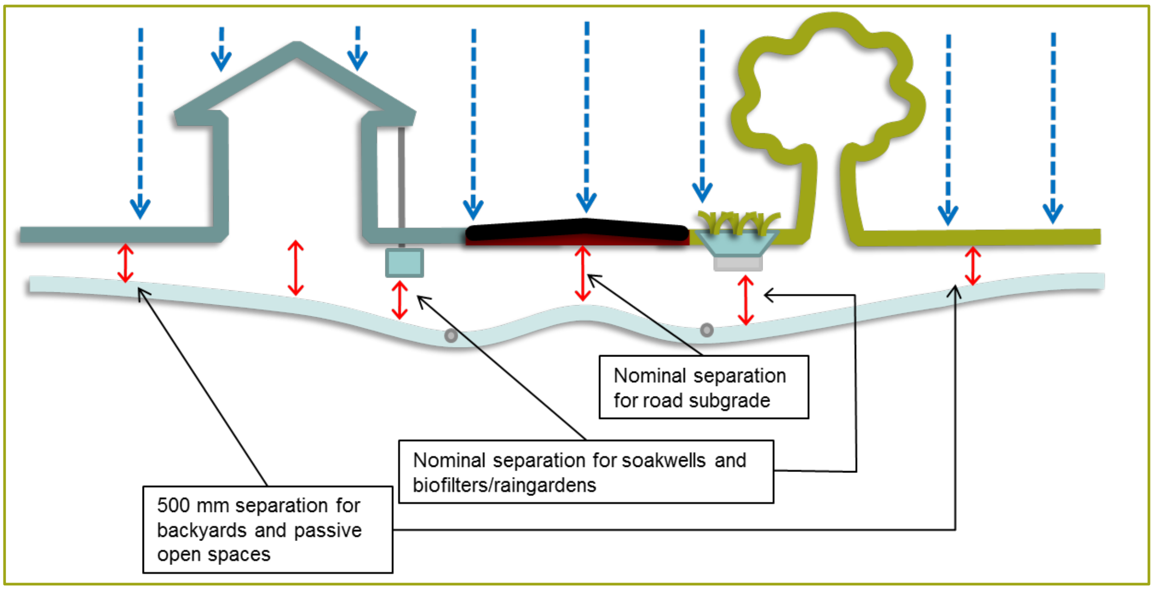


Figure 5: Groundwater separations proposed for urban development

5.2.3 Event based hydrologic and hydraulic modelling

Event based hydrologic and hydraulic modelling should be undertaken for every site in all areas of the City, considering the 20% and 1% Annual Exceedance Probability (AEP) events and the one exceedance per year (1EY) event.

Boundary conditions for modelling must be defined through explicit modelling of the upstream or downstream system undertaken by the proponent or incorporation of inflow hydrographs or fixed downstream flood levels where modelling has previously been undertaken by others and is publicly available.

Appropriate parameter selection for hydrologic and hydraulic modelling is dependent on many factors including:

- The modelling methodology being applied
- Catchment characteristics such as slope, soil type, land use and extent of clearing
- The storm event under consideration
- The stormwater management strategy being applied

It is therefore not considered useful to define a fixed suite of parameters for use in modelling. However, the fraction impervious (FI) of various land uses present in the City of Armadale can be estimated from existing developed areas and typical values in the City are presented in Table 4 below. This table is not intended for use as a 'lookup table', rather it is expected that site specific analysis will be undertaken and presented to support the values selected for use in a development.

Table 4: Typical City of Armadale land uses, surface types and estimated fraction impervious

Land use	Typical surface type make-up	Estimated FI range
Rural residential lots	• Residential dwelling • Separate sheds or other structures • Driveway • Garden/lawn/paddock areas • Lakes/ponds/other waterbodies	5-20%

Land use	Typical surface type make-up	Estimated FI range
Large urban residential lots (>750 m2)	• Residential dwelling • Driveway • Garden/lawn	30-50%
Mid-sized urban residential lots (400-750 m2)	• Residential dwelling • Driveway • Paved areas • Garden/lawn	60-80%
Small urban residential lots (<400 m2)	• Residential dwelling • Driveway • Paved areas • Garden/lawn	80-95%
Public open space	• Garden/turf • Playground • Club houses or other structures • Paved footpaths	0-5%
Rural road reserve	• Road pavement • Infrequent footpaths • Soft verge	35-50%
Urban road reserve (residential streets)	• Road pavement • Footpath • Vegetated verge including street trees • Paved crossovers	60-80%
Urban road reserve (commercial/ city centre streets)	• Road pavement • Footpath • Paved verge • Street tree pits • Paved crossovers	90-100%
Highway reserve	• Road pavement • Footpath • Vegetated verge • Cycle path • Median strip	50-60%

The fraction impervious is useful for developing an understanding of the runoff that is likely to be generated by each land use, how this runoff behaves thereafter and how much of it enters a waterway or drainage system must be the subject of site specific analysis. Furthermore the way that this is represented as a 'runoff parameter' will depend on the modelling approach used.

For example, a mid-sized urban residential lot on clayey soils with an FI of 60% may be considered to contribute as much as 80% runoff with very small initial losses where it is provided with a direct connection and no soakwells or other on-site retention system. Conversely, if the lot is sandy, provided with soakwells and has no piped connection it may contribute far less at around 40% to account for continuous infiltration from the soakwell and have a higher initial loss to account for its volume.

The City of Armadale is supportive of the Department of Water's approach to 'disconnection' of lots and small streets from piped drainage systems. No piped drainage connections are necessary for lots and streets where overland flow can be accommodated with allowable spread for gutter flow and meeting standard safety criteria for flow across driveways and footpaths (depth x velocity < 0.4). The effect that this disconnection will have on modelled flows, particularly for small and minor events, is recognised.

The City of Armadale does not wish to be prescriptive in setting fixed runoff parameters or a standardised modelling methodology. However to facilitate this approach it is essential that proponents provide sufficient information to enable a proper consideration of the validity of the modelling approach, parameters and assumptions.

It is expected that all modelling parameters and assumptions together with a clear account of the modelling methodology used is provided with sufficient detail to provide an understanding of the way that the parameters presented have been applied and how they relate to the expected FI of each land use.

The City wishes to encourage proponents to consult directly with staff to discuss the establishment of parameters and the rationale for selected modelling methods.

5.2.4 Water quality modelling

Water quality modelling is not currently widespread in WA, however with the expected future release of the Department of Water's UNDO modelling tool this is expected to change.

The City of Armadale is supportive of the Department of Water's general approach to establishing water quality targets and evaluating the efficacy of proposed water management strategies and managing water quality impacts using the tool. It is recommended that this analysis is undertaken at LWMS stage and repeated with increased detail at UWMP.

Where UNDO is used, proponents are expected to provide the full UNDO generated model report as an appendix to the water management strategy or plan. Where any alternative water quality modelling methods are used, modelling inputs and outputs together with a full description of the methodology will be required within the water management strategy or plan.

It is noted that UNDO is not expected to provide an assessment of legacy nutrient export and it is therefore likely that additional treatment will be required for groundwater exported from sites known to have elevated nutrient levels compared to the baseline for the receiving environment.

For these sites, so that treatment can be appropriately targeted, it will be necessary to consider:

- Speciation of nutrients;
- Locations of point source;
- Mobilisation pathways; and
- Sensitivity of the receiving environment.

For example; In Bletchley Park, Southern River; 'wrap-around' treatment media is being used on a trial basis to provide treatment for groundwater exported in subsoil drainage pipes. It is recognised that the efficacy of the treatment may deteriorate over time but that this will potentially coincide with the duration of 'flushing-out' for the targeted legacy nutrients.

Similarly, where new living streams or drains are proposed that intercept groundwater and provide an export pathway, additional treatment may be required.

The City of Armadale wishes to promote the use of natural systems for water quality treatment including the modification of existing drains into living streams. The City recognises the value of healthy functioning ecosystems in providing water quality benefits and natural mosquito control.

It should be noted that preliminary findings from research projects underway by the CRC for Water Sensitive Cities and others indicate that 'in-stream' treatment efficacy is critically related to path length and detention time, as well as vegetation extent and type. For this reason, living streams should be designed to incorporate meanders and pool-riffle sequences where possible.

Similarly, research has shown that the presence of bats, frogs, fish and dragonflies is important for preventing problem mosquito populations. It is therefore critical that living stream and other open drainage systems are designed to support healthy functioning ecosystems.

The City expects that future learnings about water quality assessment and treatment from research undertaken by the CRC for Water Sensitive Cities and others will be adopted in future water management documents. These learnings may result in revised requirements for the design of water quality treatment systems in relation to issues including:

- The roles and relative importance of various nutrient species in Western Australian environments
- Calculation and quantification of nutrient mobilisation issues
- Surface water and groundwater interactions
- Treatment of Dissolved Organic Nitrogen

5.2.5 Minimum modelling and analysis reporting requirements

As a minimum, it is expected that the following information (Table 5) is provided at each reporting stage. Information presented should be based on rigorous analysis with parameters, assumptions and modelling methods clearly articulated.

Table 5: Minimum modelling and analysis reporting requirements

Information requirement	Local water management strategy	Urban water management plan
Seasonal water balance based on monthly timestep	• Parameters, assumptions and methodologies • Pre and post-development annual rainfall, evapotranspiration, recharge and runoff • Analysis of likely impacts and management strategies	• Refined assessment of LWMS analysis based on increased local scale information • Where a significant change in data or understanding is presented it may be necessary to consider changes to the proposed urban form in response.
Groundwater level analysis	• Parameters, assumptions and methodologies • Pre and post development groundwater level including assessment of spatial variability for: o Winter in an average rainfall year o Winter in a 'wet' year o In storm events (1EY and 20%AEP) • Resulting separations to various elements of urban form	• Refined assessment of LWMS analysis based on increased local scale information • Where a significant change in data or understanding is presented it may be necessary to consider changes to the proposed urban form in response.

Information requirement	Local water management strategy	Urban water management plan
Event based hydrologic and hydraulic modelling	• Parameters, assumptions and methodologies • Pre and post development flows levels and volumes for: o 1EY o 20% AEP o 1% AEP	• Refined assessment of LWMS analysis based on increased local scale information • Where a significant change in data or understanding is presented it may be necessary to consider changes to the proposed urban form in response.
Water quality modelling	• Parameters, assumptions and methodologies	• Refined assessment of LWMS analysis based on increased local scale information • Where a significant change in data or understanding is presented it may be necessary to consider changes to the proposed urban form in response.

5.3 Post development monitoring

The following guidance is adapted from the Metropolitan Redevelopment Authority's monitoring guidelines (2015). The City expects that future learnings about water quality assessment and treatment from research undertaken by the CRC for Water Sensitive Cities and others will be adopted in future water management documents. These learnings may result in revised requirements for monitoring in relation to issues including:

- The roles and relative importance of various nutrient species in Western Australian environments
- Calculation and quantification of nutrient mobilisation issues
- Surface water and groundwater interactions
- Treatment of Dissolved Organic Nitrogen

The key objectives of post-development monitoring are to:

- Determine the quantity and quality of groundwater and surface water on site and downstream of the site post-development;
- Ascertain whether the quantity and quality of groundwater and surface water has significantly changed post-development; and
- Establish the performance of water quality systems that have been installed by the developer and to determine whether they are successful. Where water quality systems are found to be less effective than is desirable, they will act as 'lessons learnt' for future subdivisions.

To achieve these objectives, monitoring should be aligned to the following phases of development:

- Subdivision Phase

- Development Phase, and
- Post-development

5.3.1 Assessment of pre-development baseline data

All available pre-development data should be used to define baseline water quality conditions against which post-development monitoring data can be assessed. Trigger values should be used to determine when to initiate contingency actions.

Trigger values should be established using available pre-development data in accordance with ANZECC & ARMCANZ guidelines (2000).

Definition of baseline water quality and establishment of trigger values should be undertaken with reference to relevant targets and standards for the site including (where applicable):

- Australian and New Zealand guidelines for fresh and marine water quality (ARMCANZ & ANZECC 2000)
- Water quality improvement plan for the rivers and estuary of the Peel-Harvey system – phosphorus management (EPA 2008)
- Swan Canning Water Quality Improvement Plan (SRT 2009)
- Operational Water Quality Objectives – Report for Wungong Urban Water Project (GHD for MRA 2011)
- Targets as defined in future documents as appropriate

5.3.2 Subdivision phase monitoring

Subdivision phase surface water and groundwater monitoring is to be undertaken by the developer and should commence during construction and continue until practical completion of the subdivision and landscaping works.

5.3.3 Development phase monitoring

Development phase surface water and groundwater monitoring is to be undertaken by the developer and should commence immediately following practical completion of the subdivision and landscaping works and continue for two (2) years.

5.3.4 Post-development monitoring

Post development monitoring is to be undertaken for a period of two (2) years including at least one year following completion of the majority (deemed to be 80%) of the development.

Post-development monitoring within the Wungong Urban Water Masterplan area will be undertaken by the Metropolitan Redevelopment Authority commencing after completion of development phase monitoring.

5.3.5 Monitoring specification

Surface water

Surface water monitoring sites should be selected to address the key objectives of post-development monitoring outlined above. Monitoring should include but not necessarily be limited to:

- Flow
- Quality
- Visual inspection and photographic record of drainage outlets and water quality treatment systems. Any outflows observed at these locations during inspection should be sampled opportunistically to coincide with other sampling.
- Visual inspection and photographic record of overland flowpaths to detect the occurrence of any maintenance and management issues such as the deposition of waste, sediment, and the presence of mosquitoes or algal growth.

The specific methodology for flow data collection may vary from site to site and does not necessarily include continuous monitoring. However, flow monitoring should be undertaken with site specific consideration of an appropriate methodology for estimation of contaminant loads to receiving environments.

Surface water sampling should be undertaken fortnightly from August to October (i.e. six fortnightly monitoring events) to capture peak winter baseflows, and once in March to capture the first baseflows post-summer.

Surface water samples should be submitted to a NATA-accredited laboratory in accordance with Australian Standards and analysed for the following parameters:

- In situ pH, electrical conductivity (EC), dissolved oxygen, temperature;
- pH
- Total suspended solids (TSS);
- Total nitrogen (TN) and total dissolved nitrogen (TDN)
- Ammonia (NH4);
- Nitrate and nitrite (Nox-N);
- Total phosphorous (TP); and
- Filterable reactive phosphorous (FRP).

The following additional parameters should be included in the laboratory analysis on an annual basis:

- Major anions (chloride, bromide and sulphate);
- Major cations (calcium, magnesium, sodium and potassium); and
- Iron (Fe) and aluminium (Al).

Groundwater

Groundwater monitoring sites should be selected to address the key objectives of post-development monitoring outlined above. Monitoring should include but not necessarily be limited to:

- Levels
- Quality

Monitoring of groundwater levels and the collection of groundwater samples should be undertaken on a quarterly basis.

Groundwater samples should be submitted to a NATA-accredited laboratory in accordance with Australian Standards and analysed for the following parameters:

- In situ pH, electrical conductivity (EC), dissolved oxygen, temperature;
- pH

- Total suspended solids (TSS);
- Total nitrogen (TN) and total dissolved nitrogen (TDN);
- Ammonia (NH4);
- Nitrate and nitrite (Nox-N);
- Total phosphorous (TP); and
- Filterable reactive phosphorous (FRP).

The following additional parameters should be included in the laboratory analysis on an annual basis:

- Major anions (chloride, bromide and sulphate);
- Major cations (calcium, magnesium, sodium and potassium); and
- Iron (Fe) and aluminium (Al).

5.3.6 Reporting

The City of Armadale should be advised of any trigger value exceedances immediately.

The City of Armadale requires annual reports to be provided for all post development monitoring programs. Monitoring data should be provided in electronic format, preferably as an excel spreadsheet. Reports should include:

- Summary tables, graphs and maps presenting spatial and temporal variations of flow and quality
- Estimation of contaminant loads to the downstream environment based on collected water quality and flow data
- Discussion of findings including investigations undertaken in response to trigger value exceedances
- Recommendations for modified monitoring regime and/or trigger values where required
- Presentation of site inspection findings including photographs and field notes
- Groundwater bore construction logs

APPENDIX 1 – MAPPING

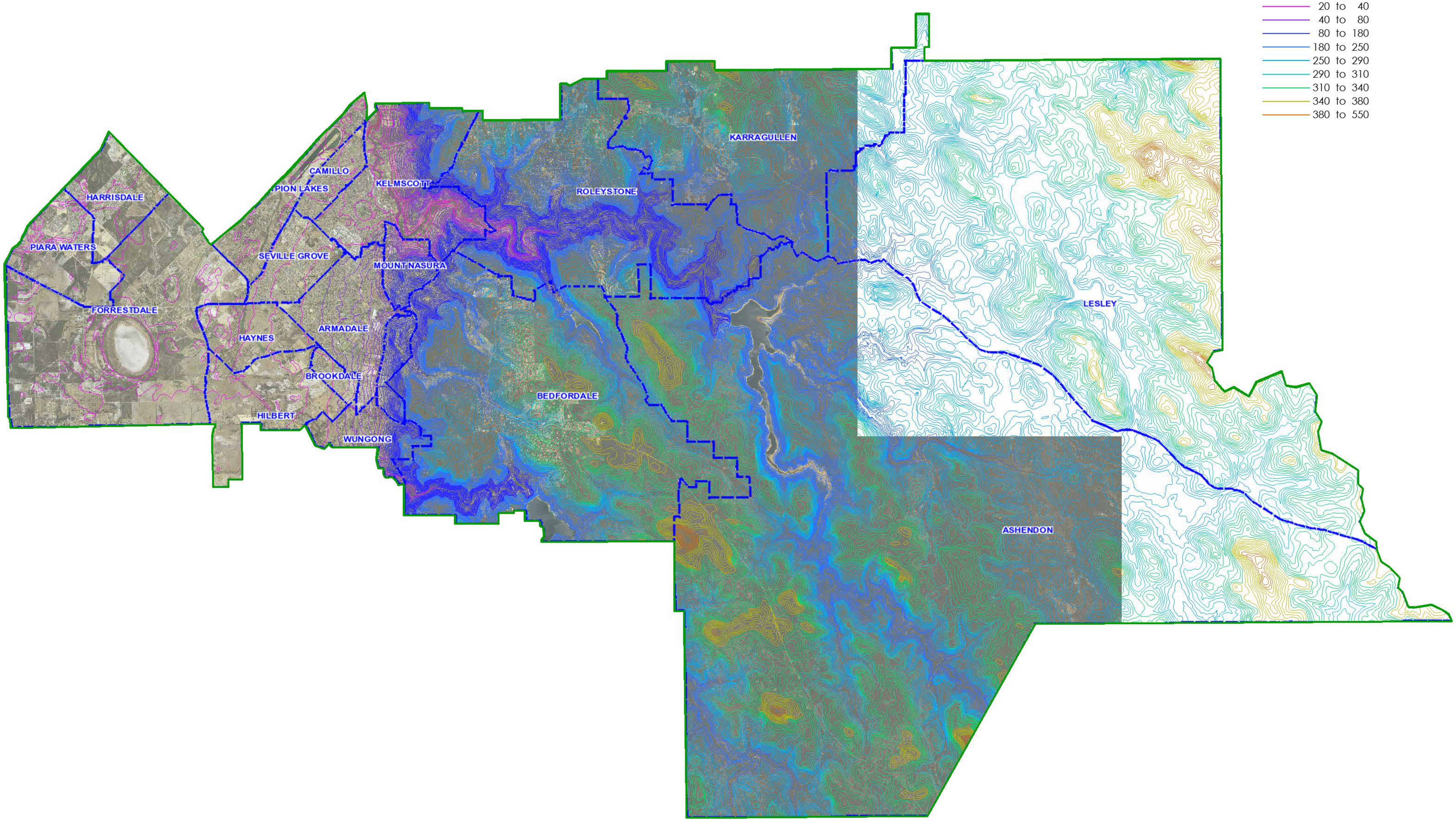
City of Armadale - water resource position paper
Figure 6 - Topography

Legend

City of Armadale boundary

Topographic contours m(AHD)

0	to 20
20	to 40
40	to 80
80	to 180
180	to 250
250	to 290
290	to 310
310	to 340
340	to 380
380	to 550



N

Scale 1: 110,000 at A3

0 3.5km

 Data source: Landgate, LGA.
Created by: R. Mackintosh Projection: MGA: zone 50.

essential environmental

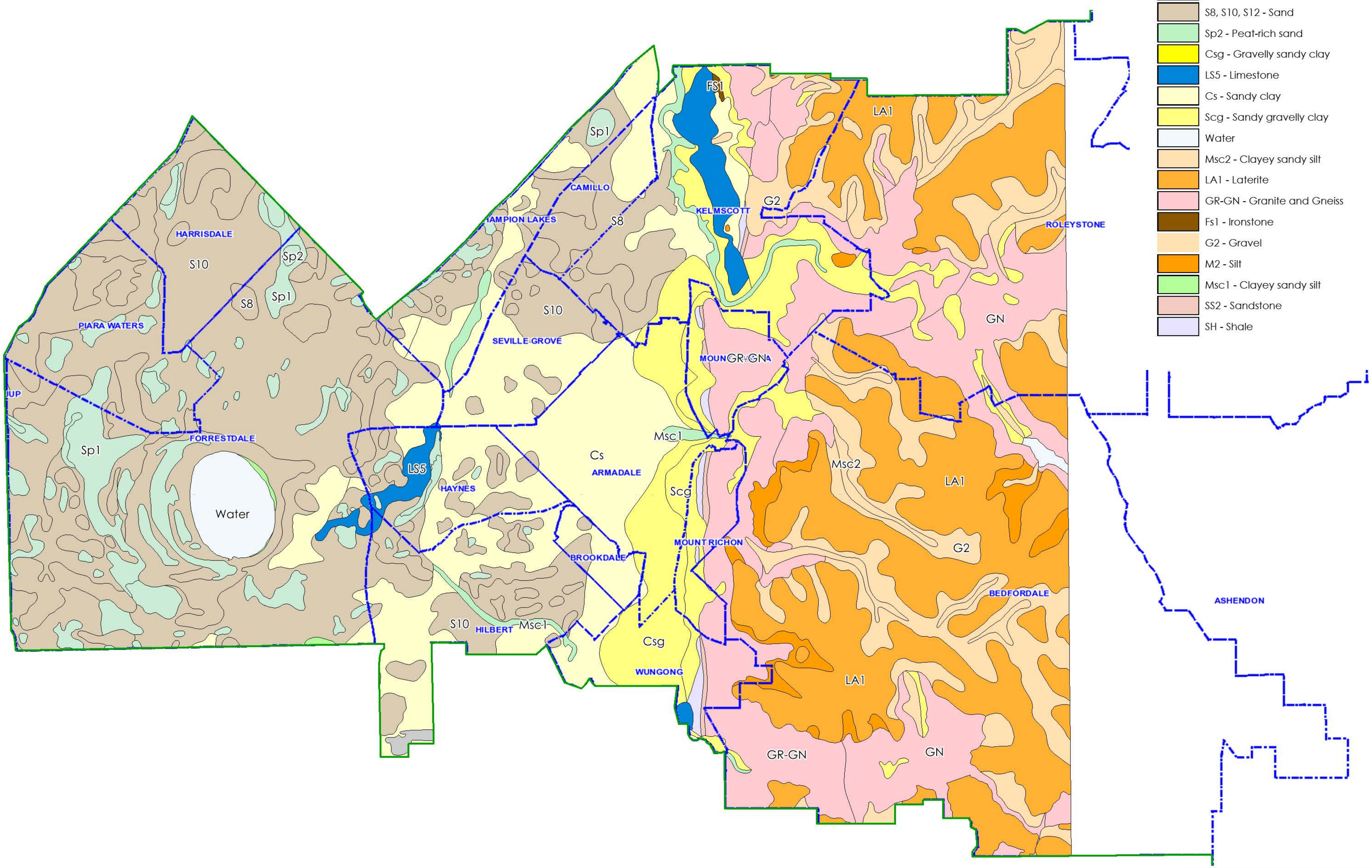
City of Armadale - water resource position paper
Figure 7 - Surface geology

Legend

City of Armadale boundary

Surface Geology

- Sp1 - Peaty sand
- S8, S10, S12 - Sand
- Sp2 - Peat-rich sand
- Csg - Gravelly sandy clay
- LS5 - Limestone
- Cs - Sandy clay
- Scg - Sandy gravelly clay
- Water
- Msc2 - Clayey sandy silt
- LA1 - Laterite
- GR-GN - Granite and Gneiss
- Fs1 - Ironstone
- G2 - Gravel
- M2 - Silt
- Msc1 - Clayey sandy silt
- SS2 - Sandstone
- SH - Shale



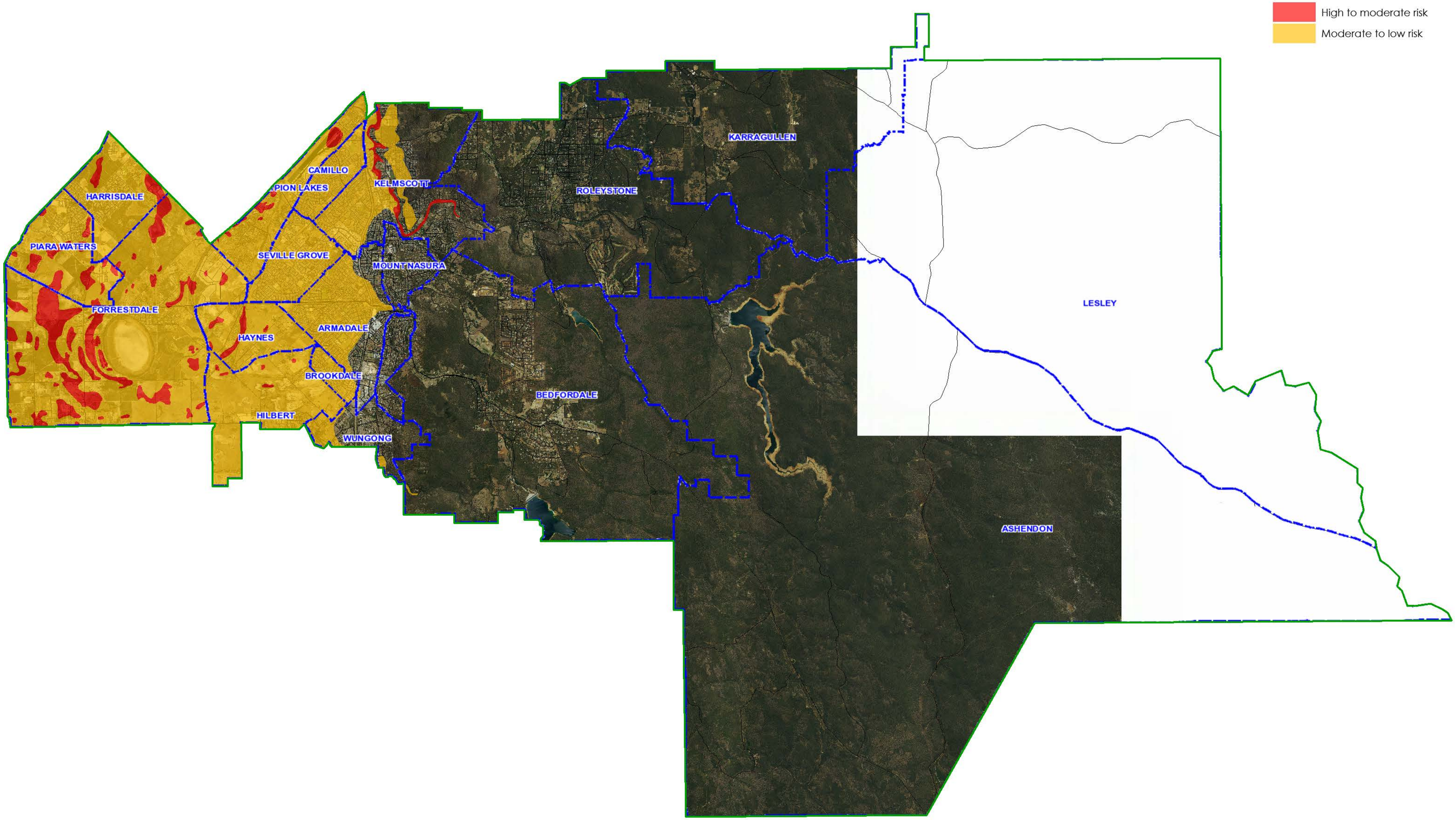
Scale 1: 60,000 at A3

0 1.2km

essential environmental

City of Armadale - water resource position paper
Figure 8 - Acid sulfate soil risk

Legend
Road centrelines
City of Armadale boundary
Acid sulfate soil risk
High to moderate risk
Moderate to low risk



N

Scale 1: 110,000 at A3
0 2.2km

essential environmental

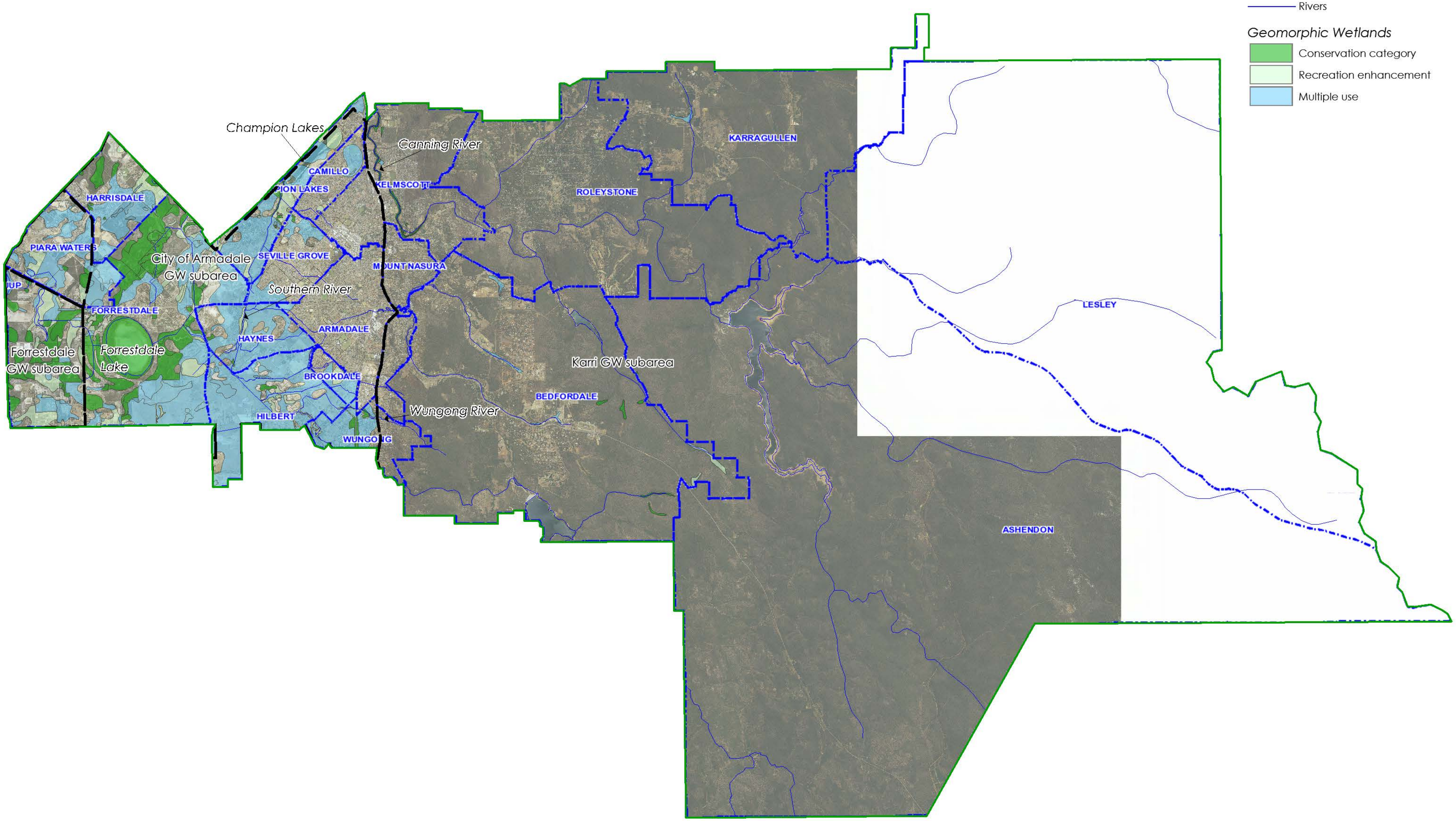
City of Armadale - water resource position paper
Figure 9 - Groundwater systems

Legend

- City of Armadale boundary
- Groundwater subareas
- Rivers

Geomorphic Wetlands

- Conservation category
- Recreation enhancement
- Multiple use



N

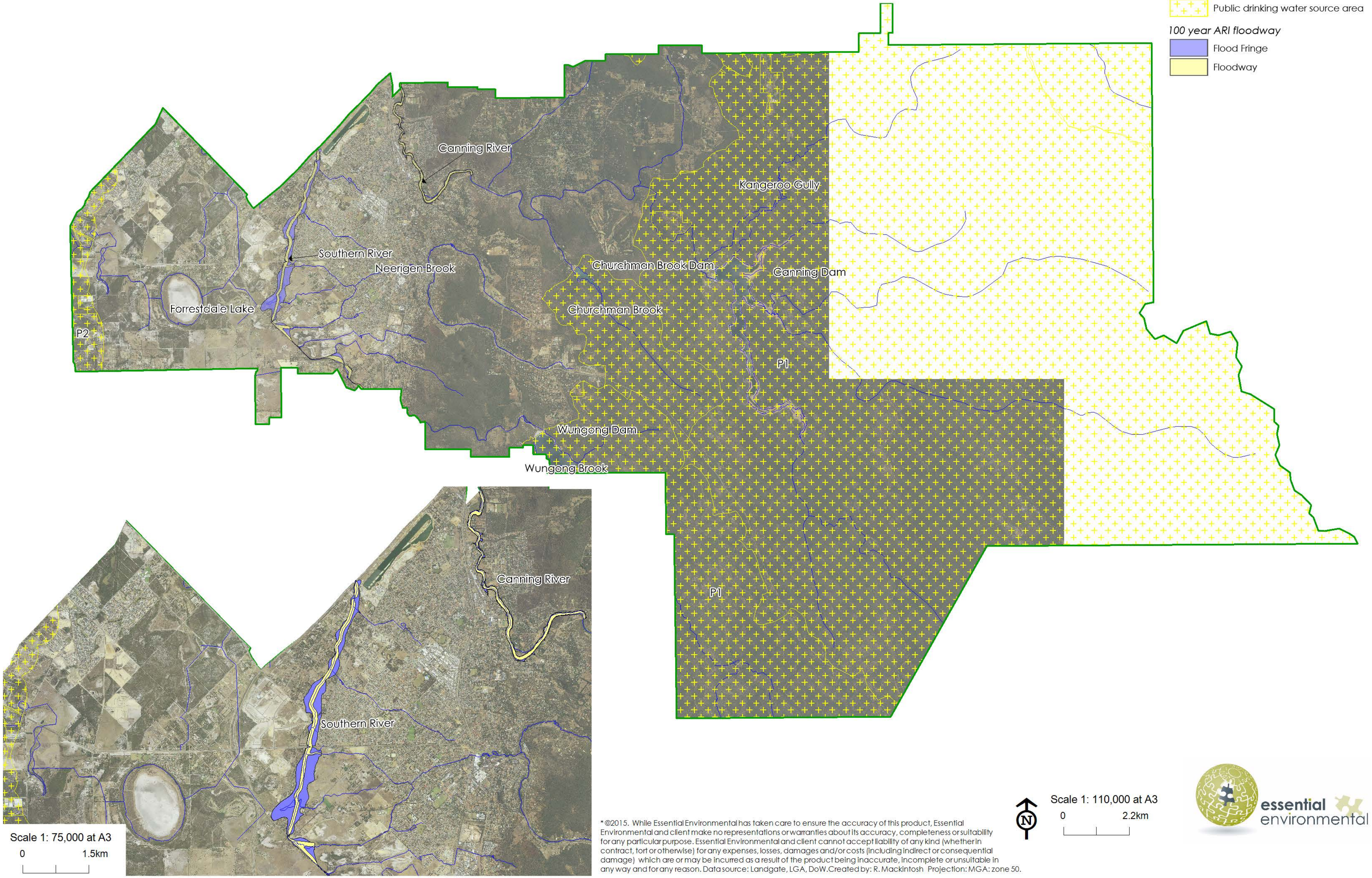
Scale 1: 110,000 at A3

0 2.2km

Created by: R. Mackintosh Projection: MGA50: zone 50.

essential environmental

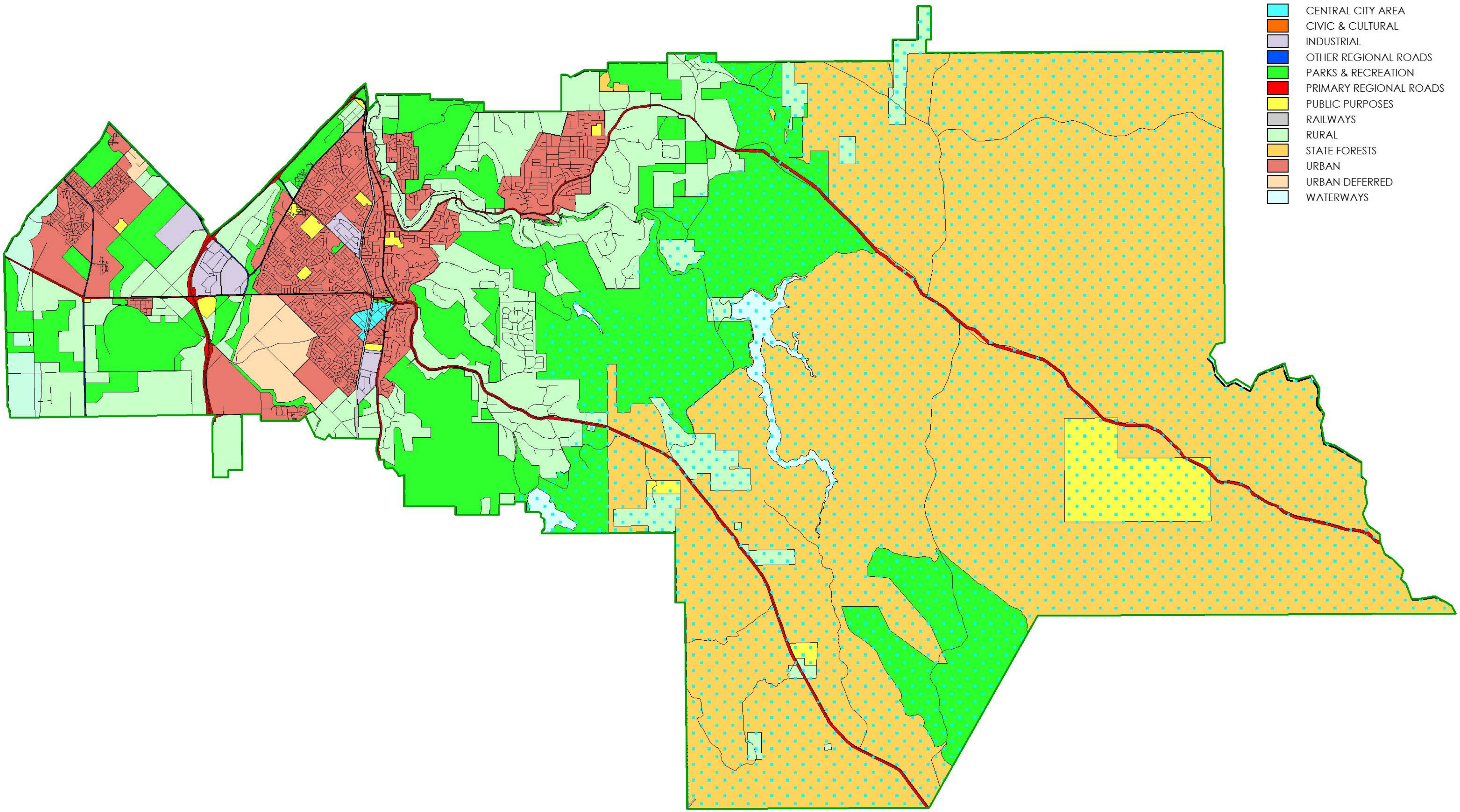
City of Armadale - water resource position paper
Figure 10 - Rivers and 100yr ARI event flood fringe



 Data source: Landgate, LGA, DoW. Created by: R. Mackintosh Projection: MGA: zone 50.

essential environmental

City of Armadale - water resource position paper
Figure 11 - Metropolitain Regional Scheme



Legend

- Road centrelines
- City of Armadale boundary
- Water catchment

MRS - Local Scheme Reserves

- CENTRAL CITY AREA
- CIVIC & CULTURAL
- INDUSTRIAL
- OTHER REGIONAL ROADS
- PARKS & RECREATION
- PRIMARY REGIONAL ROADS
- PUBLIC PURPOSES
- RAILWAYS
- RURAL
- STATE FORESTS
- URBAN
- URBAN DEFERRED
- WATERWAYS

 Data source: Landgate, LGA, Dept. of Planning.
Created by: R. Mackintosh Projection: MGA: zone 50.

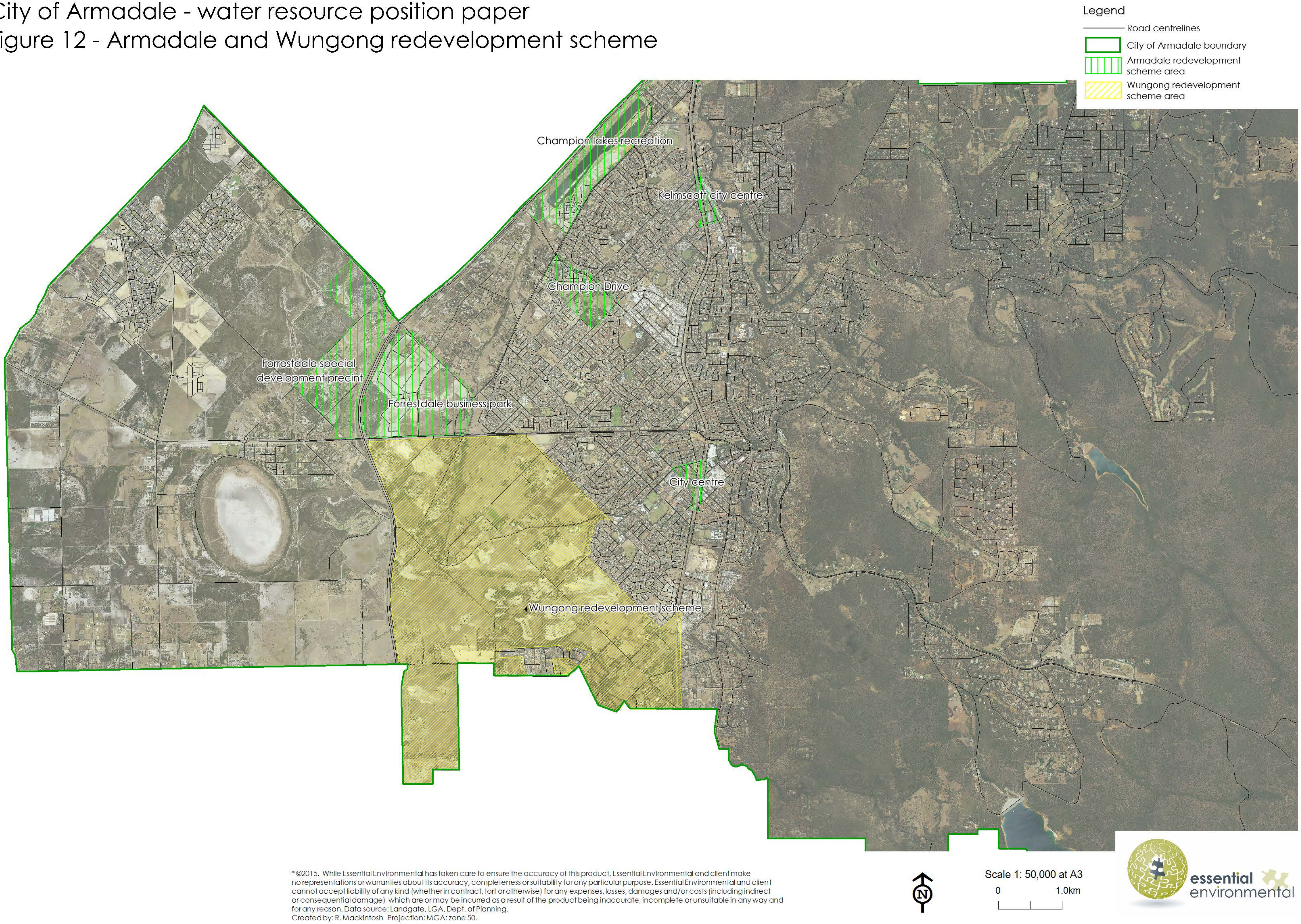
N

Scale 1: 110,000 at A3
0 2.2km

essential environmental

City of Armadale - water resource position paper

Figure 12 - Armadale and Wungong redevelopment scheme

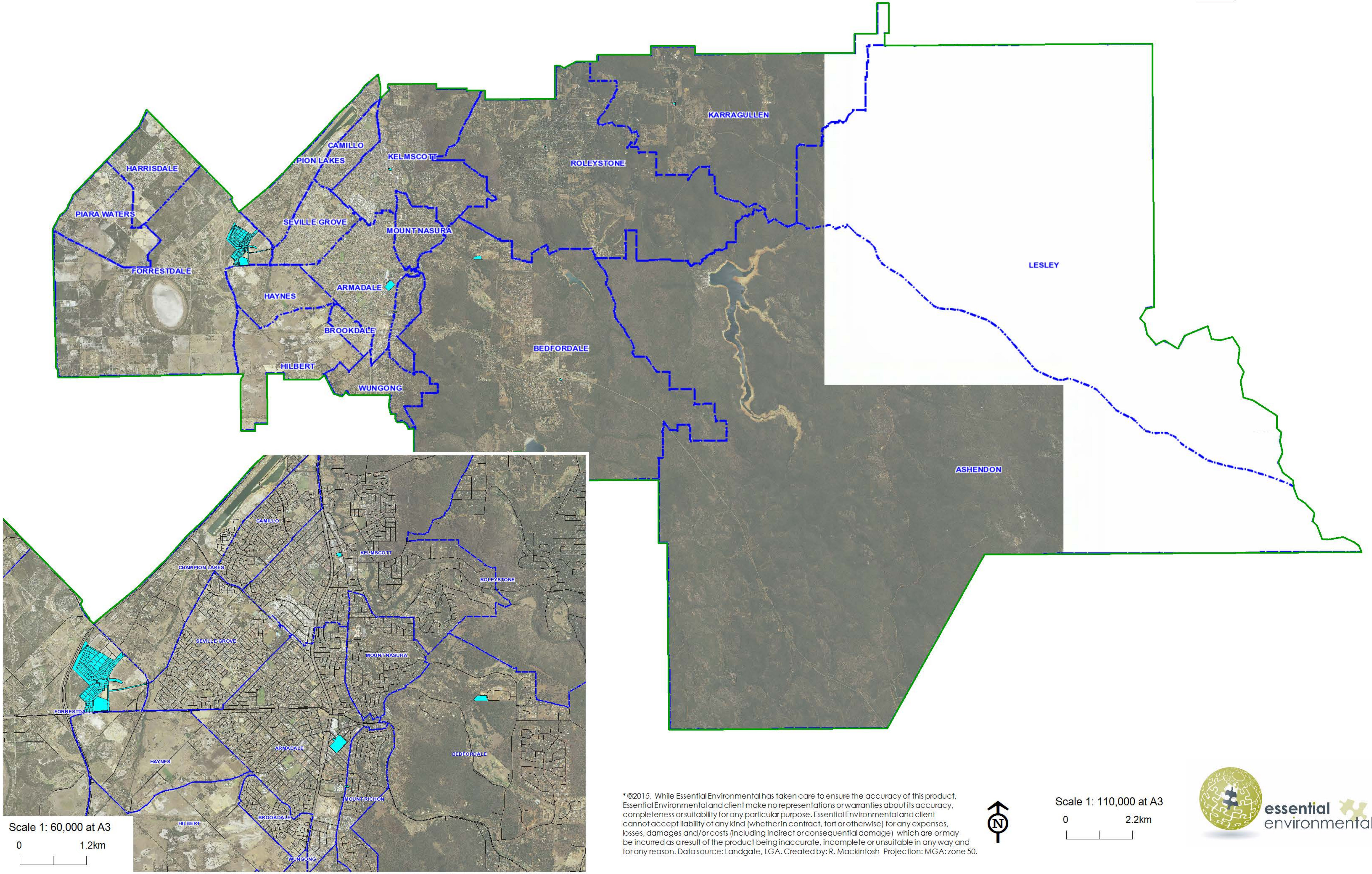


Created by: R. Mackintosh Projection: MGA: zone 50.

essential environmental

City of Armadale - water resource position paper
Figure 13 - Contiminated sites

Legend
Road centrelines
City of Armadale boundary
Contaminated sites



N

Scale 1: 110,000 at A3
0 2.2km

essential environmental

APPENDIX 2 – FRACTION IMPERVIOUS CALCULATION EXAMPLES

Impervious fraction calculations

R20 Density (500m² average) 450m² to 550m² range

3 Gilman Ct, Piara Waters, Built 2009, 495m²

Roof Area = 244m² (49.3%)

External impervious = 75m² (15%)

External pervious = 176m² (35%)

375 Wright Rd, Piara Waters, Built 2008, 532m²

Roof Area = 347.5m2 (65%)

External impervious = 53m² (10%)

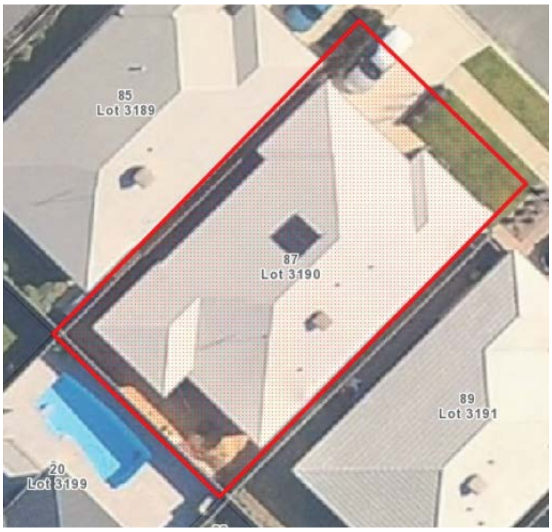
External pervious = 131.5m² (25%)

29 Fernhill Prom, Harrisdale, Built 2012, 450m²

Roof Area = 283.5m² (63%)

External Impervious = 57.5m² (13%)

External pervious = 108m² (24%)

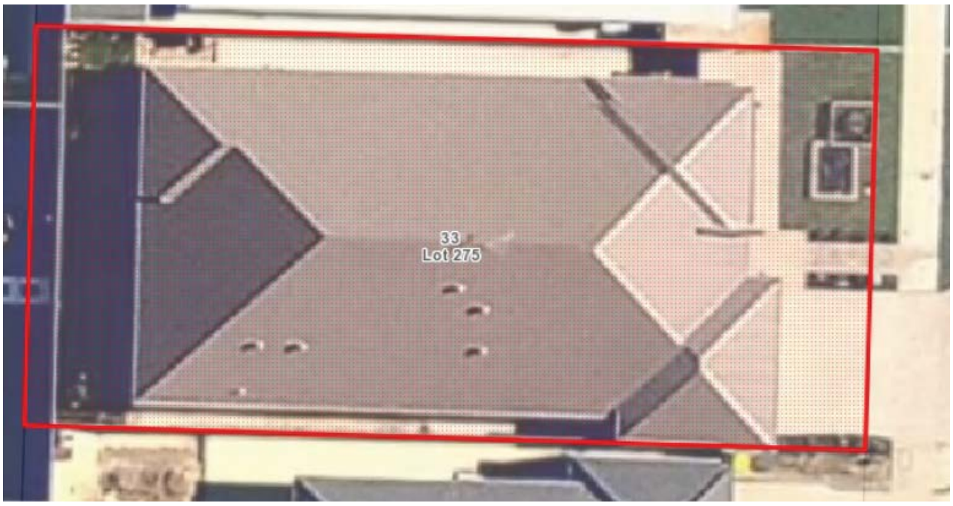


87 Lafayette Avenue, Piara Waters, Built 2013, 423m²

Roof Area = 288 m² (68%)

External Impervious = 80 m² (19%)

External Pervious = 55m² (13%)

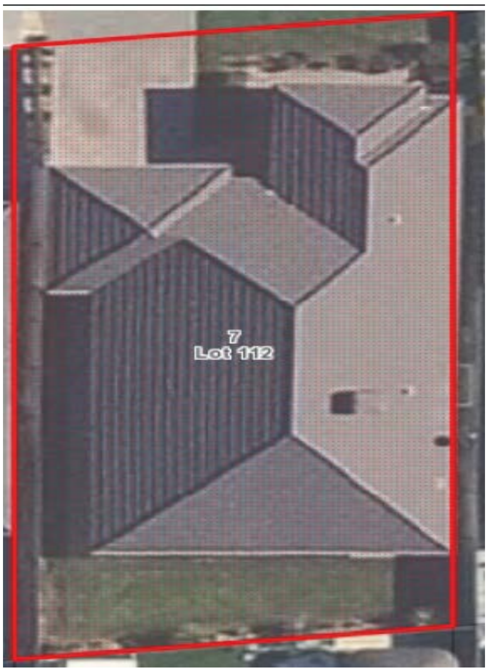


33 Sandstone Prom, Piara Waters, Built 2013, 473 m²

Roof Area = 300 m² (63%)

External Impervious = 92 m² (20%)

External Pervious = 81 m² (17%)



7 Montpellier Way, Piara Waters, Built 2011, 454 m²

Roof Area = 270.5 m² (60%)

External Impervious = 47.5m² (10%)

External Pervious = 136 m² (30%)

10 Albavale Road, Piara Waters, Built 2014, 470 m^2

Roof Area = 316.5 m^2 (67%)

External impervious = 40.5 m^2 (9%)

External Pervious = 113 m^2 (24%)

22 Novelli Parade, Piara Waters, Built 2013, 450m^2

Roof Area = 268.5m^2 (60%)

External Impervious = 91.5 m^2 (20%)

External Pervious = 90 m^2 (20%)

22 Trusty Way, Piara Waters, Built 2014, 462 m^2

Roof Area = 292.4 m^2 (63.3%)

External Impervious = 80 m^2 (17.3%)

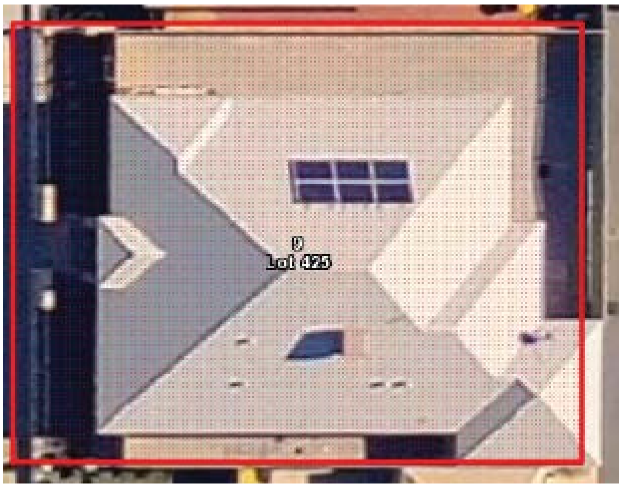
External Pervious = 89.6 m^2 (19.4%)

5 Montpellier Way, Piara Waters, Built 2013, 455 m^2

Roof Area = 244 m^2 (53.6%)

External Impervious = 145 m^2 (32%)

External Pervious = 66 m^2 (14.4%)



9 Pricklybark St, Harrisdale, Built 2012, 443m^2

Roof Area = 280m^2 (63%)

External Impervious = 123m^2 (27.8%)

External Pervious = 40m^2 (9.2%)

3 Sandpiper St, Harrisdale, Built 2011, 432m^2

Roof Area = 287m^2 (66.4%)

External Impervious = 100m^2 (23.2%)

External Pervious = 45m^2 (11.4%)

R20 Density Average impervious Fractions:

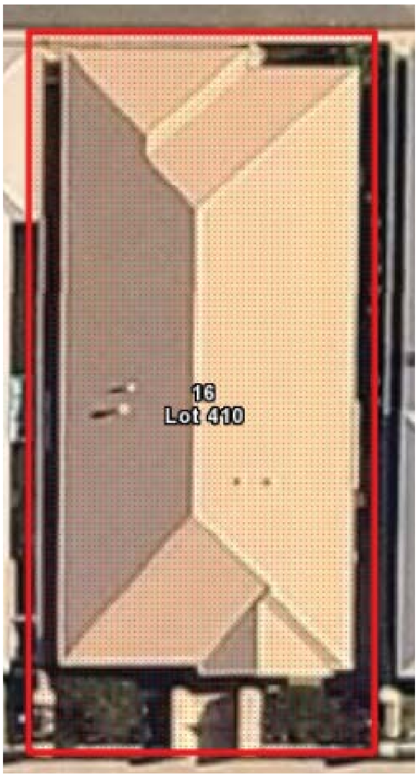
Average Lot area = 461.5 m^2

Roof Area = 285.3 m^2 (61.8%)

External Impervious = 82.1 m^2 (17.8%)

External Pervious = 94.3 m^2 (20.4%)

R30 Density (333m² average) 300m² to 400m² range



16 Flametree Boulevard, Harrisdale, Built 2011, 300m²

Roof Area = 216 m² (72%)

External Impervious = 39 m² (13%)

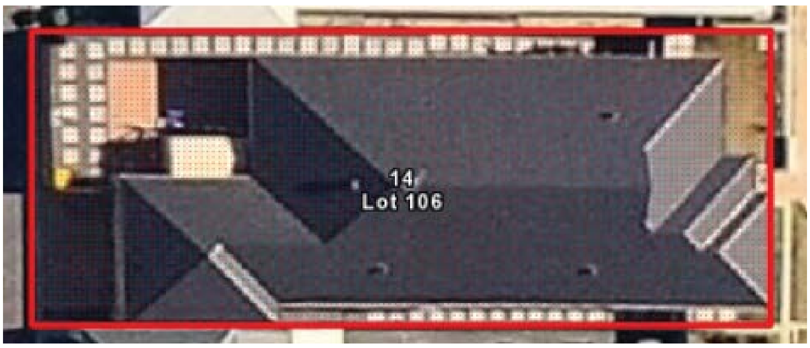
External pervious = 45 m² (15%

2 Tringa Crescent, Harrisdale, Built 2012, 331 m²

Roof Area = 220 m² (66.5%)

External impervious = 78.5 m² (23.7%)

External Pervious = 32.5 m² (9.8%)



14 St Tropez Gardens, Piara Waters, Built 2012, 360 m²

Roof Area = 238.6 m² (66.3%)

External Impervious = 105 m² (29.2%)

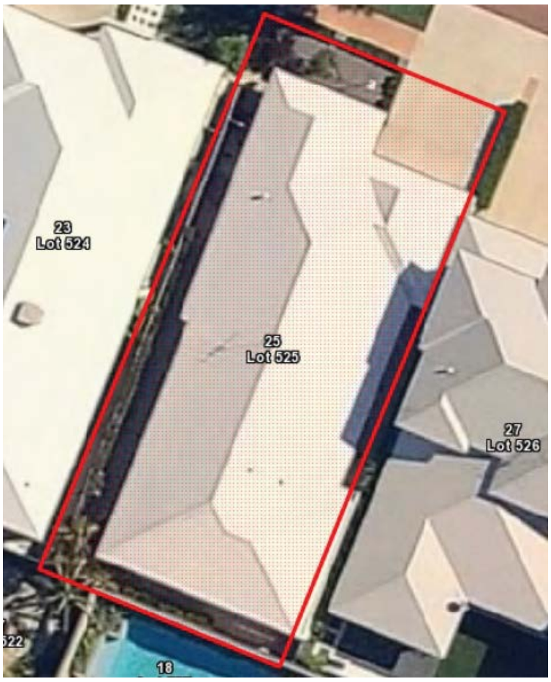
External Pervious = 16.4 m² (4.5%)

5 Anca Way, Harrisdale, Built 2008, 386 m²

Roof Area = 192.2 m² (49.8%)

External impervious = 70 m² (18.1%)

External Pervious = 123.8 m² (32.1%)



25 Foundry Turn, Harrisdale, Built 2010, 390 m²

Roof Area = 277.6 m² (71.2%)

External Impervious = 78.7 m² (20.2%)

External Pervious = 33.7 m² (8.6%)

57 Oakbella Parade, Harrisdale, Built 2013, 330 m²

Roof Area = 207 m² (62.7%)

External impervious = 73 m² (22.1%)

External Pervious = 50 m² (15.2%)

55 Kudos Circuit, Harrisdale, Built 2010, 375 m^2

Roof Area = 257 m^2 (68.5%)

External Impervious = 53.5 m^2 (14.3%)

External Pervious = 64.5 m^2 (17.2%)

5 Turnstone Link, Harrisdale, Built 2008, 360m^2

Roof Area = 252.2 m^2 (70%)

External impervious = 66.8 m^2 (18.6%)

External Pervious = 41 m^2 (11.4%)

13 Gleeson Way, Harrisdale, Built 2013, 300 m^2

Roof Area = 203 m^2 (67.7%)

External Impervious = 58m^2 (19.3%)

External Pervious = 39 m^2 (13%)

10 Emanuele Bend, Harrisdale, Built 2011, 306 m^2

Roof Area = 194.5 m^2 (63.6%)

External impervious = 76.5 m^2 (25%)

External Pervious = 35 m^2 (11.4%)

7 Wadham Link, Piara Waters, Built 2013, 319 m^2

Roof Area = 208 m^2 (65.2%)

External impervious = 62.4 m^2 (19.6%)

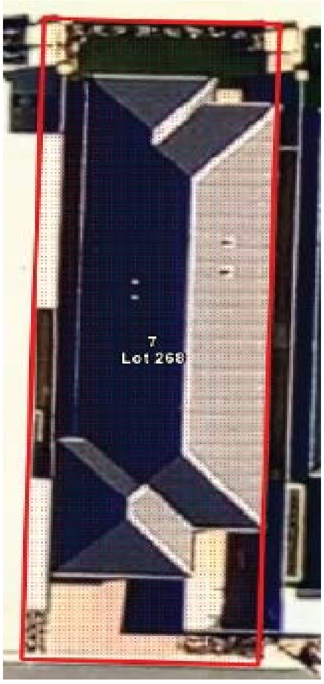
External Pervious = 48.6 m^2 (15.2%)

13 Leroy Way, Piara Waters, Built 2012, 390 m^2

Roof Area = 224.6 m^2 (57.6%)

External Impervious = 99 m^2 (25.4%)

External Pervious = 66.4 m^2 (17%)



7 Slate Way, Harrisdale, Built 2013, 320 m²

Roof Area = 202 m² (63.1%)

External Impervious = 107 m² (33.4%)

External Pervious = 11.2 m² (3.5%)

8 Frost Bend, Piara Waters, Built 2011, 332 m2

Roof Area = 217.8 m² (65.6%)

External Impervious = 110.2 m² (33.2%)

External Pervious = 4 m² (1.2%)

R30 Density Average impervious Fractions:

Average Lot area = 342.8 m²

Roof Area = 222.2 m² (64.8%)

External Impervious = 77 m² (22.5%)

External Pervious = 43.7 m² (12.7%)

if not now...

land & water solutions

when?

Client: City of Armadale

Report	Version	Prepared by	Reviewed by	Submitted to Client	
				Copies	Date
Preliminary draft	1	HB	SS	electronic	June 2015
Draft for review	2	HB	SS	electronic	Aug 2015
Consultation draft	3	HB	SS	electronic	Sept 2015
Final	4	HB	SS	electronic	Dec 2015

Essential Environmental
land & water solutions
622 Newcastle St Leederville 6007
p: 08 9328 4663 | f: 08 6316 1431
e: info@essentialenvironmental.com.au
www.essentialenvironmentArmadaleal.com.au