WATER SENSITIVE URBAN DESIGN STRATEGY FOR BELLAMACK (FINAL)

Prepared for the Northern Territory Department of Planning and Infrastructure
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Executive Summary

The City of Palmerston contains the major urban growth area of the Darwin Region, and Bellamack is the next suburb to be developed within Palmerston. The planning for the Bellamack site is currently being undertaken by the Northern Territory Government – Department of Planning & Infrastructure (DPI). DPI has identified the overarching philosophy associated with the design of Bellamack as that of sustainability.

Sustainability in the context of Bellamack is directed towards achieving a standard of development which is informed by the environment of the place, its topography, vegetation, soils and distinctive drainage regime. Water Sensitive Urban Design (WSUD) provides a key set of design principles underpinning the planning and design for Bellamack. WSUD principles for Bellamack are as follows:

- Protect existing natural features and ecological processes.
- Protect water quality of surface and ground waters.
- Maintain natural hydrologic behaviour of catchments.
- Minimise demand for potable water.
- Minimise wastewater generation and discharge to the natural environment.
- Integrate water into the landscape to enhance urban design, visual, social, cultural and ecological values.
- Add value while minimising development costs.

These principles support two overarching goals: (1) to minimise the potential impact of stormwater pollution and wastewater discharges on Darwin Harbour; and (2) to conserve potable water and reduce potential demands on water supplies in the Darwin Region. This WSUD Strategy for the Bellamack development site is to deliver these goals through the following initiatives:

- Three constructed ephemeral wetlands for the treatment of stormwater
- A non-potable water supply reticulation network (i.e. third pipe) within the development for outdoor uses, including irrigation of public and private landscapes
- Interim provision of precinct groundwater bores to supply the non-potable reticulation network
- Ultimately wastewater reuse from Palmerston WSP connected to the Bellamack non-potable water supply reticulation network
- Additional water conservation by adopting demand management measures within all public buildings and public open space, and the active promotion of demand management within private dwellings and private open space

Delivery of the WSUD Strategy for Bellamack represents the first step in the process of embracing integrated water cycle solutions for the protection of the Northern Territories aquatic ecosystems and will illustrate the Territory Governments commitment to the National Water Initiative and the National Water Quality Management Strategy.

The WSUD Strategy outlined in this document will be developed and refined throughout the design process for Bellamack, in consultation with the urban design, landscape architecture and wider project teams. EDAW will design the three constructed wetlands and provide design documents to the successful developer(s) to construct at their cost, along with other drainage components (which they will also design and construct at their cost).

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1 Introduction

The City of Palmerston contains the major urban growth area of the Darwin Region. Development commenced in the early 1980's, with the release of the first residential suburbs of Driver and Gray, followed by Moulden and Woodroffe. Over the ensuing 14 years, land for another 5 suburbs was released for development, with sites now identified for the final four urban areas, comprising Bellamack, Johnston, Mitchell and Zuccoli. Growth of Palmerston has been rapid, particularly through the 1990's, where population increased from 6 – 11% per annum. In 2005, Palmerston housed an estimated 24,123 residents with the capacity to increase by a further 20,000 residents over the next 15 – 20 years. It was initially envisaged that Palmerston would accommodate an estimated 50,000 residents, however recent investigations into land capability indicate a more conservative estimate of between 45,000 – 50,000.

Bellamack is the next suburb to be developed. As illustrated in Figure 1, Bellamack is located to the south of Rosebery at the Elizabeth River end of Palmerston, contained by existing arterial roads to the north west (Chung Wah Terrace), Elrundie Avenue to the south west and the proposed extension of Roystonea Avenue to the east. Whilst the total site comprises approximately 118.6 hectares, constraints including drainage, soil type, buffers to biting insect breeding areas and the possible need to incorporate 8 hectares with the Rosebery community hub, limit urban development to approximately 75 hectares. The development target is 650 detached dwellings, 200 townhouses/apartments, 16 'Shop top' units and 20 homes on larger rural style allotments equating to a population of between 2500 – 2800 persons.

The planning for the site being undertaken by the Northern Territory Government – Department of Planning & Infrastructure (DPI) has identified the overarching philosophy associated with the design of Bellamack is that of sustainability. Providing a framework for a community which is sustainable in an environmental, social and economic sense is the cornerstone of the planning for the site. Sustainability in the context of Bellamack, is directed towards achieving a standard of development which is informed by the environment of the place, its topography, vegetation, soils and distinctive drainage regime.

In this regard Water Sensitive Urban Design (WSUD) is identified as a key design principle underpinning the design for Bellamack. It is envisaged that WSUD will enable the creation of a development zone that promotes sustainable and integrated management of land and water resources, and incorporates best practice stormwater management, water conservation/reuse and environmental protection. To meet these principles a WSUD Strategy has been developed for Bellamack in collaboration with all relevant stakeholders (i.e. relevant Government Agencies, Palmerston City Council, consultants) and is presented in this document.

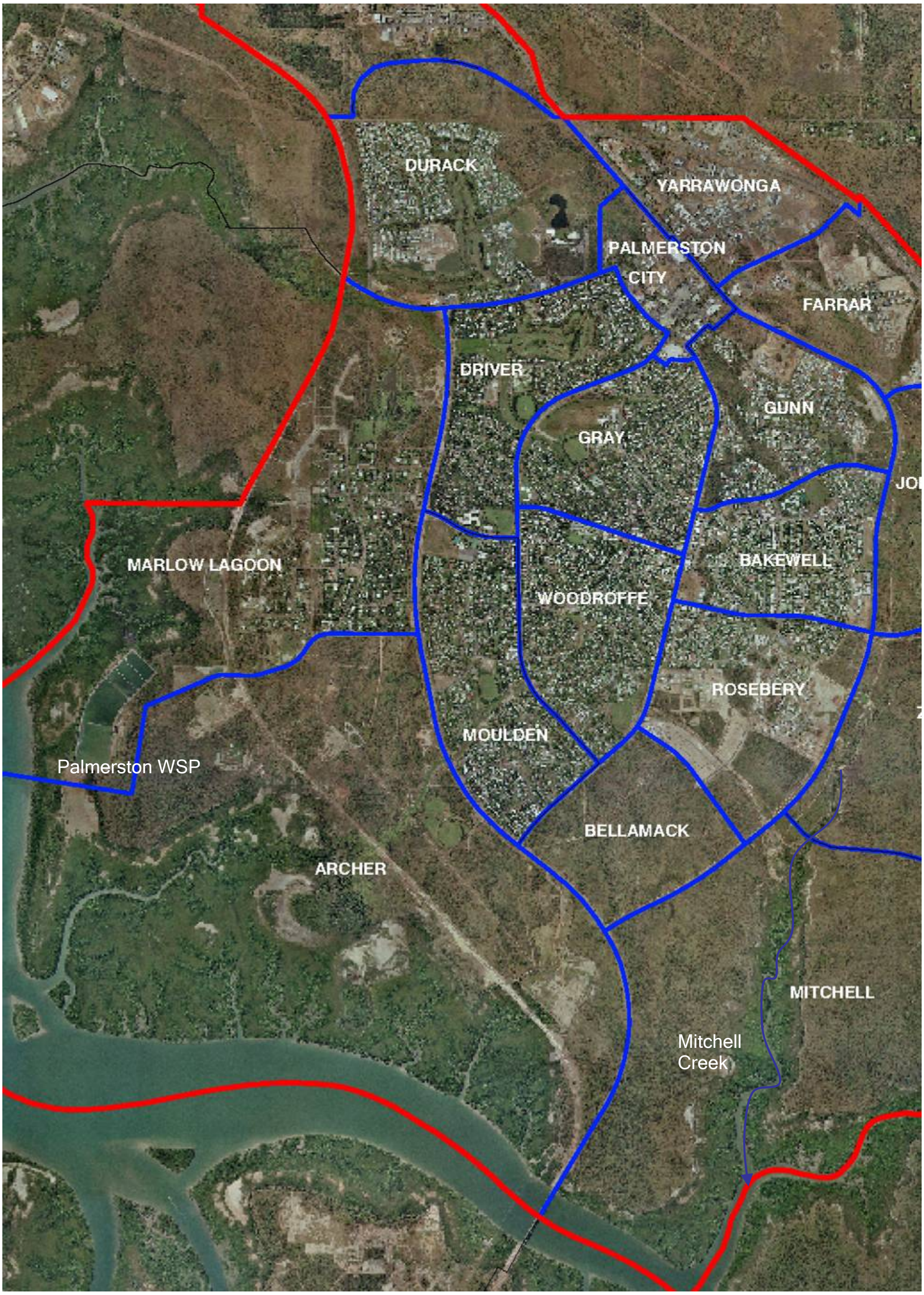


Figure 1: Location of Bellamack

1.1 WSUD – What is it?

WSUD represents a new paradigm in the planning and design of urban development that aims to minimise impacts on the natural water cycle and protect the health of aquatic ecosystems. WSUD promotes the integration of the urban water streams, namely stormwater, water supply, sewerage management and groundwater, centred on delivering sustainable water cycle solutions.

Additionally, WSUD aims to integrate these urban water cycle solutions into the planning and design of the layout (buildings and landscapes) of an urban development, towards an overall goal of ecologically sustainable development (ESD), as illustrated in Figure 2. Further description of the philosophy and implementation of WSUD is provided in Australian Runoff Quality (Engineers Australia, 2005).

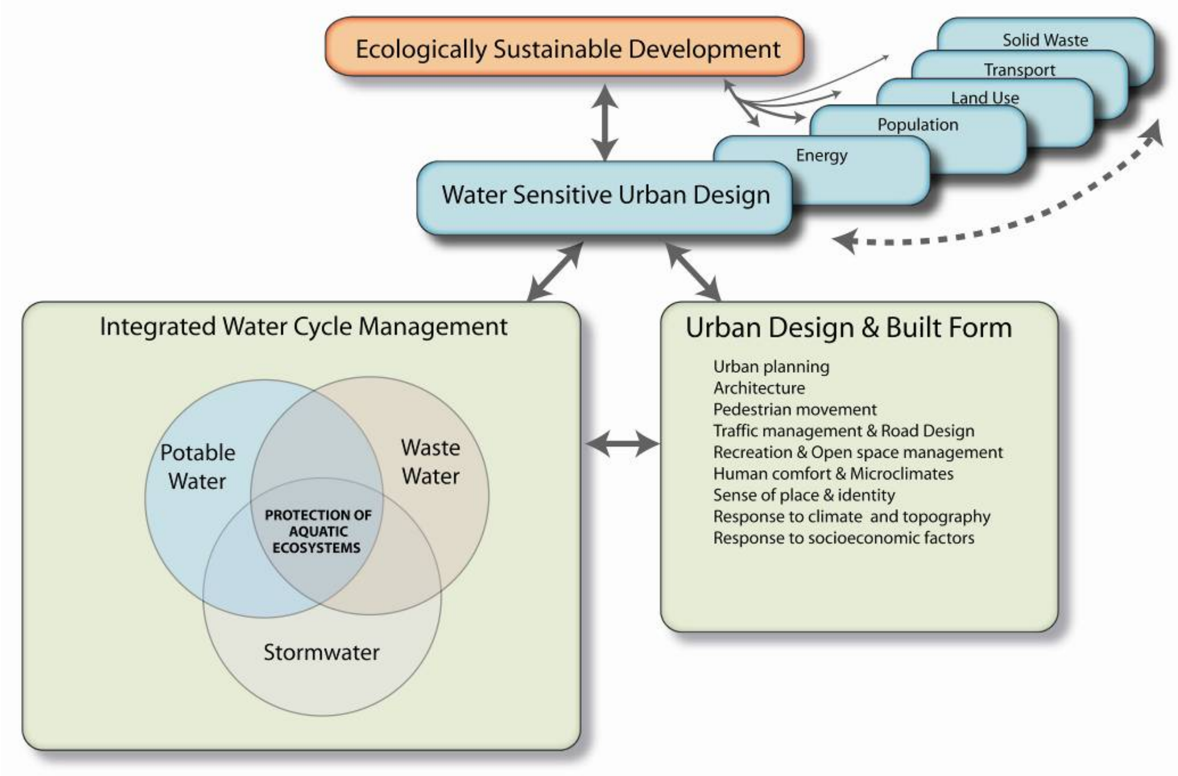


Figure 2: Relationship between water sensitive urban design, ecologically sustainable development and integrated water cycle management

To effectively implement WSUD into individual allotments, streets, suburbs and even master planned communities, water cycle management considerations should be incorporated into the planning and design process as early as possible (Mouritz et. al. in ARQ). The Department of Planning and Infrastructure is ensuring this early integration occurs for the Bellamack by developing and adopting this WSUD Strategy as part of the landuse and infrastructure planning for the site.

1.2 WSUD Principles for Bellamack

The guiding principles of the WSUD Strategy for Bellamack were established in response to the site and receiving environment characteristics and through consultation with all relevant stakeholders. The guiding principles for the strategy are to:

- Protect existing natural features and ecological processes.
- Protect water quality of surface and ground waters.
- Maintain natural hydrologic behaviour of catchments.
- Minimise demand for potable water.
- Minimise wastewater generation and discharge to the natural environment.
- Integrate water into the landscape to enhance urban design, visual, social, cultural and ecological values.
- Add value while minimising development costs.

1.3 This Document

This document summarises the design considerations for applying WSUD at Bellamack, establishes the WSUD objectives and presents the IWCM Strategy in the following sections:

- SECTION 2 Design Considerations - Provides a general description of various considerations which influence WSUD.
- SECTION 3 WSUD Objectives - Establishes the specific objectives for WSUD at Bellamack.
- SECTION 4 WSUD Strategy – Provide an overview of the WSUD strategy for Bellamack.
- SECTION 5 Stormwater Treatment – Detailed discussion of the stormwater treatment options for the site.
- SECTION 6 Potable Water Conservation & Wastewater Minimisation – Detailed discussion of the potable water conservation and wastewater minimisation initiatives for Bellamack.

This document will be used as a reference to guide the planning, design and implementation of WSUD at Bellamack through the design, approval and construction process.

2 Design Considerations

Successful WSUD strategies respond to the specific characteristics and conditions of a site, the local and regional receiving environments and the relevant water and landuse planning. The following sub-sections provide a summary of issues considered important in defining the WSUD Strategy for Bellamack.

2.1 Site Characteristics

2.1.1 Climate

The climate of Darwin region is highly seasonal and, as elsewhere in the wet/dry tropics, is dominated by an extreme wet season between December and March and an extreme dry season between April and October-November. The average rainfall at Darwin is 1700 mm/year and as illustrated in Figure 3, essentially all this rain falls in a three to four month period. The average evaporation at Darwin is approximately 2590 mm/year, ranging from 165 mm in February to 260 mm in October.

The seasonal nature of the climate dictates all elements of the natural and urban water cycle. During the wet season vegetation is lush, soils become waterlogged, groundwater recharge fills local aquifers, local waterways/streams flow permanently and there is no need to irrigate landscapes. During the dry season, the site becomes parched with only very hardy vegetation present, local streams cease to flow, groundwater levels drop within aquifers and extensive irrigation is required to sustain landscapes.

The design of WSUD Strategy and public realm landscapes needs to account for this seasonal variability.

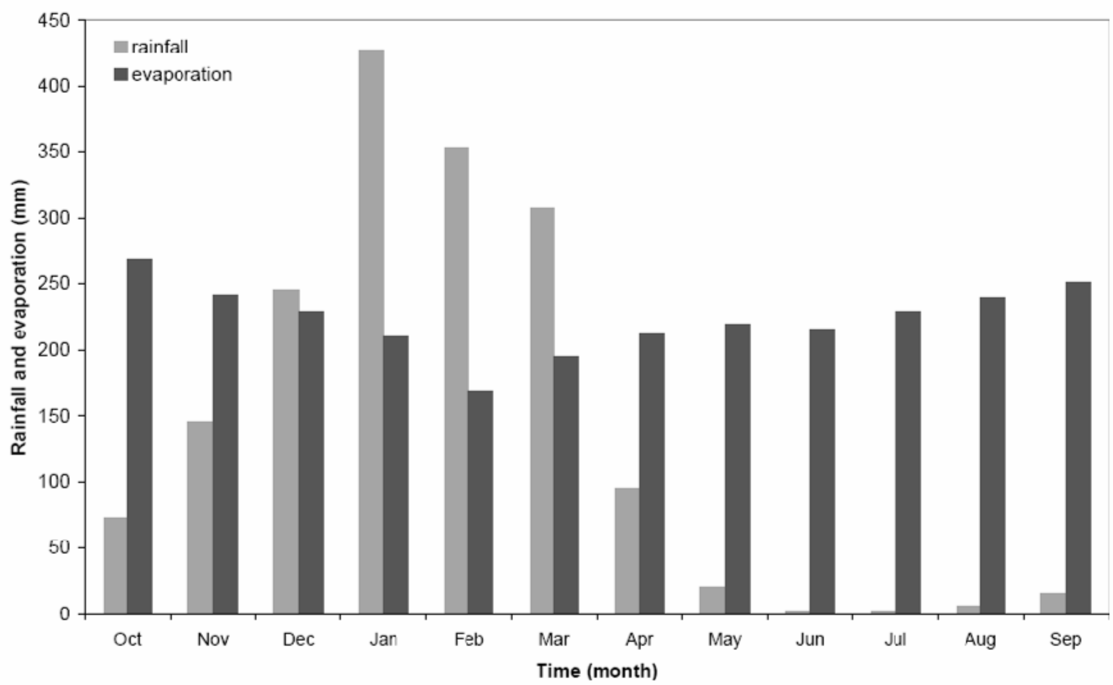


Figure 3: Summary rainfall and evaporation characteristics for Darwin

2.1.2 Topography & Drainage

The topography across the Bellamack is flat to moderate, with the existing natural surface contours indicating slopes in the range of 2 – 5%. The site generally slopes in a southerly direction towards Elrundie Avenue and the proposed Roystonea Avenue Extension, which form the southern boundaries of the site.

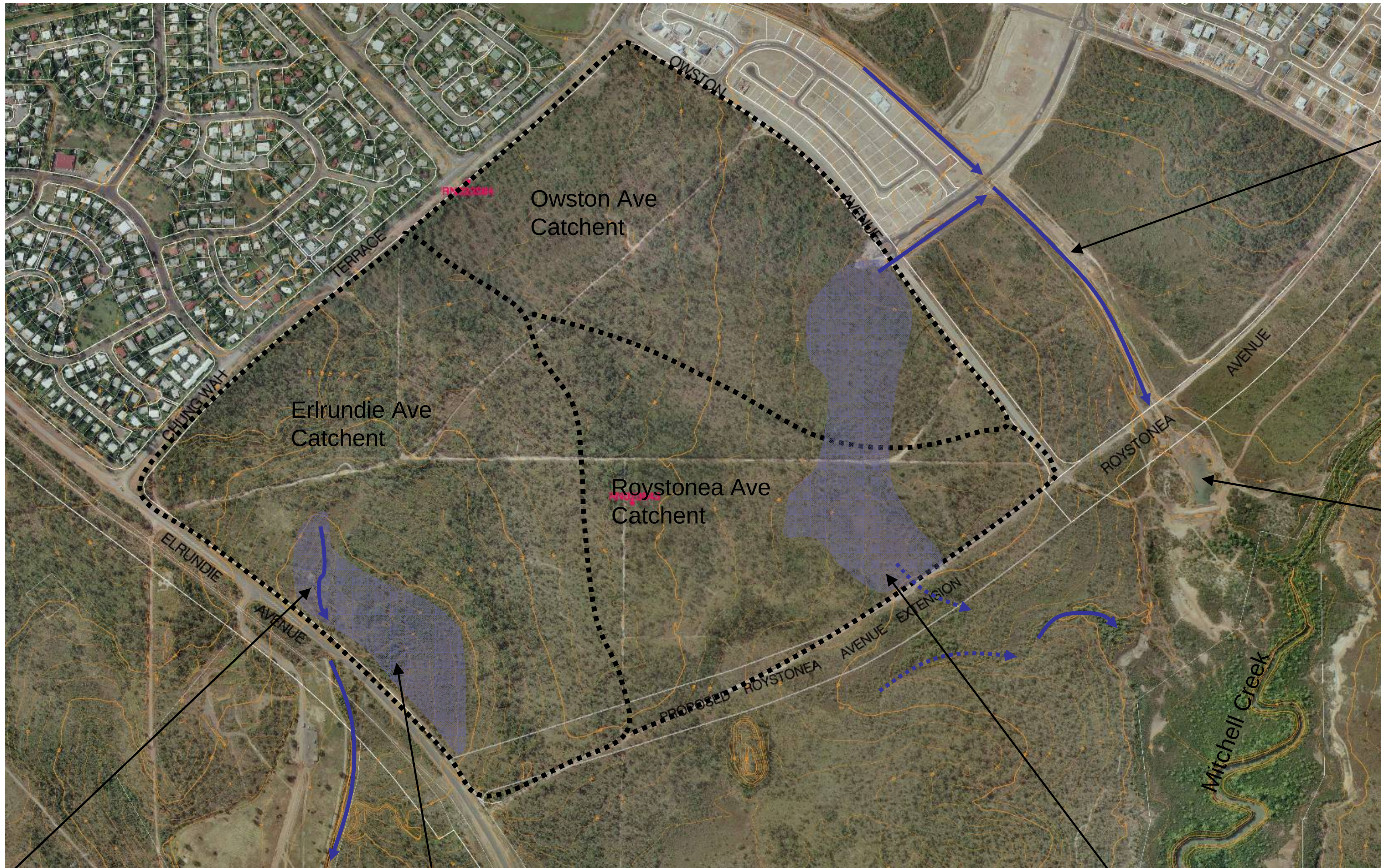
Figure 4 shows the existing natural surface contours on the site and location of the existing drainage pathways within and external to the site. A ridge running north-south through the centre of the site directs site runoff via local sheet flow to three discharge points at the boundary of Bellamack:

- Owston Avenue – The northern portion of Bellamack drains via sheet flow to low zone adjacent to Owston Avenue. During the wet season this zone becomes waterlogged (refer Figure 4) with surface runoff discharged from the site via a culvert to a constructed open channel. At this point flows combine with flows from a large catchment draining Rosebery and Woodroffe and eventually enters Mitchell Creek via a sedimentation basin (Figure 4).

- Proposed Roystonea Avenue Extension – The south eastern portion of the site drains via sheet flow to a low zone adjacent to the proposed Roystonea Avenue Extension. This zone also becomes waterlogged during the wet season. Flows exit the site south to enter Mitchell Creek.

- Elrundie Avenue – The western half of the Bellamack catchment drains via a combination of sheet flow and channel flow to a low zone adjacent to Elrundie Avenue. During the wet season this area becomes waterlogged with discharge from the site occur via a set of culverts under the road to a large trapezoidal channel. The channel conveys flows around the landfill/refuse station to Elizabeth River.

It is envisaged these discharge locations will be retained along with the low waterlogged zones, and associated vegetation, to provide stormwater drainage and treatment functions.



Open drain east of Owston Avenue which accepts runoff from Bellamack, Woodroffe and Rosebery

Sedimentation basin at end of drain prior to discharge to Mitchell Creek

Incised section of drainage

Low level waterlogged area adjacent to Roystonea Avenue Extension

Low level waterlogged area adjacent to Erlrundie Avenue

Approximate extent of waterlogged zones (refer to NRETA Mapping)

Catchment extents

Waterways and drainage paths

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FIGURE 4
Topography & Drainage

2.1.3 Land Units & Soils

As illustrated in Figure 5, a number of land units have been mapped across Bellamack the details of which are discussed in the Bellamack Environment Management Plan (Connell Wagner). The site soils are variable with the elevated areas of the site consisting of well drained gravel loams and the lower zones consisting of poorly drained loams and clay loams which become waterlogged.

The sandy loam topsoils are prone to erosion from both direct rainfall impact and channelling of flows. Inspection of the small drainage pathway which drains the western portion of Bellamack under Elrundie Avenue indicates the presence of an incised stream with actively eroding headwater erosion.

2.1.4 Vegetation

The Bellamack site is covered by open woodland and forest consisting mostly of non-threatened native species including Eucalypts, Melaleuca, Acacia, Palms, Grevillias and grasses. The woodlands transition to water tolerant vegetation, typically Pandanus Palms and mixed ground cover grasses, in the low lying zones (i.e. drainage pathways) where soils become waterlogged during the wet season.

2.1.5 Groundwater

As illustrated in Figure 5, a significant aquifer exists under the Palmerston and the Bellamack site. The total extent of this aquifer is not well known but typically runs in a north south direction from south of Bellamack to north of Marlow Lagoon. The confined dolomite aquifer is relatively high yielding (>10L/s) and fresh (<1000mg/L TDS). Discussions with the Department of Natural Resources, Environment and the Arts (NRETA) and Palmerston City Council indicate the aquifer is currently accessed by bores during the dry season for landscape irrigation and that significant spare capacity exists in the aquifer to supply additional demands.

Bore logs of the aquifer over more than 10 years have shown that the aquifer currently is drawn down more than 8m during the dry season and recharges completely during the wet season. This would indicate that based on current extraction limits there is currently no need to actively promote recharge of the aquifer. However there is a risk to the aquifer from future urban development over the recharge zone of the aquifer reducing the amount of recharge. Designs of WSUD elements in Bellamack should be flexible to accommodate future recharge of the aquifer, if monitoring indicates that full recharge of the aquifer is not occurring.

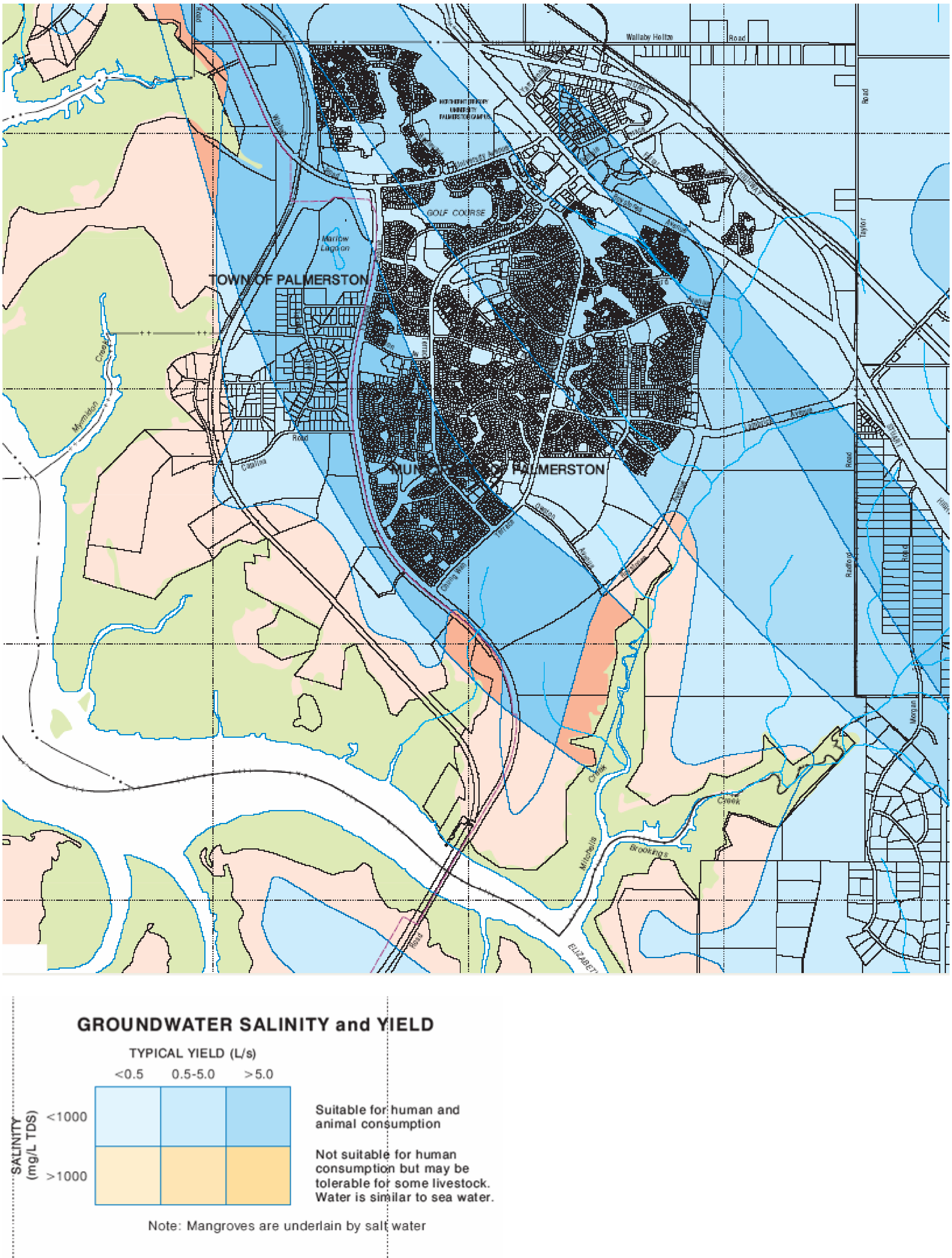

Figure 5: Regional groundwater

2.2 Receiving Ecosystems

2.2.1 Mitchell Creek

The eastern portion of Bellamack discharges to Mitchell Creek which is a regional waterway that drains a catchment of 1,570 ha including the eastern suburbs of Palmerston urban area

(Ecosystems, 1996). The natural form of the creek includes mangrove forests and tidal flats located at its downstream reaches adjacent to Bellamack, incised creek channels fringed by monsoonal forest, broad drainage lines and waterlogged gullies to open woodlands on the slopes.

The catchment contains diverse flora and fauna, with some rare species including the herb Typhonium praetermissum and the tree Eucalyptus atrovirens. The creek is recognised as an important corridor for faunal movement linking the upland areas to the more permanently wet areas lower in the catchment. A relatively large number of macroalgae species have been found in Mitchell Creek in 2002-2004, indicating that this creek was in good health during that monitoring period. However, macroinvertebrate sampling over 2001-2004 has indicated declining macroinvertebrate community health over that time, likely to be associated with urban development (Water Monitoring Branch, 2005).

The Mitchell Creek Parkland (Ecosystems, 1996) and Palmerston Eastern Suburbs Area Plan establishes a significant corridor either side of Mitchell Creek (called the Mitchell Creek Reserve). The reserve will preserve key habitat and provide a suitable buffer from the developed zones to the creek to minimise impacts on the corridor function provided by the creek. Additionally, the reserve will provide an important natural backdrop and recreational asset for the residential suburbs of Bellamack, Rosebery, Blackwell, Gunn and ultimately the entire Palmerston Eastern Suburbs Area.

In terms of WSUD within Bellamack, protection of Mitchell Creek is critical and will involve the best practice management of stormwater.

2.2.2 Darwin Harbour

The aquatic environment of Darwin Harbour has many uses and values (NRETA, 2005). It is a recreation resource, providing significant amenity to the region and underpins economic activity. Importantly the harbour represents the key aquatic ecosystem of the region providing habitat for a range of estuarine and freshwater flora and fauna. For example 27,350ha of mangrove forest is found in Darwin Harbour which constitutes approximately 5% of the total mangrove area of the Northern Territory.

Darwin Harbour is the ultimate receiving environment for all stormwater and wastewater discharge from Darwin and Palmerston urban areas which support a population of approximately 110,000 people. Recent research has identified that although the water quality of the harbour is generally good, the impacts of urban stormwater runoff and wastewater discharges are evident. Wastewater discharges are resulting in localised degradation within the estuarine tributaries of the harbour. During the wet season, stormwater runoff from urban areas is resulting in high loads of sediments, nutrients and heavy metals entering local waterways.

The Darwin Harbour Regional Plan of Management and the Draft Management Strategy for the Darwin Harbour Catchment establishes the initial elements of a framework for managing these water quality impacts. In terms of managing stormwater and wastewater entering Darwin Harbour the following objectives were established as part of the Draft Stormwater Management Strategy for the Darwin Harbour Catchment:

- Maintain the declared Beneficial Uses and Environmental Values of the Darwin Harbour through Integrated Catchment Management planning.
- Maintain water quality through improved practice.
- Promote opportunities for, and benefits of, pollution reduction in stormwater.
- Generate knowledge and certainty of stormwater management, for all relevant stakeholders, in the Darwin Harbour Catchment.

In terms of WSUD within Bellamack, the above mentioned objectives are to be delivered through the implementation of best practice management of stormwater and the reduction of wastewater discharge.

2.3 Relevant Legislation

The Northern Territory's water resources are controlled under the *Water Act (1992).* The Water Act legislates the extent to which both surface and groundwater can be used and for what purpose. The Act declares *Beneficial Uses* for the water throughout Darwin and requires that the potential impact of water pollution be managed to ensure the protection of natural water resources. NRETA are currently in the process of reviewing and updating the Beneficial Uses for all the water resources in the Darwin Region.

Under the current Beneficial Use declarations, Bellamack is located within the Elizabeth and Howard Rivers Region and the following applies:

Surface Waterways – The beneficial uses are list below and the objectives applied to preserve these uses are specified in Chapters 2 and 3 of ANZECC (1992).

- Aquatic ecosystem protection
- Recreational water quality and aesthetics

Groundwater - The beneficial uses are list below and the objectives applied to preserve these uses are specified in Chapters 4 and 5 of ANZECC (1992).

- Raw water for drinking
- Agricultural water use

Discussions with NRETA confirm the aquifer located below the Bellamack site is not used for drinking water purposes and therefore the above mentioned groundwater objectives do not apply. Regarding the surface water objectives, ANZECC (1992 and 2000) notes that scheduled receiving water quality (concentration) objectives are derived ambient “dry weather” pollutant concentrations measured in receiving waters and therefore should not apply stormwater discharges. ANZECC (2000, p.3.3-2) recommends that load based guidelines be developed for nutrients (Total Nitrogen and Total Phosphorus), biodegradable organic matter and suspended particulate matter (or Total Suspended Solids). This is in recognition of the important impact of the total mass (or load) of these pollutants on aquatic ecosystem health. Therefore, in order to comply with the requirements of the current Water Act (1992) load based stormwater quality objectives have been established for Bellamack which represent the best practice management of stormwater.

2.4 Water Supply & Wastewater Planning

Traditionally, water servicing to Bellamack would involve sourcing potable water from either the Darwin River Dam or the Howard East/McMinns borefield to supply all water demands irrespective of the quantum of water used and the collection of wastewater for treatment and subsequent discharge to Darwin Harbour. The recent "Darwin Water Story" initiative under taken by Power and Water highlights the water supply and environment risks associated with this old paradigm and suggests a range of alternative water supply alternatives to ensure current and potential water resources are protected. The following sub-sections identify some of the key points raised by the "Darwin Water Story" initiative.

2.4.1 Demand for Water

Darwin residents use twice as much water per head as people in other capital cities (Darwin Water Story). The average consumption per person, including government and industry related water use, is 960L/person/day. Of this demand, 65% is associated with irrigating landscape with all of this irrigation occurring during the dry season. Water use data for the Darwin Region is summarised in Figure 6.

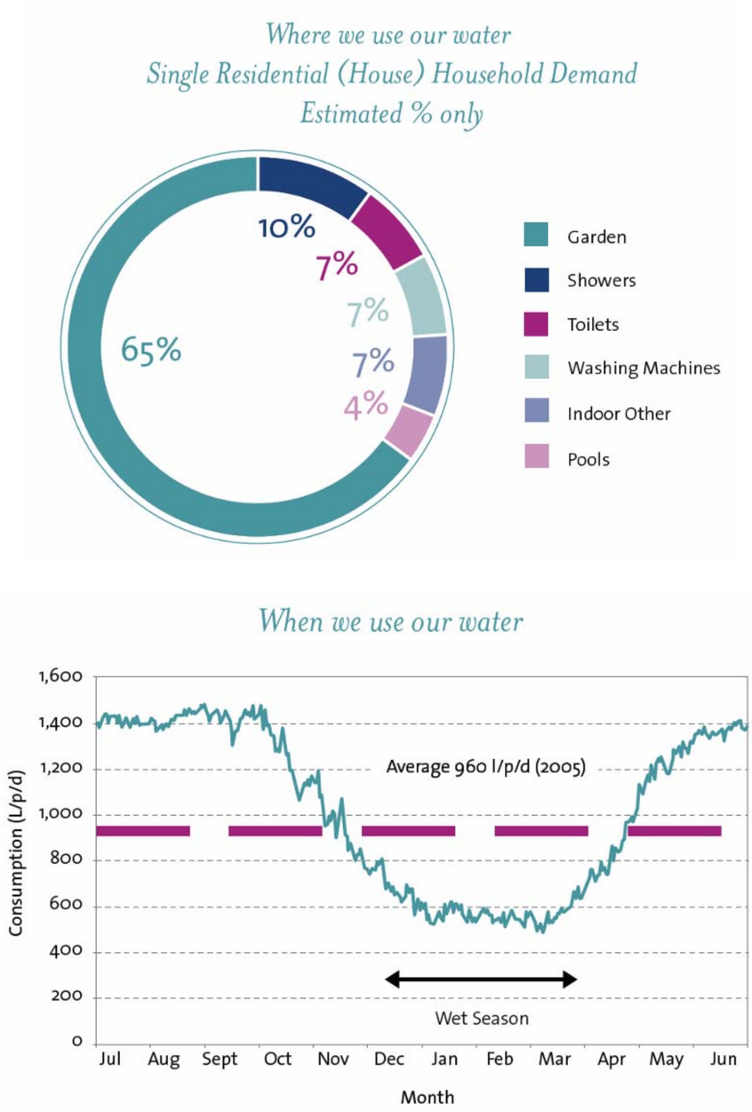

Figure 6: Water use in the Darwin Region

This extreme demand for water combined with rapid population growth has resulted in overall water demand (40GL/yr) reaching the current supply capacity of Darwin River Dam and Howard East/McMinns borefield (46GL/yr). Projected future population growth of between 120,000 – 260,000 people is expected to increase demand to approximately 70GL/yr and meeting this demand will require a range of initiatives.

2.4.2 Power & Water Initiatives

There is currently a community education campaign being undertaken by Power and Water to highlight the role of conserving water through demand management practices. This has involved communicating the current water situation facing Darwin (i.e. Darwin Water Story) and rolling out a number of initiatives aimed at reducing water consumption. These include:

- Supporting and promoting the national mandatory labelling scheme and raising awareness about the scheme.
- Establishing a set of water saving ‘information sheet’ type material to promote residential water savings (available online). This includes the booklet “How to Create a Water Wise Garden in the Top End” for use in private gardens, which includes a list of locally indigenous plant species with low water demands, advice on garden layout, soil improvements, mulching and irrigation techniques.
- Power and Water are also treating and reusing wastewater for irrigation of public open space in the Darwin region. Wastewater reuse projects include:
  - Recycling more than 200 ML/yr at Darwin Golf Course at Northlakes
  - Recycling more than 100 ML/yr at Marrara Sports Complex

  Both of the above use water from the Northlakes wastewater treatment plant, which produces recycled water at a quality suitable for irrigation with unrestricted public access. Northlakes wastewater treatment plant takes secondary treated wastewater and further treats it to tertiary standard, including disinfection.

In support of the above initiatives, the Northern Territory Government and Power and Water are currently working with the “SaveWater!” Alliance to establish a water conservation programme. The programme will provide a centralised education and information resource for anyone wanting to reduce water consumption while maximising economic or commercial opportunities. It will also provide access to water conservation products at cheap subsidised costs.

A recent survey undertaken by Power and Water has shown there is widespread community support demand management initiatives. The survey found that:

- More than half of all residents and businesses believe that water conservation in Darwin is critical
- Residents and businesses agree that it is socially responsible for them to monitor water usage
- Mandatory water efficient devices in new buildings and residences is the first preference to encourage water efficiency
- The majority of residents and businesses state that they would use recycled greywater.

The WSUD Strategy for Bellamack will provide a best practice example of potable water conservative by reducing demand for water and promoting the reuse of wastewater.

2.4.3 Palmerston WSP

Bellamack is located within the Palmerston Waste Stabilisation Pond (WSP) sewer catchment. The Palmerston WSP treats all sewage from the City of Palmerston via five ponds operating in series with discharges entering Darwin Harbour. The Palmerston WSP is currently close to its hydraulic

design capacity (PowerWater, 2005) and advice from Power and Water indicates the system has the capacity to accept only an additional 2000EP (refer SKM letter dated 29th June 2007).

Details of the Palmerston WSP are shown in Table 1 below. The volume of wastewater discharged to the Harbour combined with the relatively high concentrations of nutrients means the WSP is a significant source of pollution. During the wet season significant wet weather infiltration occurs resulting in the WSP becoming overloaded for short periods. WSUD initiatives that reduce the generation of wastewater to Palmerston WSP and reuse water from the WSP have the potential to delay upgrade requirements and reduce pollutant load to the harbour.

Table 1: Palmerston WSP Discharge Concentrations

Dry Season Parameters	Value
Typical Inlet Flows	120 – 150 ML/mth
Typical Discharge Flows	85 -100 ML/mth
Ammonia median	2 mg/L
BOD median	40 mg/L
TP median	10 mg/L
TN median	20 mg/L
TDS median	200 mg/L
E. Coli median	200 (CFU/100mL)
SS median	100 mg/L

The TDS levels for the WSP discharge indicate low levels of salinity which is a key criteria for reuse, particularly irrigation, however further treatment of wastewater from the Palmerston WSP will be required if this water is to be reused.

3 WSUD Objectives

The proximity of Bellamack to sensitive aquatic ecosystems coupled with the changes in the water cycle (i.e. increases in flows and water borne contaminants, increase in demand for water, the discharge of wastewater) requires a carefully considered WSUD Strategy aimed at supporting the intended residential land uses on the site whilst also affording protection to the aquatic ecosystems. The objectives of the Bellamack WSUD Strategy have been developed with the aim of delivering on the key principles of WSUD outlined in Section 1.2 and are based on the outcomes of the WSUD Workshop held on 14th June 2007 (refer Darwin WSUD Objectives Discussion Paper).

3.1 Stormwater Quality

To ensure the protection of Mitchell Creek and Darwin Harbour, stormwater quality objectives have been established for the operational phase of Bellamack. These objectives require specific reductions in pollutant load based on best practice stormwater treatment. The numerical values of the load-based targets are based on achievable load reductions from current best practice stormwater management infrastructure operating in Darwin climatic and pollutant export conditions and operating near the limit of its economic performance. This means that higher load reductions could potentially be achieved, but substantial extra cost would be incurred to obtain a very small additional water quality benefit.

The specific stormwater quality management objectives that apply to Bellamack were established through desk top analysis and discussion of the results at the WSUD Objectives Workshop held on 14th June 2007. Details of the stormwater quality objective derivation are provided in the WSUD Objectives for Darwin Discussion Paper. Table 2 below summarises these stormwater quality objectives.

Table 2: Stormwater quality objectives for Bellamack (Operational Phase)

Constituent	Discharge Criteria
Total suspended solids (TSS)	80% reduction in post development mean annual load
Total phosphorus (TP)	60% reduction in post development mean annual load
Total nitrogen (TN)	45% reduction in post development mean annual load
Gross pollutants	90% reduction in post development mean annual load

Because there will be limited commercial and no industrial land uses within Bellamack, other pollutants such as hydrocarbons, metals and anthropogenic litter are not expected to be generated in significant loads and therefore the WSUD management strategy does not specifically focus on these pollutants. However, each of these pollutants would be managed appropriately by the proposed WSUD stormwater treatment systems.

3.2 Note on Waterway Stability Objective (Stormwater Quantity)

The intent of the waterway stability objective is to control the impacts of urban development on channel bed and bank erosion by limiting changes in flow rate and flow duration within the receiving waterway. The objective is applied by limiting the post-development peak 1yr ARI event discharge in the receiving waterway to the pre-development peak 1yr ARI discharge.

It is not considered appropriate to apply the 'waterway stability management' design objective to the Bellamack site because stormwater runoff from the site discharges into the receiving waterway (i.e. Mitchell Creek) within the tidal or estuarine reach of the creek. Therefore, although the development of the Bellamack site will lead to increases in the volume and magnitude of flows being discharged into Mitchell Creek, this is not expected to result in increased erosion potential within the creek itself.

3.3 Potable Water Conservation

One of the core initiatives of WSUD is potable water (drinking water) conservation. Potable water conservation ensures that urban areas are less reliant on limited high quality water resources, which is important in the context of the water supply issues which currently face Darwin. Additionally, conserving potable water potentially reduces the considerable infrastructure costs of supplying water. In this regard, the WSUD Strategy for Bellamack will:

- Reduce the garden irrigation demand for potable water by adopting low water use landscapes in public parks and encouraging low water used gardens on private allotments.
- Reduce the indoor demand for potable water through the adoption of mandatory dual flush toilets and encourage the adoption of water efficient fixtures and appliances
- Maximise the use of treated wastewater and groundwater for non-potable end uses, in particular landscape irrigation which constitutes 65% of residential water demand.

The use of alternative water supplies for non-potable end uses will be facilitated through the provision of a “third pipe” recycled water reticulation system. This will be a reticulation system to provide recycled water to private and public landscape irrigation. This is discussed further in Section 6.2.

3.4 Wastewater Minimisation

As outlined in Section 2.4.3, the Palmerston WSP will accept wastewater from Bellamack. The WSPD is close to its hydraulic design capacity and is a significant source of pollution to the harbour. WSUD initiatives that reduce the generation of wastewater to Palmerston WSP and reuse water from the WSP have the potential to delay upgrade requirements and reduce pollutant load to the harbour. In this regard, the WSUD Strategy for Bellamack will:

- Minimise the generation of wastewater from Bellamack, through demand management and the reduction of wet weather infiltration.
- Maximise the use of treated wastewater for non-potable end uses. A “third pipe” recycled water reticulation system will be installed at Bellamack, so that wastewater can be recycled and used within the development.

3.5 Landscape Integration

Many WSUD measures associated with the harvesting, treatment, storage and reuse of stormwater involve infrastructure that is readily incorporated into the built form and local landscape. Integration of public spaces with conservation corridors, stormwater management systems and recreational facilities is a key principle of WSUD. It can provide opportunities for passive recreation (such as a constructed wetland system in a park area) as well as enhancing educational opportunities in regard to promoting stormwater and waterways as valuable resources. WSUD systems can also be used to create interesting public realm spaces. The stormwater management elements that will apply to Bellamack have been conceived to readily integrate into the landscape of public realm zones and add value to the experience of visitors and residents.

3.6 Summary

The WSUD Strategy for Bellamack has been established with the aim of achieving the objectives summarised in Table 3.

Table 3: Summary of WSUD Objectives

IWCM Objective	Performance Measure/Target
Stormwater Quality	Stormwater discharged from development areas to be treated in accordance with best practice: • 80% reduction in the mean annual load of Total Suspended Solids (TSS) • 60% reduction in the mean annual load of Total Phosphorus (TP) • 45% reduction in the mean annual load of Total Nitrogen (TN) • 90% reduction in the mean annual load of Gross Pollutants
Potable Water Conservation	• Reduce the garden irrigation demand for potable water by adopting low water use landscapes in public parks and encouraging low water used gardens on private allotments. • Reduce the indoor demand for potable water through the adoption of mandatory dual flush toilets and encourage the adoption of water efficient fixtures and appliances • Maximise the use of treated wastewater and groundwater for non-potable end uses, in particular landscape irrigation which constitutes 65% of residential water demand.
Wastewater Minimisation	• Minimise the generation of wastewater from Bellamack, through demand management and the reduction of wet weather infiltration. • Maximise the use of treated wastewater for non-potable end uses. A “third pipe” recycled water reticulation system will be installed at Bellamack, so that wastewater can be recycled and used within the development
Landscape Integration	• The stormwater management elements for Bellamack to readily integrate into the landscape of public realm zones and add value to the experience of visitors and residents.

4 WSUD Strategy

There are a range of WSUD techniques available to deliver the objectives outlined in Section 3. Selecting the most appropriate suite of measures for Bellamack required matching the available techniques to the wet/dry climate, site conditions, management objectives, the demand for water and the desired urban form and landscape intent.

A preferred WSUD strategy has been developed based on existing information, workshops and ongoing discussion with the project team, as well as investigations undertaken as a component of this WSUD strategy. This strategy may be further revised as more is known about the site and during discussions with the urban designer, landscape architect and wider project team during the detailed design phase. Therefore as well as the preferred strategy, alternate options are also discussed.

The WSUD strategy has been based on the Outline Development Plan of November 2006, as shown in Figure 7. The site has been divided into three major subcatchments, named the Owston Avenue, Roystonea Avenue and Elrundie Avenue catchments for the purposes of this report.

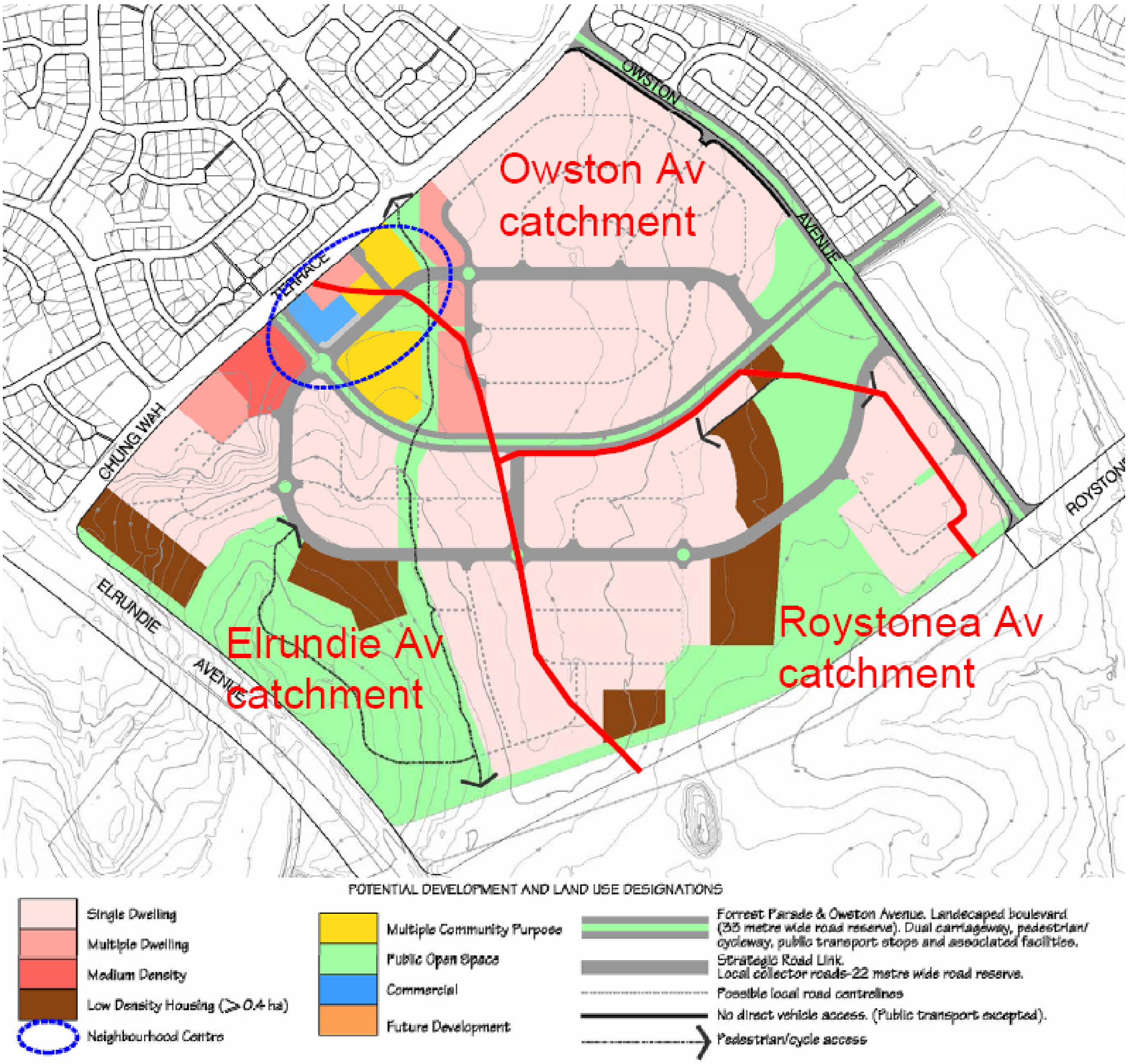

Figure 7: Bellamack Outline Development Plan, November 2006

Catchment areas and land uses were estimated from the Outline Development Plan. A summary of land area assumptions is included in Table 4.

Table 4: Catchment areas and land use at proposed Belllamack development

Catchment	Owston Avenue	Roystonea Avenue	Elrundie Avenue
Total area, ha	42.2	34.1	46.5
Estimated area of roofs, ha	13.6	8.4	11.5
Estimated area of roads, ha	5.1	3.1	4.3
Estimated total paved areas, ha	25.1	15.5	21.2
Overall impervious fraction, %	60%	45%	45%

The key elements of the preferred WSUD strategy are:

- The use of three constructed ephemeral wetlands for the treatment of stormwater. These have been sized approximately based on the catchment and land use estimates in Table 4
- The provision of a non-potable water supply reticulation network within the development for outdoor uses, including irrigation of public and private landscapes
- Interim provision of precinct groundwater bores to supply the non-potable reticulation network
- Ultimately wastewater reuse from Palmerston WSP connected to the Bellamack non-potable water supply reticulation network
- Additional water conservation by adopting demand management within all public buildings and public open space, and the active promotion of demand management within private dwellings and private open space

Tables 4 and 5 present the preferred strategy and alternate options of the elements of the WSUD Strategy for Bellamack. Table 5 outlines the strategy for potable water conservation and wastewater minimisation, while Table 6 outlines the strategy for stormwater quality treatment. Further information on the individual WSUD elements is provided in Sections 5 (Stormwater Treatment) and 6 (Potable Water Conservation & Wastewater Minimisation), as referenced in Tables 4 and 5.

The preferred stormwater treatment strategy is centred on the use of constructed wetlands. Figure 8 identifies the preferred wetland location for each of the catchments and provides preliminary design criteria, including the footprint required, volume and sediment basin details. The scale of the various WSUD elements have been sized based on:

- Expected landuse in Bellamack, based on the Bellamack Outline Development Plan of November 2006, as shown in Figure 7.
- Standard stormwater runoff, stormwater pollutant and stormwater treatment performance assumptions
- The goal to achieve the stormwater quality objectives summarised in Section 3

Further refinement of the catchments, landuse assumptions and associated WSUD solutions (sizes, layout, function) will occur as part of the design and development assessment process. EDAW will design the three constructed wetlands and provide design documents to the successful developer(s) to construct at their cost, along with other drainage components (which they will also design and construct at their cost).

Table 5: Summary of WSUD Strategy for Bellamack – Potable Water Conservation & Wastewater Minimisation

POTABLE WATER CONSERVATION & WASTEWATER MINIMISATION	Preferred Solution	Optional Solution	Section Reference
Demand management Demand management reduces water consumption by reducing demand for water. Within public and private buildings, demand management can be reduced through the use of low water use fixtures and appliances, such as taps, showers, toilets, urinals, washing machines and dishwashers. Demand management measures are proposed as part of the preferred WSUD strategy in public and private buildings as well as public and private landscapes: • *Public Buildings* – To promote awareness of sustainable water management and conservation, all public buildings will adopt best practice demand management. Buildings which use cooling towers should investigate using bore water. • *Private Buildings* (allotments) – Power and Water Corporation have a good set of promotional material relating to residential water saving. Provision of information packs, water efficient display homes and incentives for water efficient fixtures will encourage residents to adopt these measures. Developers should be encouraged to adopt a minimum rating for water efficient fixtures for all dwellings. • *Private landscapes* (allotments) - Power and Water Corporation have a good set of promotional material relating to residential water saving in the garden. Provision of information packs, water efficient gardens at display homes and incentives for low water use plants and materials will encourage residents to adopt these measures. Additionally, a “third pipe” recycled water reticulation system is to be installed within Bellamack to ultimately supply treated wastewater to allotments to supply garden irrigation. • *Public landscapes* - Public open space landscape practices should adopt endemic and low water use plant species to reduce demand for irrigation and to raise awareness of low water using garden techniques. Additionally, public landscapes will be irrigated via a “third pipe” recycled water reticulation system (treated wastewater) and groundwater bores.	✓		Section 6.1
Non potable water supply system Based on typical Darwin data, approximately 65% of the water to be used at Bellamack will be used for outdoor use, including irrigation (i.e. public open space and private landscapes). Thus the focus of the WSUD strategy for Bellamack is to supply a non potable water supply for outdoor irrigation use. This will involve provision of a “third pipe” non potable water reticulation system within the development. The third pipe system will, at a minimum, connect to irrigation systems for public and private allotment landscapes. Investigation into the use of groundwater for cooling tower use should be undertaken during the next design phase.	✓		Section 6.2
Wastewater Reuse Ultimately the non potable water supply system will supply treated wastewater through the third pipe system. Wastewater reuse will involve upgrading Palmerston WSP to provide a higher level of treatment. It will also involve the provision of a regional recycled water pipeline to Bellamack, which will supply the local Bellamack non potable water supply system. Considering Bellamack forms part of the large Palmerston Eastern Suburbs development release area, a regional wastewater reuse strategy is recommended. This strategy should provide a cost effective solution and ensure that the cost is spread equitably across the whole land release area.	✓		Section 6.2
Wastewater reuse within buildings Greywater or wastewater recycling is an option within large public buildings. Greywater or wastewater can be harvested and treated within a building using a small package treatment plant, and can be reused for applications such as toilet flushing and cooling systems.		✓	Section 6.3

POTABLE WATER CONSERVATION & WASTEWATER MINIMISATION	Preferred Solution	Optional Solution	Section Reference
Groundwater Bore It is likely that the regional wastewater reuse scheme will not be developed before the Bellamack development. Hence in the interim period, the non-potable water supply system will be supplied with water from a local aquifer. The local aquifer beneath Bellamack is to be accessed via bores to supply top-up and irrigation water for the WSUD systems, if required. The successful proponent(s) will need to construct these groundwater bores.	✓		Section 6.4
Low Infiltration Sewers In order to minimise wet weather infiltration to the sewer, it is proposed the wastewater collection system will be designed as a reduced infiltration (i.e. NuSewer, Smart Sewer) wastewater system. These systems reduce the overall volume of wastewater during the wet season, reducing the size of the wastewater collection and conveyance systems. They will also reduce the need for upgrades at Palmerston WSP and will ultimately reduce the amount of inadequately treated wastewater discharged to the Harbour.		✓	Section 6.5

Table 6: Summary of WSUD Strategy for Bellamack – Stormwater Treatment

STORMWATER TREATMENT	Preferred Solution	Optional Solution	Section Reference
OWSTON AVENUE CATCHMENT			
Constructed Wetland – Ephemeral (Partially located in the Rosebery Hub and partially located in and adjacent to a retrofitted existing sedimentation basin). Estimated area required = 3 ha It is proposed to divert part of the Owston Avenue catchment into an ephemeral constructed wetland located within the Rosebery Hub and part of the catchment into the area to the west of the existing sedimentation basin. The Rosebery Hub has a buffer zone which will not be developed but can be used for stormwater treatment. The available footprint for stormwater treatment will need to be confirmed during the next design phase. The existing sedimentation basin located at the downstream end of Owston Avenue can be adjusted to create the inlet zone to a large regional ephemeral wetland. The wetland would be located at the interface between the tidal mangrove flats and the slightly steeper terrestrial zone. This system has the potential to treat runoff from Bellamack as well as the wider Rosebery and Woodroffe catchments thus achieving a greater level of stormwater treatment and protection for Mitchell Creek. Further resolution of this template, function and design will occur as part of the desgin process. EDAW will design this constructed wetland and provide design documents to the successful developer to construct at their cost, along with other drainage components. The system could be established as a regional landscape feature with pathways and viewing decks to allow visitors to interact and observe the wetland system.	✓		Section 5.1
Bioretention Basin(s) Created as landscape features within local open space zones and integrated into vegetated areas adjacent to the low level waterlogged areas to accept and treat piped stormwater flows.		✓	Section 5.2
Bioretention Swales – Centre Median Created as linear landscape features within road centre medians (where road sections use centre medians) to convey and treat stormwater runoff from road reserves and potentially adjacent lots. Swales should not be adopted on roads where centre medians are not proposed.		✓	Section 5.3
ROYSTONEA AVENUE CATCHMENT			
Constructed Wetland – Ephemeral (Adjacent to Roystonea Avenue). Estimated area required = 2.5 ha Create an ephemeral constructed wetland in the low waterlogged zone upstream of Roystonea Avenue to treat stormwater prior to discharge to the downstream environment. The system could be established as a landscape feature within local open space and preserve much of the existing canopy vegetation (created via low level bunds through the existing vegetation). The existing drainage flow path should be maintained. It is possible that the drainage from this wetland will need to be discharged as distributed overland flow, rather than a low flow channel. Further site investigation is required during the detailed design phase to confirm this component of the design. EDAW will design this constructed wetland and provide design documents to the successful developer to construct at their cost, along with other drainage components.	✓		Section 5.1
Bioretention Swales – Centre Median Created as linear landscape features within road centre medians (where road sections use centre medians) to convey and treat stormwater runoff from adjacent lots and the road reserve. Swales should not be adopted on roads where centre medians are not proposed.		✓	Section 5.3

STORMWATER TREATMENT	Preferred Solution	Optional Solution	Section Reference
ELRUNDIE AVENUE CATCHMENT			
Constructed Wetland – Ephemeral (Upstream of Elrundie Avenue). Estimated area required = 3.5 ha Create an ephemeral constructed wetland in the low waterlogged zone adjacent to and upstream of Elrundie Avenue to treat stormwater prior to discharge to the existing downstream channel. The system could be established as a landscape feature within local open space and preserve much of the existing canopy vegetation (created via low level bunds through the existing vegetation). The system may contain permanent pools (refer Section 5.1.2) provided existing vegetation is retained. EDAW will design this constructed wetland (or the alternative option below) and provide design documents to the successful developer to construct at their cost, along with other drainage components.	✓		Section 5.1
Constructed Wetland – Ephemeral (Downstream of Elrundie Avenue) Where inverts levels allow, stormwater could be diverted out of the drainage channel located downstream of Elrundie Avenue into a large ephemeral wetland located in the proposed Archer Rehabilitation Area. The system could form a large regional ephemeral wetland treatment system that manages runoff from Bellamack and the wider Palmerston Eastern Suburbs develop across Mitchell. Further assessment of this opportunity will occur as part of the design process.		✓	Section 5.1
Bioretention Basin(s) Created as landscape features within local open space zones and integrated into vegetated areas adjacent to the low level waterlogged areas to accept and treat piped stormwater flows.		✓	Section 5.2

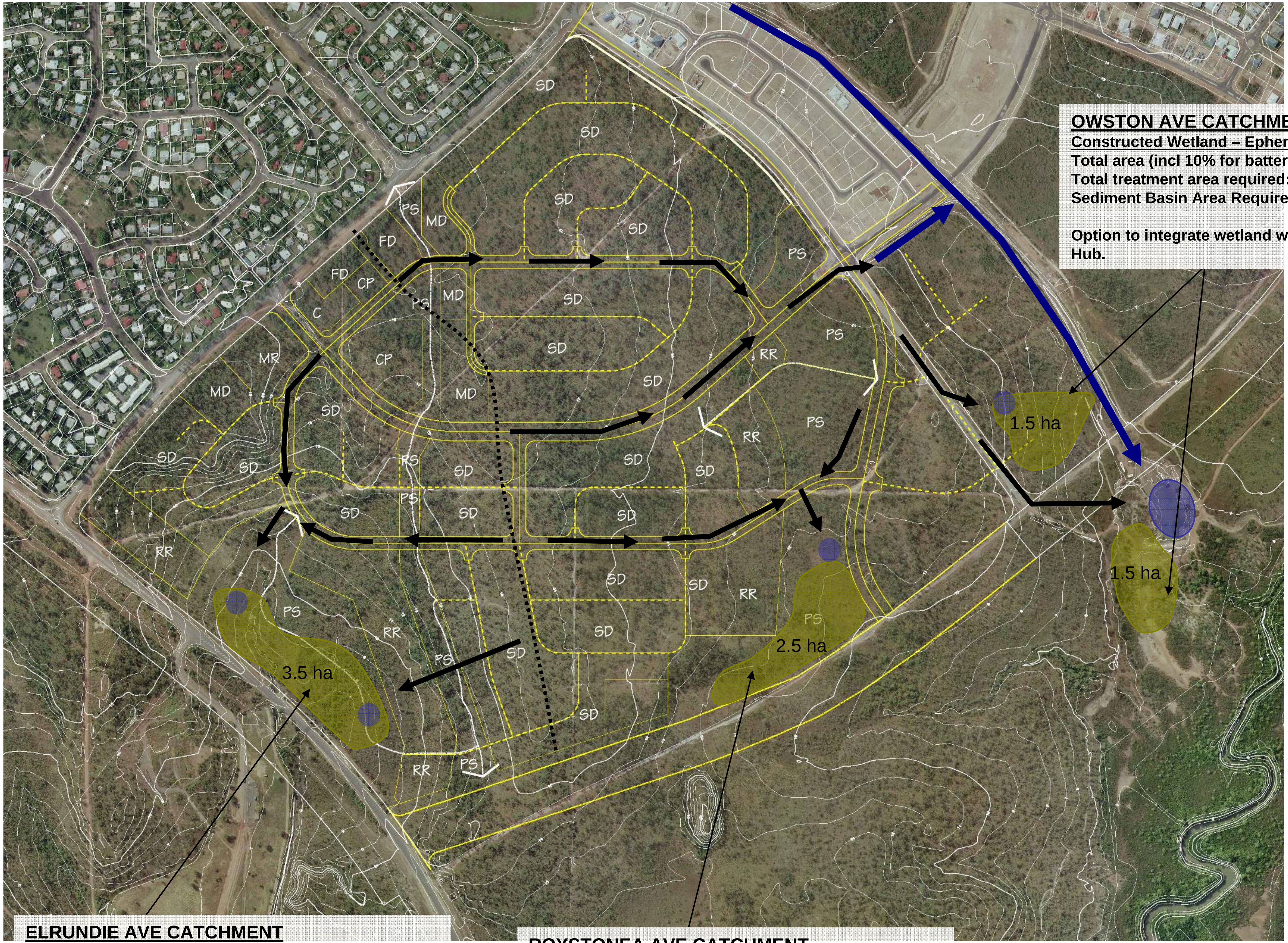

FIGURE 8
WSUD Strategy for Bellamack

4.1 Staging

The implementation of Water Sensitive Urban Design needs to be considered in the context of the overall staging of the development.

Typically, stormwater drainage infrastructure is installed in the early phases of development, as it needs to be installed before roads and other infrastructure is constructed over it. When stormwater drainage is installed for a new development, it needs to include all components downstream of the development, as well as within the development itself, so that it can operate as a complete system. This means that when upstream catchments are developed prior to downstream catchments, trunk stormwater drainage infrastructure needs to be constructed for the whole catchment when the upstream part is developed.

Stormwater treatment systems can be installed at the same time as stormwater drainage infrastructure, however they need to be protected from the impacts of erosion and sedimentation while there is still intensive development activity occurring within their catchment. Stormwater treatment systems designed for urban areas cannot cope with the high sediment loads generated during construction. The following installation procedures are recommended for stormwater treatment systems:

- **Stage 1 - Functional Installation -** Construction of the function elements of the WSUD systems at the end of sub-division construction and the installation of temporary protective measures. For example, protection of bioretention systems has been achieved by using a temporary arrangement of a suitable geofabric covered with shallow topsoil (e.g. 50mm) and instant turf, in lieu of the final basin planting.

- **Stage 2 - Sediment & Erosion Control** - During the allotment building phase the temporary protective measures preserve the functional infrastructure of the WSUD systems whilst also providing a temporary erosion and sediment control facility throughout the building phase to protect downstream aquatic ecosystems

- **Stage 3 - Operational Establishment -** At the completion of the allotment building phase, the temporary measures protecting the functional elements of the WSUD system can be removed with all accumulated sediment and the system planted in accordance with the design planting schedule.

These stages are illustrated in Figure 9.

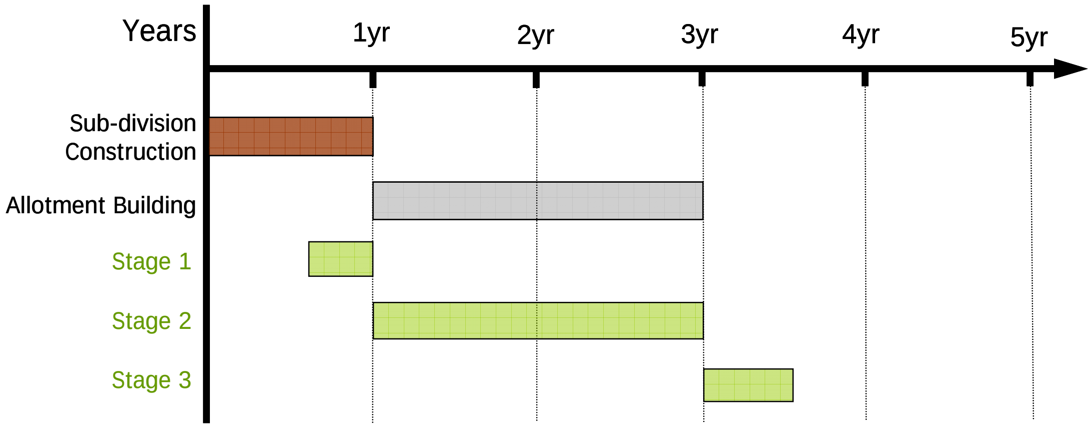

Figure 9: Staged approach to stormwater treatment construction

This three staged approach utilised for establishing stormwater treatment systems has been widely recognised by authorities and designers as setting the industry standard in South East Queensland, and many of the technical aspects of the approach are now being incorporated into regulation and documented in industry guidelines. The approach is also being adopted elsewhere in Australia.

5 Stormwater Treatment

5.1 Constructed Wetlands

Constructed wetland systems are shallow, extensively vegetated water bodies that use enhanced sedimentation, fine filtration and biological uptake processes to remove pollutants from stormwater. Water levels rise during rainfall events and outlets are configured to slowly release flows. In addition to treating stormwater, constructed wetlands can also provide habitat, passive recreation, improved landscape amenity and temporary storage of treated water for reuse schemes.

Please refer to Appendix A for further description of constructed wetland function and design considerations. Further detail can also be found in the *Water Sensitive Urban Design Stormwater Treatment Options for Darwin* Discussion Paper (prepared by EDAW for the NT Department of Planning and Infrastructure, October 2007).

In the context of Bellamack, wetland design needs to respond to the local conditions, in particular the wet-dry tropical climate. The natural response of waterbodies, such as wetlands and billabongs, in the wet dry tropics is typified by lush vegetation during the wet season and then "die off" back to predominantly bare earth during the protracted dry period as illustrated photo log below (Figure 10). It is understood this seasonal "response" of the natural landscape is not traditionally preferred in a residential landscape.

Figure 10: Seasonal Changes in water level and vegetation in Korebum Lagoon – May, August, November and February (Schult and Welch, 2006)

The "Treatment Options" discussion paper proposes three conceptual options for wetland designs that would be suitable for Darwin's wet-dry tropical conditions:

1. Conventional permanent waterbody wetlands, which are topped up with a secondary water supply during the dry season

2. Ephemeral wet/dry wetlands, which would dry out completely during the dry season

3. Ephemeral wetlands with deep water zones, which would include one or more deep pools, large enough to maintain permanent water during the dry season

The "Treatment Options" discussion paper includes information on key design considerations, including:

- Sizing wetlands to achieve pollutant load reduction objectives
- Hydraulic design of inlet and bypass structures to cope with major storm events and protect the macrophyte zone from high, erosive flows
- Selection of suitable plants for the macrophyte zone
- Weed management
- Prevention of algal blooms
- Prevention of mosquito breeding

The "Treatment Options" discussion paper should be consulted for further information.

Ephemeral wetlands with deep water zones, Option 3, are the preferred option for Bellamack. This option is the most sympathetic to the climate, location and ecology of Bellamack, in particular the hydrology and high evapotranspiration during the dry season which favours ephemeral waterbodies. It may be beneficial to retain a permanent pool within the ephemeral wetland to create a habitat for mosquito larvae predators. This deep water zone will be predominantly open water and be approximately 2 to 10% of the total surface area of the ephemeral wetland. In terms of landscape amenity, this design creates a series of small "perennial" versions of these otherwise seasonal landscapes which, if provided within a braided pattern within parkland areas could give the impression of substantial areas of "waterway gardens" without necessarily having to have large evaporative surface areas.

Over the dry season these permanent pools will drawdown, in a typical year, between 0.75m and 1.25m as shown in Figure 11**Error! Reference source not found.**. In response to this issue there are two options available for preserving the permanent pools:

- Create the permanent pools with a suitable depth such that it does not dry out. As illustrated in Figure 11 this depth will need to be a minimum of 1.5m (preferably 2m). In this case it will not be possible to sustain fringe vegetation over this water level variation and hence the edge treatment of the pond will need to be considered in the design (i.e. trees around perimeter to mask bare banks).
- Where a suitable source of water is available (i.e. harvested stormwater, groundwater), use this water to sustain a constant water level in the permanent pool. The volume of water required for top up in a typical dry season is 1 kL/m2 (i.e. 1kL of top up water per m2 of permanent pool per dry season).

In the Bellamack case, it is suggested groundwater is used to preserve small permanent pools within the ephemeral wetlands with the size of the pools established in response to the landscape desires for the adjacent parkland. In order to manage the amount of groundwater used for top up the permanent pools should be not greater that 10% of the ephemeral wetland area.

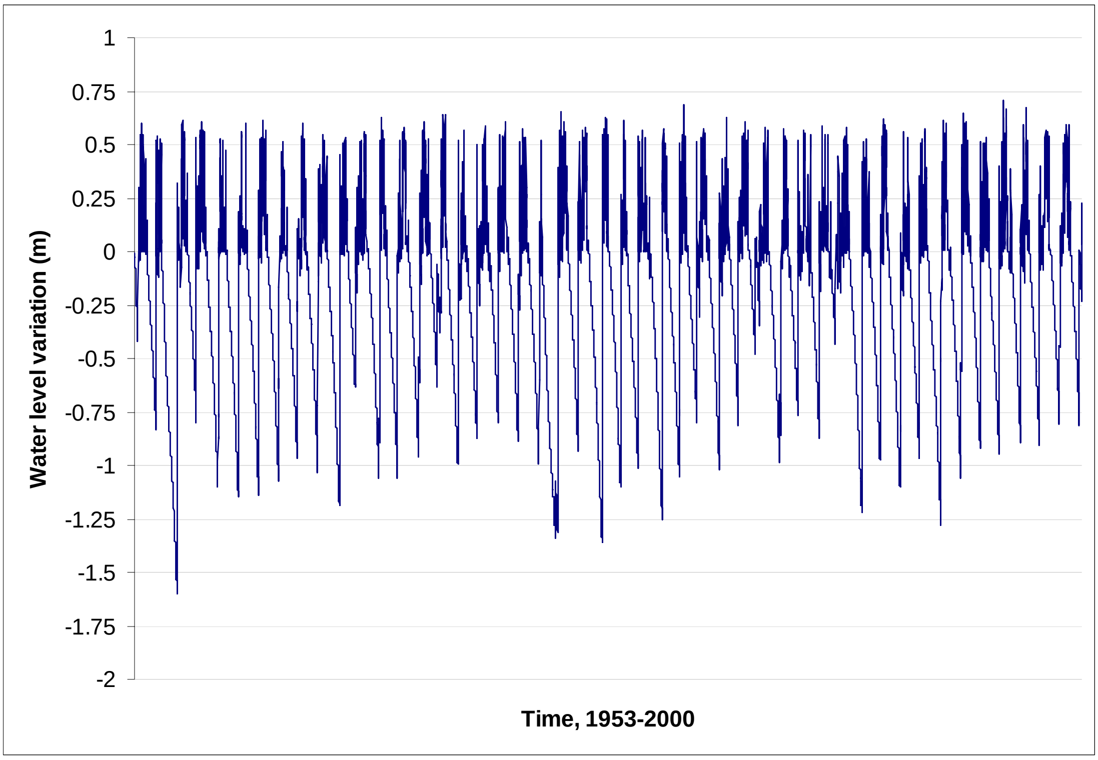

Figure 11: Water level variation in the deep water zone

A typical cross-section of an ephemeral wetland system is shown in Figure 12.

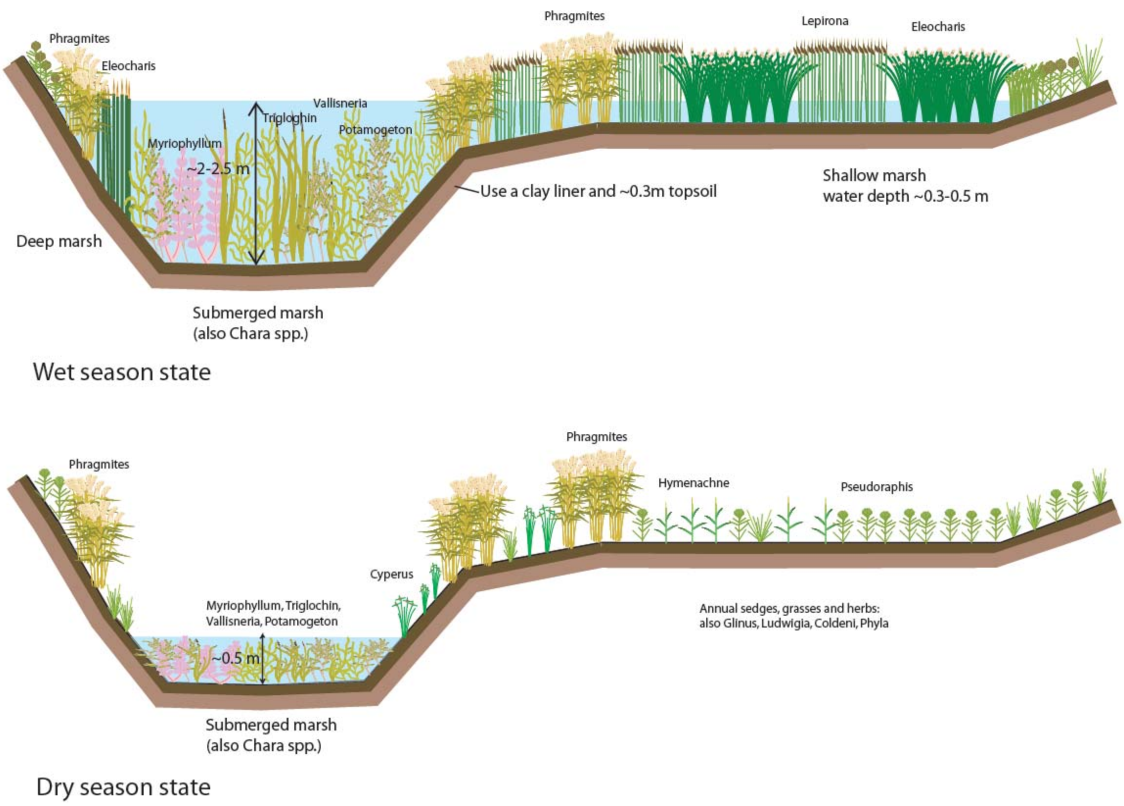

Figure 12: Conceptual diagram of an ephemeral wet/dry wetland

The conceptual diagram includes the following features:

- The wetland is shown as being lined with a relatively impervious clay layer. This is suggested to maximise the retention of water into the start of the dry season, and retain any dry season flows from urban catchments.

- Topsoil would need to be included above the impervious liner; a minimum of 300 mm is required for plant growth.

- The wet season water level is shown as approximately 2.0 m in the deepest part of the wetland, and 0.2-0.5 m in the shallowest part of the wetland.

- The species composition in the wetland would change with the seasons:

    - During the wet season, the deep water would be populated by submerged macrophytes, with shallower zones populated by emergent macrophytes such as *Phragmites*, *Eleocharis* and *Bolboschoenus*. The shallowest part of the wetland would be populated with floodplain grasses such as *Pseudoraphis*, *Oryza* and *Leersia*.

    - During the dry season, wetland vegetation that is relatively shallow rooted and unable to access groundwater will die off. Macrophytes would be replaced with terrestrial species of annual grasses, herbs and sedges as the water recedes. However typically the percentage cover of the dry season annuals are lower than that during the wet season. This low percentage of cover will have an impact on aesthetics and erosion and will be a key component of the urban design of wetlands.

Further information on ephemeral wetlands and other potential wetland options is included in the "Treatment Options" discussion paper.

5.2 Bioretention Basins (Raingardens)

Bioretention basins are vegetated areas where stormwater runoff is filtered through a soil layer (e.g. sandy loam) as it percolates downwards. It is then collected in a drainage layer via perforated under-drains and flows to downstream waterways or storages for reuse. Bioretention basins typically use temporary ponding of 0.2-0.4 m depth above the filter media surface to increase the volume of runoff treated through the filter media.

The nature of the bioretention basins, being planted soil profiles, means there is a reasonable amount of flexibility regarding the size, shape and location of the systems. As such, there are opportunities to integrate the bioretention basins as landscape features within the overall development layout. Some examples of bioretention systems are shown in Figure 13.

Photos: Ecological Engineering

Figure 13: Examples of Landscape Form for Bioretention Basins

Please refer to Appendix B for further description of bioretention basin function and design considerations. Further detail can also be found in the *Water Sensitive Urban Design Stormwater Treatment Options for Darwin* Discussion Paper (prepared by EDAW for the NT Department of Planning and Infrastructure, October 2007).

The challenge associated with applying bioretention basins in the wet/dry tropics of Darwin is maintaining the surface vegetation during the dry season, and the associated landscape amenity, and preserving the permeability and treatment performance of the filter media during the wet season.

The "Treatment Options" discussion paper proposes three conceptual options for bioretention system designs that would be suitable for Darwin's wet-dry tropical conditions:

1. Conventional bioretention systems, which may take one of several alternative forms:

    a. Seasonally dry bioretention systems, which would include vegetation that dies back during the dry season, then re-establishes at the start of the wet season

    b. Irrigated bioretention systems, where vegetation within the systems would be maintained by irrigation during the dry season

    c. Non-lined bioretention systems, where the vegetation within the systems could potentially access groundwater during the dry season

2. Saturated zone bioretention systems, which would include a layer in the base of the bioretention system that retains water, thereby providing a source of water which would be drawn down gradually by evapotranspiration during the dry season.

If bioretention systems are used at Bellamack, it is recommended that one of the former ("conventional") options is utilised, i.e. seasonally dry, irrigated or non-lined systems should be used. A typical cross-section of a bioretention basin suitable for Bellamack is shown in Figure 14.

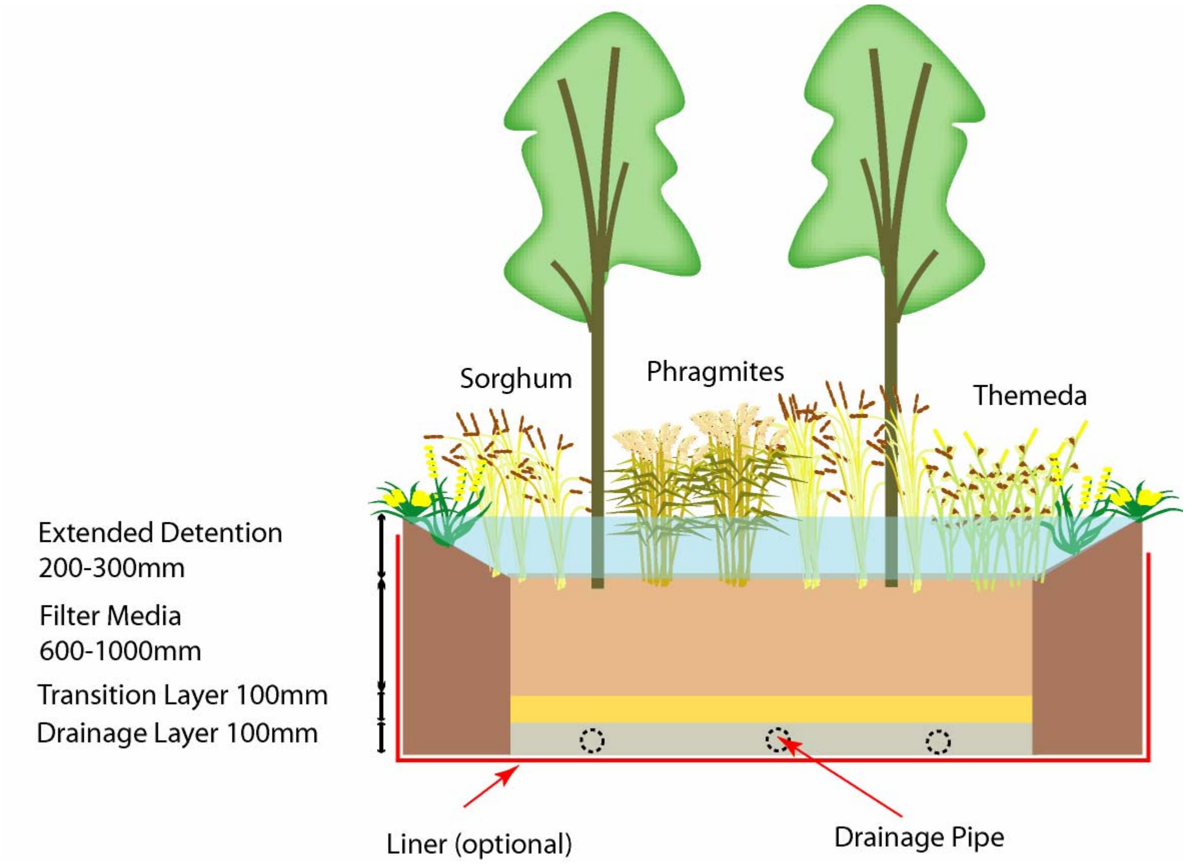

Figure 14: Conceptual diagram of a bioretention basin suitable for Bellamack

Conventional bioretention basins at Bellamack could operate in the following ways:

- **Seasonally dry bioretention systems**: Allow bioretention vegetation to die back during the dry season. This will need to be carefully integrated with the urban design and aesthetics of the landscape. Suitable vegetation, such as savanna vegetation should be chosen that can survive the dry season without complete die-off.

- **Irrigated bioretention systems**: Irrigate the bioretention system during the dry season. If shallow rooted perennial vegetation which cannot withstand the long dry season are used in the bioretention system and the vegetation is to be maintained during the dry season it will be necessary to irrigate the bioretention system. A non potable source of water is preferable (i.e. harvested stormwater), however using a wastewater source that is high in nutrients is likely to compromise the bioretention system. There are a number of advantages to maintaining the bioretention system vegetation via irrigation, including the ability to cope with sediment and pollutant loads during the first rain events at the beginning of the wet season, reduced risk of wind blown erosion, and landscaping and aesthetic reasons.

- **Non-lined bioretention systems**: Use trees and shrubs which are adapted to tropical savanna conditions, in an un-lined bioretention system. Subject to site-specific considerations, such vegetation would be able to access groundwater during the dry season. Shallow rooted grass and sedge species will 'die back' during the drought season and regenerate during the beginning of the wet season. Hence these bioretention systems will have the appearance of open woodland or forest during the dry season. This option is likely to require irrigation during its initial one or two dry seasons, until the vegetation is established. Unlined systems may not be appropriate at all sites, e.g. they should be avoided in areas with very high wet season groundwater levels. Trees may also be able to survive in shallow lined systems as rooting depths of savanna trees are often in shallow soils less than 1m deep.

Further information on bioretention system design for the Darwin Region is included in the "Treatment Options" discussion paper.

5.3 Bioretention Swales

Bioretention swales are densely planted to create a landscape feature that compliments the general streetscape. In terms of stormwater treatment, the bioretention swales operate in a similar way to the bioretention basins described in the previous section. The key difference is that the surface of a bioretention swale has a slope, whereas the surface of a bioretention basin is typically designed to be flat. Therefore, a bioretention swale is capable of providing a conveyance function as well as a treatment function. The bioretention swales can also be designed to accept drainage from the adjacent lots as well as sheet runoff from the road pavement.

Figure 15 below provides a typical section through a bioretention swale along with examples of bioretention swales integrated into streetscapes.

Within Bellamack bioretention swales can be incorporated into the medians of Forrest Parade and Owston Avenue (33 metre wide landscaped boulevards), the north-south drainage corridor and Strategic Road Links (22m wide road reserves).

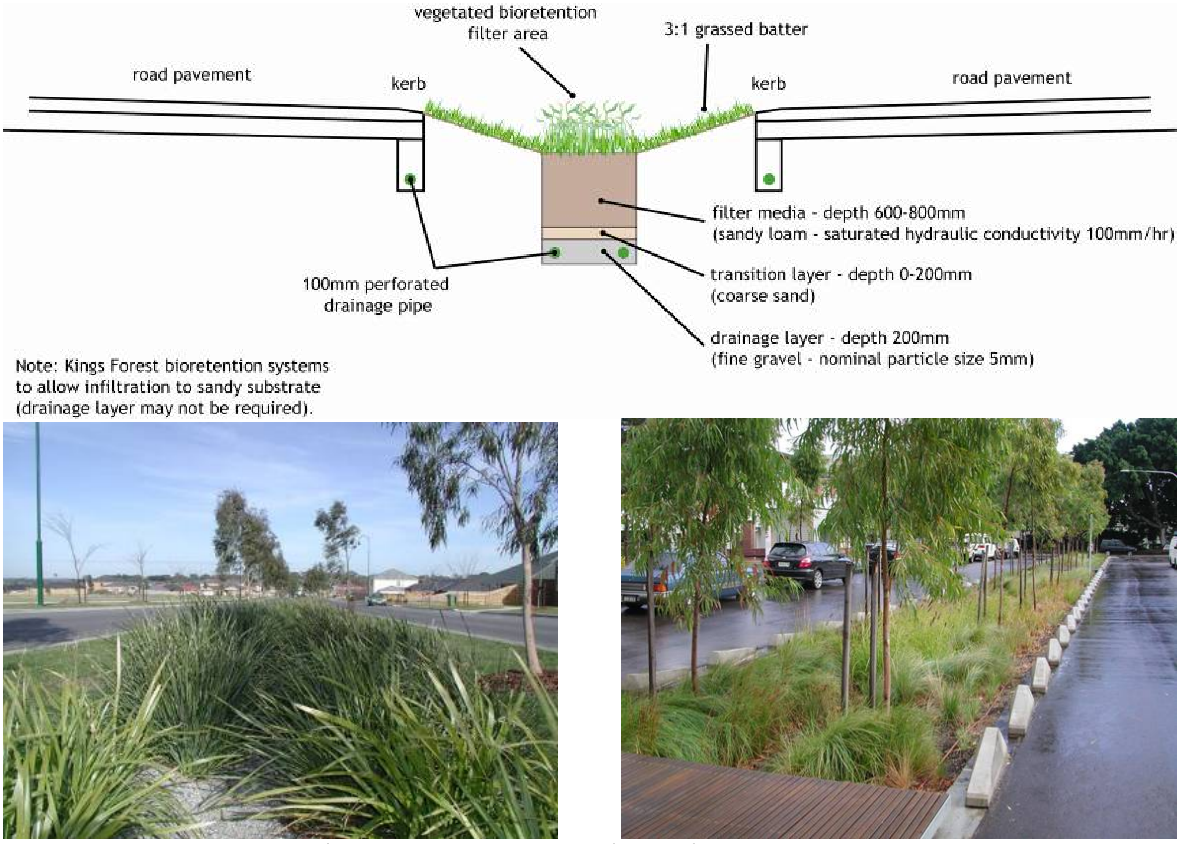

Figure 15: Typical Bioretention Swale Section and examples

6 Potable Water Conservation & Wastewater Minimisation

A conceptual water balance for the future developed Bellamack site is shown in Figure 16. This figure highlights:

- The large consumption of water for outdoor garden irrigation.
- The large volumes of stormwater that fall on the Bellamack catchment during the wet season, the majority of which is runoff as surface flow.
- The volume of wastewater being conveyed back to Palmerston WSP. This volume is similar to the volume being used for outdoor irrigation.

The potable water conservation and wastewater minimisation strategy for Bellamack involves:

- Reducing the demand for water, particularly the outdoor irrigation demand.
- Reusing treated wastewater (ultimate) or groundwater (interim) to supply outdoor irrigation demands
- Minimising wet weather infiltration to the sewerage system.

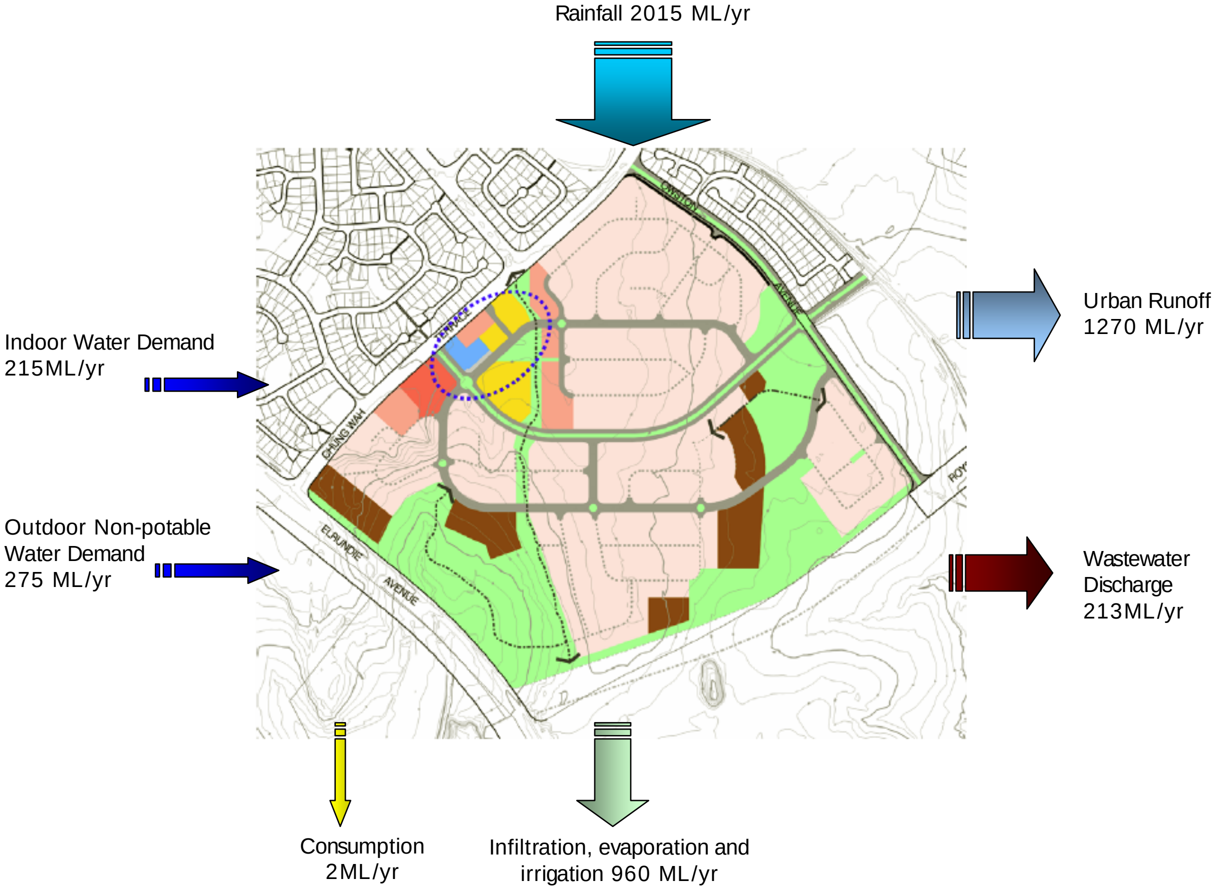

Figure 16: Bellamack Water Balance (traditional water servicing)

6.1 Demand Management

Demand management includes a range of activities including:

- Education and incentives
- Using water efficient fittings and appliances
- Designing landscapes for minimal irrigation requirements
- Metering water use more effectively to provide useful feedback on the activities, processes or systems using significant amounts of water

The NT Power and Water Corporation is already undertaking significant demand management activities, as outlined in Section 2.4.2. The “SaveWater!” Alliance programme has the potential to assist in all of these activities, through providing:

- Education and information resources
- Incentives such as prizes and awards
- Access to low-cost water saving products

The following sections (6.1.1 to 6.1.4) outline potential demand management initiatives recommended for public and private buildings and landscapes in Bellamack.

6.1.1 Public Buildings

The Northern Territory Government and Palmerston City Council have the ability to undertake water conservation in public buildings. Through adopting minimum standards in the procurement processes governments can achieve minimum standard of water efficiency throughout the fixtures and appliances within the building. By promoting water efficient devices, linked to awareness and education campaigns, these buildings can provide a leadership and awareness raising role within the wider community.

It is recommended that the Bellamack development is to adopt and implement potable water conservation measures for public buildings. This will involve:

- <u>Demand management</u> to reduce potable water consumption by applying water efficient appliances and demand reduction strategies. This includes:

  - Mandatory use of 3 star water efficiency fixtures or better for indoor water uses (i.e. kitchen and bathroom sink, basin and shower taps and mixers) for all public buildings
  - Use of 4 star toilets (dual flush toilets) for all public buildings
  - Water efficient gardens (selection of drought tolerant plant species and hydro-zoning, which involves grouping plants with similar water requirements in designated areas or zones)
  - Where possible, smart metering for water should be installed on public buildings, monitoring key water usages within the building such as cooling towers and toilets

6.1.2 Private Buildings

The NT Power and Water Corporation has a good set of material available to promote residential water savings. To build upon and extend this education campaign, particular education techniques to encourage indoor water conservation for Bellamack could include:

- Open house and display home schemes
- Provision of information packs, especially to new home owners. These should include information on the water efficient fittings that have been installed in their home, as well as any other measures they could take to reduce their water demand
- Providing rebates or encouraging industry to offer discounts or other incentives to purchase water efficient appliances. Discount vouchers could be included in new home owner information packs

6.1.3 Private Landscapes

The Northern Territory Power and Water Corporation has released a booklet “How to Create a Water Wise Garden in the Top End”, with useful advice for private gardens. This includes a list of locally indigenous plant species with low water demands. The booklet also contains advice on garden layout, soil improvements, mulching and irrigation techniques.

To further the adoption of water wise gardening techniques, the following methods may be considered:

- Providing information packs, especially to new home owners, including the water wise garden booklet. Garden supplies businesses may be willing to donate samples of their products
- Encourage residents with good examples of water wise gardens to participate in an open garden scheme, to show their garden to others
- Publicise examples where water savings have been made in public open space, to show that government is taking the lead and to set an example to residents

Additionally, a non-potable source of water will be used to irrigate the private landscapes. As described in Sections 6.4, a “third pipe” recycled water reticulation system is to be installed within Bellamack which will ultimately deliver treated wastewater to each allotment for garden irrigation.

6.1.4 Public Landscapes

Public open space landscape practices can adopt endemic and low water using exotic species to reduce the demand for irrigation. Public open space has an important education and awareness raising role within the community. Council and other government agencies can be a leader in changing attitudes to landscapes within the community. Streetscapes in particular are areas that can be easily designed to use little or no water and if designed and constructed well can reduce maintenance and irrigation costs.

Similarly, grassed areas such as sports ovals and golf courses can be designed for lower water use, warm season grasses can use less water than cool season grasses. Design and management practices can both affect water demands.

Design for Bellamack public landscapes:

- Select species with low water demands, adapted to the local climate. Indigenous plants are ideal
- Ensure an adequate depth of topsoil to retain water for plant roots
- Use mulch on garden beds to reduce evaporation

Management of Bellamack public landscapes:

- Regular aeration and top dressing of sports fields helps improve water efficiency
- Soils in the area generally have a low water-holding capacity and hence over-irrigation should be avoided to reduce water loss through seepage or surface runoff

- Some slow-release fertilisers can improve plant water efficiency, although high-nitrogen fertilisers should be avoided, as they encourage excessive plant growth and additional water uptake

Additionally, a non-potable source of water will be used to irrigate the public landscapes (i.e. parklands and streetscapes). As described in Sections 6.4 and 6.5, a “third pipe” recycled water reticulation system is to be installed within Bellamack which will ultimately deliver treated wastewater for public landscape irrigation. In the interim, the “third pipe” system will be supplied with water from groundwater bores and used for public landscape irrigation only.

6.2 Wastewater Reuse and Third Pipe System

The reuse of water involves the matching of available water sources with the most appropriate end uses in order to reduce the demand on high quality potable water. Uses such as irrigation and toilet flushing do not require water that meets potable standards, and alternative sources such as treated wastewater, stormwater or groundwater should be considered. The objective for water reuse at Bellamack is to replace potable water supply with other water sources where the quality is “fit-for-purpose” and the solution is cost effective. As outlined in Section 2.4.2, a recent community survey undertaken by Power and Water indicates there is widespread support for demand management initiatives and the reuse of wastewater.

Considering approximately 65% of the water to be used at Bellamack will be for landscape irrigation (i.e. public open space and private landscapes), the focus of the WSUD strategy for Bellamack is supplying reuse water for irrigation. Ultimately this will involve:

- Upgrading the treatment process at Palmerston WSP to a suitable quality for irrigation reuse (Class A, potentially Class A+). TDS levels for the WSP discharge indicate low levels of salinity which is a key criteria for irrigation reuse. The high levels of BOD and TSS will need to be further reduced. Secondary and tertiary wastewater wetlands may be a cost effective method of treatment if land is available at the WSP. Alternately a packaged treatment plant can be used to polish the wastewater if land take is critical.

- Provision of a “third pipe” recycled water reticulation system within Bellamack to supply treated wastewater from the Palmerston WSP to allotments for garden irrigation uses. There is little extra water savings achieved by plumbing water into the house, therefore, the “third pipe” system will not be connected to indoor uses.

- Provision of a “third pipe” recycled water reticulation system to public landscapes for irrigation purposes.

- Providing a “third pipe” recycled water reticulation system to public buildings for landscape irrigation. Consideration should also be given in these cases to plumbing the ”third pipe” system to toilets due to the potentially higher demand (i.e. public toilets).

- Additionally, wastewater could also be delivered to a variety of local parks and ovals in the vicinity of Bellamack and the pipeline route from Palmerston WSP and Bellamack. Parks that could potentially be irrigated from a non-potable pipeline include:

    - Woodford Park and Oval, Sirius Park, Lockwood Park (> 1.5 Has)

    - Moulden Park (> 1.5 Has)

    - Flack Rd Oval (> 3 Has)

    - Strawbridge Park and Beaumont Park

    - Any future parks to be developed in Rosebery

Based on evapotranspiration data the irrigation demand for these parks is approximately 20ML/mth or 20% of the Palmerston WSP discharge. Demands within Bellamack for wastewater are also significant with approximately 4.1 hectares of open space set aside for parks. This has an irrigation demand of approximately 10 ML/month in the dry season.

It is recommended that feasibility investigations should be undertaken for the provision of a recycled water pipeline from the Palmerston WSP to development within the Palmerston Eastern Suburbs, including Bellamack. While these feasibility investigations are undertaken, it is recommended that the "third pipe" system should be installed in Bellamack, so that the development is ready for the future availability of recycled water. "Third pipe" recycled water systems can be installed easily at the same time as other water infrastructure, however they are difficult and costly to retrofit throughout a development. Retrofit may be feasible to a few major water users (such as irrigated sports fields) however is unlikely to be feasible at a household scale.

The following process indicates the potential staging of recycled water provision to Bellamack and surrounding areas:

1. Install the "third pipe" system throughout Bellamack at the same time as other water infrastructure
2. The "third pipe" recycled water system supplying the private allotments within Bellamack will initially be supplied with potable water. The "third pipe" system connected to the public landscapes and associated WSUD systems will be supplied by a local groundwater bore.
3. Once a regional wastewater network is developed the "third pipe" system to the allotments can be switched to recycled wastewater. The public landscapes can also be switched to recycled wastewater, however bore water will continue to supply irrigation or top-up water to the WSUD systems if this is required
4. Once the regional wastewater network is developed, other existing and future developments in the area can also connect to this system. A regional planning approach should ensure that any trunk infrastructure is sized suitably for the likely future expansion of the system.

6.3 Wastewater Reuse within Buildings

Large buildings such as public facilities have potential opportunities for additional water recycling internally. Greywater and blackwater, as defined in Table 7, may be recycled on site using a package treatment plant. If the "third pipe" system is used to supply irrigation demands, wastewater recycled on-site could be used to supply toilet flushing, cooling towers and other demands.

Table 7: Wastewater types and characteristics

Wastewater type	Source	Quality	Treatment required
"Light" greywater	Showers, baths, bathroom basins	Cleanest wastewater – low pathogens and low organic content	Moderate treatment required to reduce pathogens and organic content
Greywater	As above, plus laundry water, including basin and washing machine	Low quality – high organic loading and highly variable depending on how it was used	High level of treatment required to reduce pathogens and organic content
Blackwater	As above, plus kitchen, toilet and bidet water. Can also be sourced from sewers	Lowest quality wastewater – high levels of pathogens and organics	Advanced treatment and disinfection required

One example of a public building that utilises water recycling on site is the City of Melbourne's "CH2" building, which recycles water from a mains sewer for use in toilet flushing, irrigation and cooling demands.

6.4 Groundwater Bore

The aquifer located beneath Bellamack forms an important part of the WSUD Strategy. Discussions with NRETA indicate the aquifer has significant spare capacity and it is proposed the aquifer is accessed via bore(s) on Bellamack for the following purposes:

- To supply irrigation water to public landscapes and parklands until the regional wastewater recycling network is established. Bores can either plumb water into the relevant part of the "third pipe" system servicing the landscape and parklands or a series of bores can be established within the parks for direct use. Once the regional wastewater network is developed the public landscapes can be switched to recycled wastewater.

- To supply irrigation and top-up water to the WSUD systems if this is required. Recycled water should not be used for this purpose for a number of reasons, therefore, bores will continue to supply these end uses.

There exists a minor risk that the aquifer will not provide a suitable long term supply of water. Future recharge of the aquifer may be affected by development over the recharge zone and climate changes may also change season recharge rates. Designs of WSUD elements in Bellamack should be flexible to accommodate future recharge of the aquifer (i.e. plumbing treated urban stormwater to the aquifer), if monitoring indicates that full recharge of the aquifer is not occurring.

6.5 Low Infiltration Sewers

There is significant wet weather infiltration and ingress into the sewer system. Average wet season flows into Palmerston WSP are 200 to 300% more than inflows during the dry season. This infiltration and ingress creates operational and environmental concerns. Controlled and uncontrolled overflows from the system can have significant impacts on receiving waters and the reduced treatment received at the WSP, because of reduced detention time.

In order to minimise wet weather infiltration to the sewer, it is proposed the wastewater collection system will be designed as a reduced infiltration (i.e. NuSewer, Smart Sewer) wastewater system. These systems reduce the overall volume of wastewater during the wet season, reducing the size of the wastewater collection and conveyance systems, the required Palmerston WSP upgrade requirements and ultimately the amount of wastewater discharged to the harbour.

There exist design and construction standards for these sewer systems, and extensive experience in construction and operation, which can be readily adopted by the Northern Territory Government and Power and Water to implement the initiative (http://www.brisbane.qld.gov.au/bccwr/lib85/nusewers_design_and_construction_specification_v2_rev1.pdf).

7 References

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Appendix A: Wetland Function and Design Considerations

Wetlands are a common treatment measure used to treat stormwater runoff in temperate climates. Constructed wetland systems are shallow, extensively vegetated water bodies that use enhanced sedimentation, fine filtration and biological uptake processes to remove pollutants from stormwater. Water levels rise during rainfall events and outlets are configured to slowly release flows, typically over two to three days, back to dry weather water levels. In addition to treating stormwater, constructed wetlands can also provide habitat, passive recreation, improved landscape amenity and temporary storage of treated water for reuse schemes.

Wetlands generally consist of an inlet zone (sedimentation basin to remove coarse sediments), a macrophyte zone (a shallow heavily vegetated area to remove fine particulates and uptake soluble pollutants) and a high flow bypass channel (to protect the macrophyte zone from scour and vegetation damage). Figure 17 shows the key elements of constructed wetland systems.

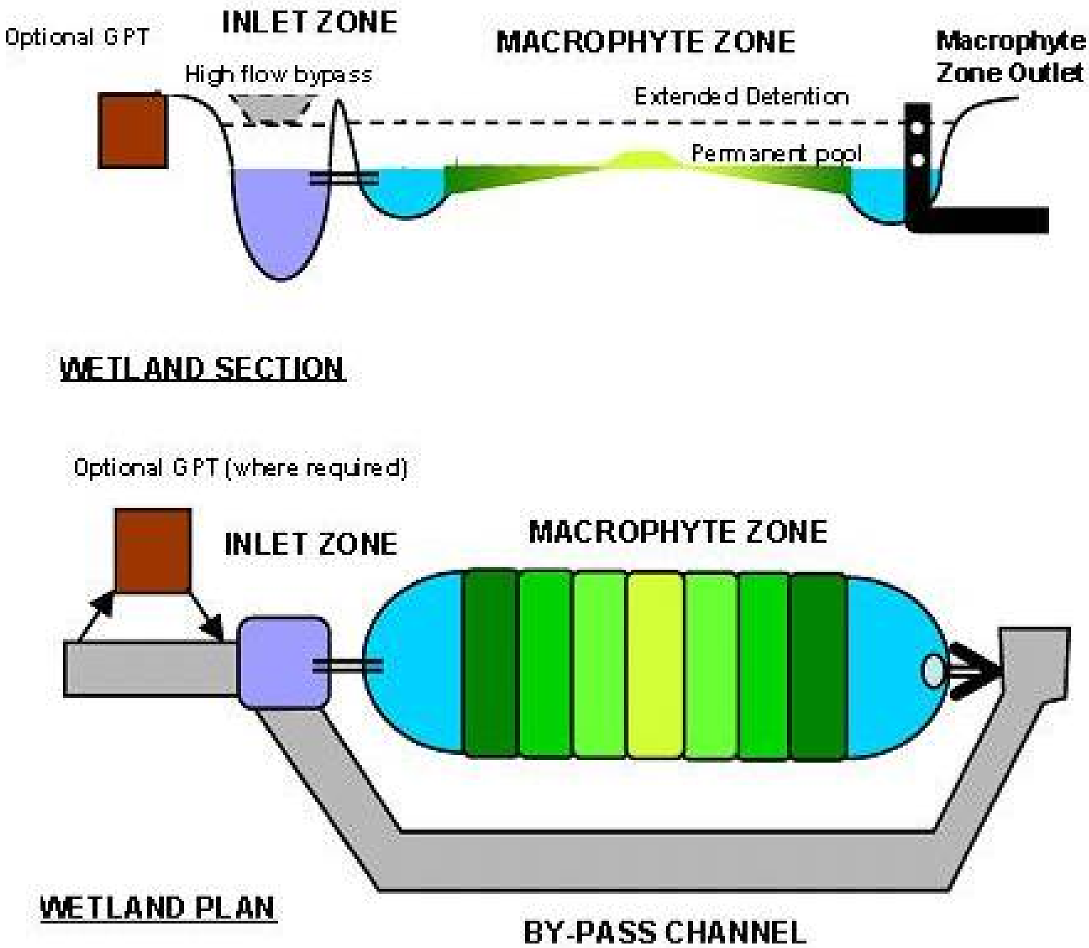

Figure 17: Schematic section and plan of a constructed wetland

Table 8, detailing constructed wetland design considerations, is reproduced from the *Water Sensitive Urban Design Stormwater Treatment Options for Darwin* Discussion Paper (prepared by EDAW for the NT Department of Planning and Infrastructure, October 2007). It summarises the key design issues for constructed wetlands, based on the *WSUD Technical Design Guidelines for South East Queensland* (Healthy Waterways Partnership, 2006).

In addition to the general design issues tabulated here, there are other key issues in Darwin's wet-dry tropical climate:

- Wetland sizing in Darwin may need to be larger than in southern Australia, to achieve the same treatment results
- Hydraulic design will need to cope with high and regular wet season inflows. It may not be feasible to achieve detention times of 72 hours
- Local plants will need to be selected for the macrophyte zone, which can tolerate a wide fluctuation between wet season and dry season hydrologic conditions
- Weed management will need to consider locally significant weed species
- Algal blooms are a particular risk during the dry season
- Mosquito control will be particularly important during the dry season when wetlands can potentially reduce to small pools with no outflow
- Waterlogged soils are a particular issue in low-lying areas around Darwin.

These issues and potential management measures are discussed further in the "Treatment Options" Discussion Paper (EDAW, 2007).

Table 8: Design considerations for constructed wetlands

Design issue	Key considerations
Landscape design	Constructed wetlands are often located within accessible open space areas and can become interesting community features. Landscape design aims to ensure that marsh planting fulfils the intended stormwater treatment function as well as integrating with their surrounds. Opportunities to enhance public amenity and safety with viewing areas, pathway links, picnic nodes and other elements should be exploited. Community education through signage and public art can also be explored. It is important that the landscape of constructed wetlands addresses stormwater quality objectives whilst being sensitive to these other important landscape aims.
Detention time and hydrologic effectiveness	Hydrologic effectiveness is a measure of the mean annual volume of stormwater runoff captured and treated within the wetland and is expressed as a percentage of the mean annual runoff volume generated from the contributing catchment (it should be greater than 80 % for well designed wetlands). Detention time is the time taken for each 'parcel' of water entering the wetland to travel through the macrophyte zone assuming 'plug' flow conditions. Detention time influence's a wetland's pollutant removal efficiency and it is recommended that the notional detention time should be approximately 72 hours to remove nutrients effectively from urban stormwater.
Hydrodynamic design	Poor wetland hydrodynamics is often identified as a major contributor to wetland operational and management problems. The general wetland layout, selection of plant species and design of inlet, outlet and bypass structures all influence a wetland's hydrodynamics. Good hydrodynamic design will encourage: • Uniform distribution of flow velocity, to avoid stagnant areas or short circuit flowpaths • Wetlands sized appropriately for their catchments and with suitable depths to ensure regular flows through the system and a wetting and drying pattern that suits each vegetation zone • Uniform vertical velocity profile, to avoid stratification • Protection from scouring during periods of high flows

Design issue	Key considerations
Inlet zone and high flow bypass	The inlet zone of a constructed stormwater wetland is designed as a sedimentation basin. Its primary role is to remove coarse to medium sized sediment (i.e. 125 µm or larger) prior to flows entering the macrophyte zone. This ensures the vegetation in the macrophyte zone is not smothered by coarse sediment. Large wetlands also usually require a gross pollutant trap as part of the inlet zone, to target litter and debris. The second role of the inlet zone is the control and regulation of flows entering the macrophyte zone. The outlet structures from the inlet zone are designed such that flows up to the 'design flow' (typically the 1 year ARI) enter the macrophyte zone whereas 'above design flows' are bypassed around the macrophyte zone. This protects the macrophyte zone vegetation against scour during high flows. Note that when space is constrained, the size of the inlet zone should not be reduced – the macrophyte zone area should be reduced if necessary.
Macrophyte zone	The layout of the macrophyte zone needs to be configured such that system hydraulic efficiency is optimised and healthy vegetation sustained. Design considerations include: • The preferred extended detention depth is 0.5 m. Deeper extended detention depths up to a maximum of 0.75m may be acceptable • The bathymetry of the macrophyte zone should be designed to promote a sequence of ephemeral, shallow marsh, marsh and deep marsh zones in addition to small open water zones • The macrophyte zone is required to retain water permanently and therefore the base must be of suitable material to retain water (e.g. clay or synthetic liner) • The bathymetry of the macrophyte zone should be designed so that all marsh zones are connected to a deeper open water zone to allow mosquito predators to seek refuge in the deeper open water zones during periods of extended dry weather • Particular attention should be given to the placement of the inlet and outlet structures, the length to width ratio of the macrophyte zone and flow control features to promote a high hydraulic efficiency within the macrophyte zone • Provision to drain the macrophyte zone for water level management during the plant establishment phase should also be considered • The macrophyte zone outlet structure needs to be designed to provide a notional detention time (usually 72 hours) for a wide range of flow depths. The outlet structure should also include measures to exclude debris to prevent clogging

Appendix B: Bioretention System Function and Design Considerations

Bioretention systems can be configured as basins (or rain gardens), planter boxes, street trees, or in the base of swales. Bioretention systems are vegetated areas where runoff is filtered through a filter media layer (e.g. sandy loam) as it percolates downwards. It is then collected in a drainage layer via perforated under-drains and flows to downstream waterways or to storages for reuse. Bioretention basins typically use temporary ponding of 0.2-0.4 m depth above the filter media surface to increase the volume of runoff treated through the filter media. Flows above the design flow are conveyed through overflow pits or bypass paths. This has the advantage of protecting the filter media surface from high velocities that can dislodge collected pollutants or scour vegetation.

Vegetation plays a key role in bioretention systems. The surface is densely planted with ground level grasses and rushes and may also contain selected tree and shrub species. The agitation of the surface of the bioretention basin caused by movement of the vegetation and the growth and die off of root systems prevents accreted sediments clogging the filtration media. Beneath the surface, vegetation provides a substrate for biofilm growth within the upper layer of the filter media. Vegetation facilitates the transport of oxygen to the soil and enhances soil microbial communities which enhance biological transformation of pollutants.

Bioretention basins are generally not intended to be 'infiltration' systems that discharge from the filter media to surrounding in-situ soils. Rather, the typical design intent is to recover stormwater at the base of the filter media in perforated under-drains and discharge to receiving waterways or to storages for potential reuse. In some circumstances however, where the in-situ soils allow and there is a particular design intention to recharge local groundwater, it may be desirable to allow stormwater to infiltrate from the base of a filter media to underlying in-situ soils.

A typical bioretention system is shown in Figure 18.

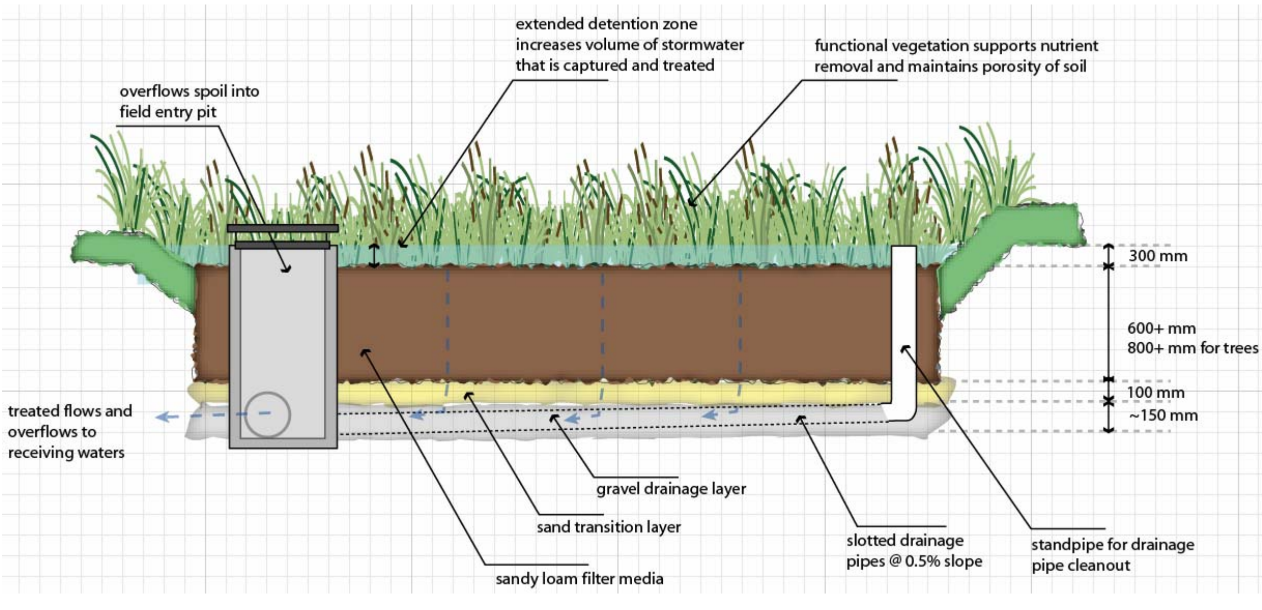

Figure 18: Typical section through bioretention basin

Table 9, detailing bioretention system design considerations, is reproduced from the *Water Sensitive Urban Design Stormwater Treatment Options for Darwin* Discussion Paper (prepared by EDAW for the NT Department of Planning and Infrastructure, October 2007). It summarises the key design issues for bioretention systems, based on the *WSUD Technical Design Guidelines for South East Queensland* (Healthy Waterways Partnership, 2006).

In addition to the general design issues tabulated here, there are other key issues in Darwin's wet-dry tropical climate:

- Bioretention systems will be subject to relatively constant loading during the wet season and long periods without water during the dry season. The systems will need to be vegetated with plants that can tolerate this wide variation in conditions
- Prolonged drying and continuous loading can both reduce bioretention system performance and reduce the efficiency of pollutant load removal, or even result in pollutant leaching
- Bioretention systems can be damaged by high loads of coarse sediment, which could be a potential issue in large storm events during the wet season
- In areas of waterlogging or shallow water tables, bioretention system design will need to consider interaction with groundwater

These issues and potential management measures are discussed further in the "Treatment Options" Discussion Paper (EDAW, 2007).

Table 9: Design considerations for bioretention systems

Design issue	Key considerations
Landscape design	Bioretention systems are predominantly located within public areas, such as open space or within streets, which provide a primary setting for people to experience their local community and environment. It is therefore necessary for bioretention systems to be given an appropriate level of landscape design consideration to complement the surrounding landscape character. The landscape design of bioretention systems must address stormwater quality objectives whilst also being sensitive to other important landscape objectives such as road visibility, public safety and community character and habitat.
Hydraulic design	The correct hydraulic design of bioretention basins is essential to ensure effective stormwater treatment performance, minimise damage by storm flows, and to protect the hydraulic integrity and function of associated minor and major drainage systems. The following aspects are of key importance: • The finished surface of the bioretention filter media must be flat to ensure even distribution of flows and avoid scouring or rutting of the surface • Temporary ponding (i.e. extended detention) over the surface of the bioretention filter media should be created through the use of raised edges • Distributed inflows should be encouraged, so as to limit the risk of scour and erosion at inlets • Where possible, the overflow pit or bypass channel should be located near the inflow zone to prevent high flows passing over the surface of the filter media. If this is not possible, then velocities should be minimised to avoid scouring of the filter media and vegetation. • Where the field inlets in a bioretention system are required to convey the minor storm flow (i.e. is part of the minor drainage system), the inlet must be designed to avoid blockage, flow conveyance and public safety issues. • For streetscape applications, the design of the inflow to the bioretention basin must ensure the kerb and channel flow requirements are preserved
Exfiltration	Bioretention basins can be designed to either preclude or promote ex-filtration of treated stormwater to the surrounding in-situ soils. When considering ex-filtration to surrounding soils, the designer must consider site terrain, hydraulic conductivity of the in-situ soil, soil salinity, groundwater and building setback. To preclude ex-filtration, the bioretention basin may need to be provided with an

Design issue	Key considerations
	impermeable liner around the base and sides of the drainage layer (unless the in situ soils are relatively impermeable). Flexible membranes or a concrete casting are commonly used to prevent excessive ex-filtration. Ex-filtration of treated stormwater to the surrounding soils can be encouraged at sites where the in situ soils have a higher permeability than the filter media and the site conditions are suitable for infiltration. A liner may be required around the sides of the bioretention system to prevent short-circuiting of the system.
Vegetation types	Vegetation is required to cover the whole bioretention filter media surface, be capable of withstanding minor and major design flows, and be of sufficient density to prevent preferred flow paths, scour and re-suspension of deposited sediments. Ground cover vegetation (e.g. sedges and tufted grasses) is an essential component of bioretention basin function. Generally, the greater the density and height of vegetation planted in bioretention filter media, the better the treatment provided especially when extended detention is provided for in the design.
Filter media	Selection of an appropriate bioretention filter media is a key design step that involves consideration of the following three inter-related factors: • Saturated hydraulic conductivity required to optimise the treatment performance of the bioretention system, given site constraints and available filter media area. • Depth of extended detention provided above the filter media. • Suitability as a growing media to support vegetation (i.e. retains sufficient soil moisture and organic content). Bioretention media can consist of three layers. In addition to the filter media required for stormwater treatment, a drainage layer is also required to convey treated water from the base of the filter media into the perforated under-drains. The drainage layer surrounds the perforated under-drains and can be either coarse sand (1 mm) or fine gravel (2-5 mm). If fine gravel is used, a transition layer of sand must also be installed to prevent migration of the filter media into the drainage layer and subsequently into the perforated under-drains.
Mulch	To help prevent erosion, discourage weed establishment and to improve aesthetics of bioretention systems, it is common to use a rock mulch or similar non-buoyant mulch on the surface of the bioretention system. Mulches can also help bioretention systems maintain soil moisture between rainfall events.
Traffic controls	Another design consideration is keeping traffic and building material deliveries off bioretention systems, particularly during the construction phase of a development. If bioretention basins are driven over or used for parking, the filter media will become compacted and the vegetation damaged. As they can cause filter media blockages, building materials and wash down wastes should also be kept out of the bioretention basin. To prevent vehicles driving on bioretention basins, and inadvertent placement of building materials, it is necessary to consider appropriate traffic control solutions as part of the design. These can include dense vegetation planting that will discourage the movement of vehicles onto the bioretention basin or providing physical barriers such as bollards and/ or tree planting. Streetscape bioretention systems must be designed to satisfy local authority requirements with respect to traffic calming devices within particular street or road reserve widths. Where bioretention is incorporated into traffic calming or control devices, or directly adjacent to mountable kerbs, consideration should be given to protection of the area immediately behind the kerb where vehicles are likely to mount the kerb.
Services	Bioretention basins or cells located within road verges or within footpaths must consider the standard location for services within the verge and ensure access for maintenance of services without regular disruption or damage to the bioretention system.