

RPS

DRAINAGE AND WETLAND MANAGEMENT PLAN

Stage 2 Cockburn Central



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SUMMARY

LandCorp is proposing to develop Cockburn Central Stage 2 which comprises Lots 1, 2, 5 and 6 Cockburn Central (Figure 1). All drainage from Stages 1 and 2 is proposed to be discharged to the west side of Midgegooroo Avenue to a stormwater treatment system within the adjacent lot (9504 Beeliar Drive). The treatment area is zoned "Regional Centre" under the City of Cockburn's Town Planning Scheme. The stormwater detention and infiltration basin will cater for up to 1:1 year Average Recurrence Interval (ARI) rainfall events. Larger events will overflow via the treatment train to the existing UFI 6659 Resource Enhancement wetland. The combined capacity of this system is up to a 1 in 100 year ARI event. A portion of the wetland is also listed under the *Environmental Protection (Swan Coastal Plain Lakes) Policy*. The drainage concept has formed part of the original plans for the Cockburn Central development and has been agreed with the Western Australian Planning Commission (land owner) and the City of Cockburn, subject to detailed design. Cockburn Central Stage 1 received subdivision approval in 2006 and Cockburn Central Stage 2 received subdivision approval in 2011.

RPS has been commissioned by Landcorp to prepare a Drainage and Wetland Management Plan to demonstrate that the Cockburn Central development will effectively manage stormwater whilst retaining and improving the environmental values of the wetland. Drainage on the site will incorporate the following:

- directing stormwater run-off from the high density Cockburn Central development through Gross Pollutant Trap and hydrocarbon trap to a detention and infiltration basin west of Midgegooroo Avenue.
- the created basin will provide standing water habitat for three to four months of the year providing additional wetland habitat type not currently represented on-site. Through the subsequent development of Cockburn Central West, permanent standing water in this basin may become a feature through lining of the basin. This will then act as a drought refuge for water birds and provide high aesthetic value to the local community in addition to providing a potential source of irrigation water from harvested stormwater. (Design and approval will be subject to more detailed assessment by the City of Cockburn and relevant stakeholders).
- road drainage within the Cockburn Central development area will incorporate a network of pipes and pits allowing for some infiltration through the use of open pit bases. The pipe system will flow to a Gross Pollutant Trap (GPT) and hydrocarbon trap prior to discharging to the basin.
- the detention and infiltration basin will accommodate up to a 1 in 1 year Average Recurrence Interval (ARI) event overflow to a connecting treatment train.
- the treatment train will discharge to the rehabilitated Resource Enhancement Wetland. To ensure maintenance of the rehabilitated wetland, trickle feed under the weir and the treatment train to the wetland will occur while sufficient standing water remains in the basin.

- during the development of Cockburn Central West (separate development subject to separate approvals), an overflow pipe will be constructed at approximately 24.7 m AHD to limit the maximum water height to a 1 in 100 year storm event in the basin and wetland system. Greater than this will empty into the Jandakot – Arterial Drainage Scheme.

To ensure the wetland water quality is not impacted by this drainage, native vegetation will be included in the treatment train, wetland rehabilitation works and surrounding riparian area to help prevent erosion, maintain soil infiltration, restrict water flows and remove particulate and soluble pollutants, particularly nitrogen. The plants will be appropriately selected based on their intended function within the treatment train and wetland using native vegetation. Existing heavy infestations of the wetland weed *Typha* will be treated prior to rehabilitating the wetland and the Victorian Tea Tree that occurs in the northern end of the wetland will also be treated and removed.

Midgegooroo Avenue forms an existing edge and buffer to the wetland on the eastern side, and rehabilitation to approximately the 25 m AHD contour will occur with riparian species around the existing wetland (refer to Figure 7). This will provide an additional 20,000 m² of riparian habitat around the wetland and the basin and 26,000 m² of wetland habitat.

A pedestrian access track around the constructed basin links to Midgegooroo Avenue and the informal track network throughout the site to enhance the recreational opportunities in this area. It is envisaged that this will be further upgraded as part of the planning for Cockburn Central West.

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1.0 INTRODUCTION

1.1 Background

LandCorp is proposing to develop Cockburn Central Stage 2 which comprises Lots 1, 2, 5 and 6 Cockburn Central (Figure 1). The site is within the City of Cockburn and is situated north of Beeliar Drive, west of Kwinana Freeway, south of Tea Tree Close and east of Polletti Road, approximately 16 km south of the Perth CBD (Figure 1)

Stage 1 of Cockburn Central has already been developed. During development of Stage 1, in order to cater for the stormwater runoff from the site, a temporary drainage basin was constructed within the Stage 2 area on Lot 1. Stage 2 has now received subdivision approval and requires the temporary basin to be moved to allow site works to commence. All drainage from Stage 1 and 2 is proposed to be discharged off site through a Gross Pollutant Trap (GPT) and hydrocarbon trap to a detention and infiltration basin to the west of Midgegooroo Avenue in Lot 9504 Beeliar Drive, that will accommodate up to one in one year Average Recurrence Interval (ARI) rainfall event. Larger events will overflow through the treatment train to the existing UFI 6659 Resource Enhancement wetland. The system will be able to accommodate up to a 1 in 100 year ARI event. As part of the (separate) Cockburn Central West development, an overflow pipe will be constructed at approximately 24.7 m AHD to limit the maximum water height to a 1 in 100 year storm event. Greater than this will discharge into the Jandakot – Arterial Drainage Scheme. (Construction of drainage works for Cockburn Central West, including the overflow, will be the subject of separate approvals once concept design for the development has further progressed).

The design concept allows for standing water in the basin for at least three to four months of the year providing trickle feed under the constructed weir to supplement the rehabilitated Resource Enhancement wetland. The harvested stormwater will also provide an opportunity to supplement the irrigation needs for the Cockburn Central West project which is currently undergoing structure planning. The drainage treatment and wetland supplement concept formed an integral part of the original plans for the Cockburn Central project.

RPS has been commissioned by Landcorp to prepare a Drainage and Wetland Management Plan to demonstrate that the site will effectively manage stormwater whilst improving the environmental values of the wetland.

1.2 Planning and Design Objectives

This Management Plan is consistent with the objectives and design philosophies discussed in Arterial Drainage Scheme Review for Cockburn Central and Solomon Road Development Areas that was undertaken by David Wills and Associates in 2004 and has been developed with reference to current statutory and guidance documents including:

- Statement of Planning Policy 2.1: The Peel Harvey Coastal Catchment (WA Planning Commission)
- Water Quality Improvement Plan for the Rivers and Estuary of the Peel-Harvey System – Phosphorus Management, (Environmental Protection Authority 2008)
- Peel-Harvey WSUD Local Planning Policy & WSUD Technical Guidelines (Coastal Catchment Initiative 2006)
- Better Urban Water Management (WAPC 2008)
- Urban Water Management Plans: Guidelines for preparing plans and for complying with subdivision conditions (Department of Water (DoW) 2008)
- Stormwater Management Manual for Western Australia (Department of Water 2004–2007)
- Waterwise Land Development Criteria (draft) (Water Corporation and LDIWA 2007)
- Interim: Developing a Local Water Management Strategy (Department of Water 2008)
- Western Australian State Water Plan (Government of Western Australia 2007)
- Water Quality Protection Note 52: Stormwater Management at Industrial Sites (DoW 2010).

The design objectives for water management at the site are:

- Maintain and if possible improve water quality (surface and groundwater) within the development in relation to pre-development water quality.
- Promote infiltration of surface water at or near to source to minimise the risk of further water quality degradation and maintain wetland function.
- Incorporate where possible, low maintenance, cost-effective landscaping and stormwater treatment systems.
- Improve existing wetland values by wetland rehabilitation, increasing diversity of wetland habitat and controlling land uses and practices that are inconsistent with maintenance of wetland values.

1.3 Better Urban Water Management

The *Better Urban Water Management* report by the WAPC, Department for Planning and Infrastructure, DoW, DEWHA and the Western Australia Local Government Association was released in 2008. The Cockburn Central Development subdivision plan was approved prior to this date and as such there were no specific conditions relating to the preparation of District of Local Water Management Strategies or an Urban Water Management Plan.

However the requirements of an Urban Water Management Plan have been addressed in this and accompanying documents. These include:

- identification of wetland areas and buffer zones
- pre-development groundwater monitoring
- flora and fauna survey at the appropriate time
- site investigations for infiltration, contamination and Acid Sulfate Soils
- map groundwater levels, nutrient sources and pollutant pathways
- modelling of 1 in 1 year ARI events and up to 1 in 100 year ARI events to ensure sufficient capacity
- irrigation and water efficiency strategies.

The subsequent Cockburn Central West development that is currently in the structure planning stage will also provide further detailed drainage design and management as part of the necessary approvals for that project, in consideration of the management of water for the Cockburn Central development.

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2.0 EXISTING ENVIRONMENT

2.1 Location

Cockburn Central is a transit orientated development located adjacent to the Kwinana Freeway and Perth to Mandurah rail line in the City of Cockburn, 16 kilometres south of Perth.

Stage 1 of the site is in advanced stages of construction. Stage 2 is currently cleared for development as discussed in Section 1.1 and has historically been used for agricultural grazing. The reserve adjacent to the site has been historically cleared for agriculture but has been left unmanaged since the 1980s and the reserve contains a Resource Enhancement wetland and EPP Lake that is heavily infested with invasive wetland weeds.

2.2 Topography

Topography on the site ranges from 25 m AHD to 33 m AHD and slopes in a north-westerly direction. Topography in the vicinity of the Resource Enhancement wetland is 22.75 m AHD (Figure 2).

2.3 Geology and Soils

Environmental geology mapping across the site shows the geology as comprising the following:

Ms5 – SANDY SILT, dark brownish grey silt with disseminated fine grained quartz sand, firm variable clay content, of lacustrine origin.

S8 – SAND, very light grey at surface, yellow at depth, fine to medium grained, sub rounded quartz, moderately well sorted, of eolian origin.

S10 – SAND, relatively thin veneer over strong, blocky brown silts and clays.

RPS installed a number of groundwater monitoring bores on the site and the bore logs are provided in Appendix I.

2.4 Acid Sulfate Soils

The WA Atlas identifies the majority of the site as being within a Class 2 area, which is defined as moderate to low ASS disturbance risk at less than three metres from the ground surface. A small section of the site, within the vicinity of the Resource Enhancement wetland is classified as high to moderate risk (refer Appendix 2).

RPS is preparing an *Acid Sulfate Soils and Dewatering Management Plan* for the Cockburn Central Stage 2 development, including the drainage area. Acid Sulfate Soils that exceed DEC ASS guidelines have been recorded at 5 sites but generally at depths greater than 1.75 mbgl which will not be disturbed by this development. The report has been reviewed by DEC and is currently undergoing amendments. The final report will be approved by DEC.

2.5 Surface Water Hydrology

2.5.1 Surface Drainage

The site is located just within the northern border of the Coastal (North) sub catchment of the surface water catchment of the Peel–Harvey Estuary.

There is currently an existing pipe and open drainage system along North Lake Road from Kentucky Court to Berrigan Drive that discharges into Lake Yangebup as part of the Jandakot – Arterial Drainage Scheme. These drains are relatively shallow and are water logged throughout winter as they pick up both surface and groundwater flows from the general area.

2.5.2 Wetlands

DEC wetland mapping shows a Resource Enhancement wetland (REW) (UFI 6659) occurring over 9504 Beeliar Drive and Lots 5 and 8 (Figure 3). The wetland is currently in poor condition and the wetland and surrounding reserve is heavily infested with invasive weeds with some existing native wetland species. Historical aerials show that the wetland and surrounding area was cleared prior to 1965 and the banks of the lake area also appear to have been altered at this time (Figure 4).

The mapped REW has been cleared for development to the east of North Lake Road.

Sections of this wetland are also classified as an EPP Lake under the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992*; as such the following restrictions apply (unless prior written approval from the EPA):

- No partial or whole fill of an EPP Lake is permitted.
- No excavation or mining of an EPP Lake is permitted.
- No discharge or disposal of effluent into an EPP Lake is authorised under the Act.

The REW does not have the same environmental values or high regional significance of wetlands such as Yangebup Lake, Thompsons Lake, Bibra Lake, Kogolup Lake and Little Rush Lake which all occur within 5 km of the site and are better protected and have larger reserves.

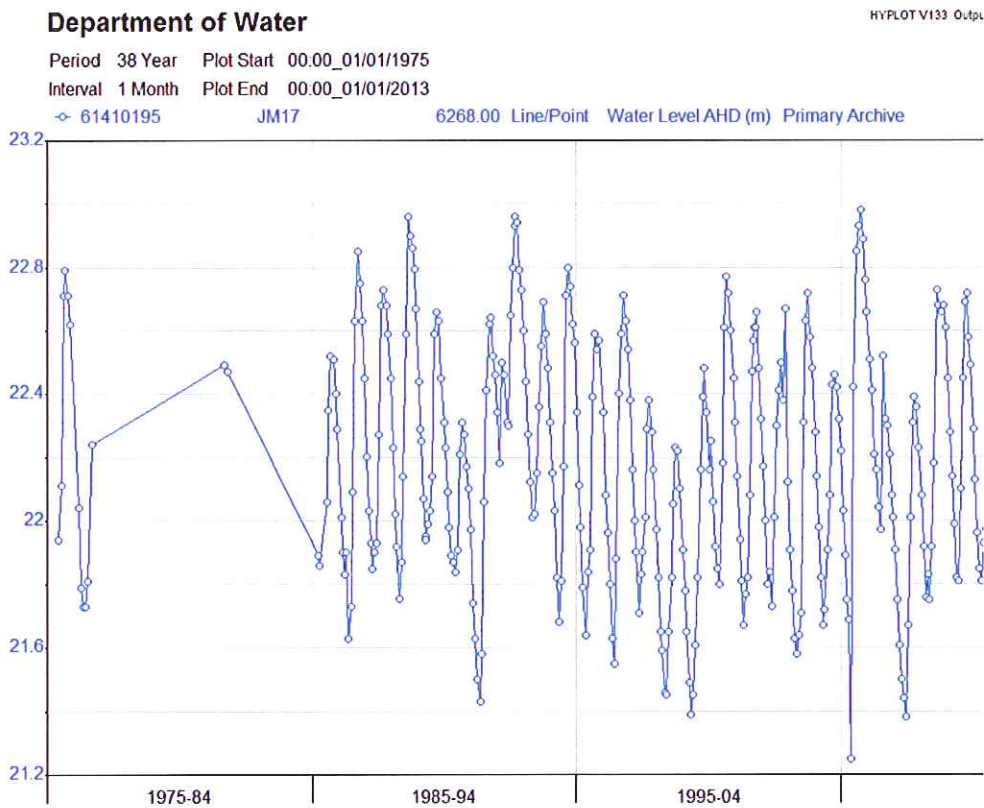
2.6 Hydrogeology

2.6.1 Groundwater Levels and Flow

In 2010, six groundwater monitoring bores were installed within the Stage 2 Cockburn Central Development and west of Midgegooroo Avenue (Figure 5). Groundwater depth at installation ranged between 1.4 m bgl and 11.8 m bgl (corresponding to 23.7 m AHD and 22.2 m AHD).

The Perth Groundwater Atlas shows groundwater ranging on the site between 23 m AHD (3 to 7 m bgl) and 24 m AHD (7 to 7.5 m bgl) which generally corresponds with data collected on site (ranging from 21.2 m AHD to 24.6 m AHD). Groundwater depth at the RE wetland ranged from 22.7 m AHD just prior to winter rains to 23.8 m AHD following spring rainfall. Groundwater on the site generally flows in a westerly direction (Figure 5).

The Cockburn Central Wetland and Drainage report reviewed a number of Water and Rivers Commission and Water Corporation Monitoring bores to validate the regional groundwater levels. The hydrograph from the closest DoW bore 61410195 (JM 17) with over 35 years of data is shown in Graph 1 below. The hydrograph suggests the monitoring period was within ± 30 cm of AAMGL for the last 10 years in this region.



Graph 1: Hydrograph for WIN Bore 61410195 (JM 17)

David Willis and Associates used the AMGLs observed to create the “Design Regional Groundwater Levels”. The Groundwater atlas was used to assist in providing the shape of the contours. The design regional groundwater levels within the vicinity of the development are between 23 and 24 m AHD. Refer to Figure 6 for details.

2.6.2 Groundwater Protection

The site occurs less than 0.5 km to the north-west of a P3 Groundwater Protection Area. However as groundwater at the site flows away from this area the development is unlikely to have any impact on water quality in the P3 area.

3.0 SURFACE WATER AND GROUNDWATER MANAGEMENT

3.1 Drainage Plan

The site will effectively manage stormwater through the implementation of WSUD principles and BMPs to control water quality and quantity from both minor and major storm events.

In accordance with the Stormwater Management Manual for Western Australia (DoW 2004–2007), the drainage system will aim to achieve the following objectives:

- The rehabilitation of the functions of the Resource Enhancement wetland (REW) located west of Midgegooroo Avenue. The wetland is currently seasonal and will remain a seasonal wetland post-development.
- Improve stormwater quality, as compared to a development that does not actively manage stormwater.
- Rainfall will be infiltrated through the use of bottomless pits and overflow directed through Gross Pollutant Trap (GPT) and hydrocarbon trap to a detention and infiltration basin west of Midgegooroo Avenue (Refer Figure 7).
- Rainfall up to a 1 in 1 year ARI event will be retained within the detention and infiltration basin. Greater than 1 in 1 year events will overflow the inlet basin through the constructed weir and be conveyed through the use of a stormwater treatment train shown in Figure 7. The treatment train empties to the RE wetland, supplementing the groundwater fed wetland.
- The basin floor will be constructed at 23.5 m AHD which will provide additional seasonal standing water habitat for three to four months of the year. The basin will dry over the summer / autumn months preventing water quality issues associated with shallow water during warm and sunny days.
- As part of the Cockburn Central West Project (unrelated to this project) an overflow pipe will be constructed at approximately 24.7 m AHD to limit the maximum water height to a 1 in 100 year storm event. Greater than this will empty into the Jandakot – Arterial Drainage Scheme.

3.2 Stormwater Management

3.2.1 Minor Events

Design of the drainage system focuses on protecting and enhancing the wetland by treating stormwater prior to supplementing groundwater in small events and enhancing wetland flows in larger events with the aim of improving the environmental values of the wetland that have been degraded through a lack of formal management and years of below average rainfall. Small events will be retained on site and infiltrated as close to source as possible through the use of the following practices:

- All lots will confine run-off from roofs and paving within the property boundary through the use of soakwells in lot boundaries.
- Drainage infrastructure will incorporate bottomless pits and leaky pipes where possible to maximise close to source infiltration. Additional runoff will be conveyed via a piped system through a GPT and hydrocarbon trap to the drainage and infiltration basin west of Midgegooroo Avenue, sized to cater for up to 1 in 1 year ARI or 12,120 m³.

3.2.2 Greater than 1:1 Year Event

During events greater than the 1 in 1 year ARI, stormwater will overtop the constructed weir and through the vegetated treatment train emptying into the RE wetland.

The wetland and infiltration basin areas, including riparian zones, will be rehabilitated with native species to replace much of the wetland values that have been lost from this system due to agricultural clearing, weed invasion and uncontrolled recreational vehicle use through the area.

3.2.3 Greater than 1:100 Year Event

The wetland area and infiltration basin, including surrounds, can retain up to a 1 in 100 year ARI event. With the construction of the Cockburn Central West project (currently in planning phase), an overflow pipe will be installed that controls maximum groundwater height to the 1 in 100 year event. In order to protect the new development, greater than 1 in 100 year events will flow via the overflow pipe to the Jandakot – Arterial Drainage Scheme that runs along North Lake Road.

is 1:1 sufficient size for basin?

3.3 Water Quality Treatment

3.3.1 Vegetation

Native vegetation will be included in the infiltration basin, wetland area and riparian zones and stormwater treatment train to help prevent erosion, maintain soil infiltration, restrict water flows and remove particulate and soluble pollutants, particularly nitrogen. The plants will be appropriately selected based on their intended function within the treatment train and wetland using native vegetation. The additional rehabilitated areas will improve the range and quality of wetland habitat currently available in this system.

3.3.2 Landscaping Requirements

3.3.2.1 Fertiliser Requirements

The Cockburn Central development is a Transit Orientated Development with medium to high density living. This style of development reduces the need for private gardens, with some courtyard style gardens and street front treatments. Therefore the water quality collected through the drainage system is expected to be of very high quality.

The rehabilitation works associated with the wetland and infiltration basin will not require additional fertiliser application.

3.3.2.2 Irrigation Requirements

The rehabilitation works associated with the wetland and infiltration basin will not require installation of irrigation. If unseasonal or extended warm or dry conditions are encountered during the first two years that threaten plant establishment then manual watering may occur over the summer period.

3.3.3 Gross Pollutants Traps and Hydrocarbon Trap

Gross pollutant traps placed prior to infiltration areas will be used to collect rubbish and coarse sediment from stormwater and a hydrocarbon trap will be installed to remove any oil or grease that may be washed from road surfaces during the first flush event.

3.4 Groundwater Management

3.4.1 Groundwater Levels

Groundwater levels have been monitored from the six bores, shown in Figure 5, over 2010–2011. The hydrographs associated with the groundwater monitoring are included in Appendix I. Graph I showing historical groundwater trends in the area suggests 2011 was a low to average year with regard to maximum groundwater levels and within ± 30 cm of AAMGL over the last 10 years.

This drainage design is not expected to impact on groundwater levels in the area.

3.4.2 Groundwater Quality

Quarterly analysis of the nutrient levels from the monitoring field was undertaken during the groundwater monitoring program (refer Appendix I). Levels of Total Nitrogen and Total Phosphorus were in line with results expected from an urban setting. There are no significant pollutant sources associated with the Cockburn Central development and the stormwater run-off water quality is expected to be significantly lower in nutrients than existing groundwater levels. Therefore water being infiltrated through the basin will likely lead to a localised improvement in groundwater quality.

4.0 WETLAND MANAGEMENT

4.1 Wetland Buffer

The portion of REW to the east of North Lake Road has been cleared for development of Cockburn Central. Therefore the only section of wetland remaining is the portion west of North Lake Road.

Due to the inaccurate nature of the DEC Geomorphic Wetland dataset in this locality, and the EPP boundary no longer reflecting the seasonal water body (refer to Figure 3), the extent of revegetation works within the buffer was defined by existing structures (Midgegooroo Avenue to the east) and approximately the 25 m AHD contour along the south and west. The northern extent of rehabilitation is restricted by necessary road connections from the proposed Cockburn Central West into the existing Cockburn Central development. This provides an effective buffer of between 25 m and 65 m from the edge of the wetland area¹. The extent of wetland buffer (or basin surrounds) is shown in the rehabilitation plan in Appendix 3. The buffer will provide approximately 20,000 m² of wetland transitional habitat planted at a density of two plants per square metre. The species list is shown in Appendix 3.

4.2 Wetland Integration

As outlined in the Arterial Drainage Scheme Review (David Wills and Associates 2004), the RE wetland has been identified for retention and enhancement as part of the drainage design within the development.

As detailed in Section 2.5.2 the wetland is currently in poor condition, with altered water regimes, excavated banks, degraded vegetation and extensive weed infestation. Therefore through drainage management and revegetation, environmental and social values of the wetland are likely to be significantly improved:

- Enhancing and improving habitat and vegetation quality in and around the wetland will also improve the social and ecological values of the wetland through encouraging appropriate recreational activities such as walking and bird watching and improve the range of wetland habitats available to wetland dependant species.
- The wetland itself has no connection to any other wetland systems and reserves and will largely be isolated within an urban environment. Species likely to use the site will be highly mobile (water birds) using the site on an opportunistic basis or small amphibians and reptiles able to persist in this environment. Maintenance of water quality and habitat in the long term will be vital.

¹ This area may be extended depending on the planning design outcomes from the Cockburn Central West development.

- The integration of the wetland and infiltration basin into the development fabric is necessary to maximise the dual ecological and social values of the site and establish an “ownership” of the wetland with existing Cockburn Central residents and those associated with the Cockburn Central West development.

Water quality entering the wetland will be managed through control techniques outlined in this document. To ensure these controls are working, water quality monitoring will be undertaken on a monthly basis while there is water in the detention and infiltration basin.

Standing water will only be present in the wetland for a portion of the year and it is not considered likely that the wetland or infiltration basin will stagnate.

4.3 Rehabilitation

4.3.1 Revegetation and Landscaping

POS areas, swales and sections around the wetland devoid of vegetation will be planted with local native overstorey and understorey species, the majority of which will be installed as tubestock sized plants to maximise the chance of site establishment and survival.

Local native plant species will be used as part of an intelligent planting design throughout the wetland, infiltration basin and buffer area to achieve minimal water and maintenance requirements. Fringing vegetation buffering the wetland is intended to capture nutrients and pollutants from overland flow prior to entry into the wetland. These perimeter areas may also be treated with stabilisation methods to minimise localised erosion during storm events and act as fauna habitat areas. Good quality existing native vegetation is to be retained and incorporated into the design of the wetland and surrounding landscape where possible.

Planting within the buffer zone will be with a diversity of species, with new planting to extend established patterns of vegetation along the edge of the wetland and into the buffer zone, in order to create seamless extensions of the wetland. Predominant tree species suitable for overstorey used within the buffer zone can include the following:

- *Melaleuca preissiana*
- *Banksia attenuata*
- *Banksia littoralis*
- *Eucalyptus marginata*.

A more detailed species list is provided in Appendix 3. A final list of species and associated works and maintenance program, including a detailed revegetation plan for the drainage and wetland area will be developed by the appropriate Landscape Consultants in consultation with the DEC, City of Cockburn and Environmental Coordinator.

Proposed plant densities (after two years) for the buffer, wetland and enhanced basin areas are outlined below.

- basin surrounds – two plants per square metre
- enhanced drainage basin (treatment train and wetland area – four plants per square metre)
- infiltration basins – four plants per square metre

4.3.2 Fencing

Ringlock fencing (approximately 0.6 m high) will be installed in areas to prevent uncontrolled access to sensitive areas of the wetland.

4.3.3 Irrigation and Water Management

The rehabilitated areas within the wetland POS buffer area will not be reticulated, however, spot watering may occur over the first two summers, if required.

4.3.4 Nutrient Management

Fertiliser application within the wetland and rehabilitation area is not considered necessary. If it becomes apparent that rehabilitation works are threatened by poor nutrient availability in soils the then use of fertilisers will be managed to minimise application and potential for nutrient export. Management techniques will include:

- minimising overall application of fertilisers
- appropriate selection of native grass species
- planting of native vegetation
- where fertiliser application is necessary, use of phosphorus-free slow release fertilisers

If fertiliser application is necessary (through visual inspection of plants) within the wetland buffer, the landscaping contractor will keep records of fertiliser application, type and application rate and will provide them to the City of Cockburn on an annual basis until hand over.

4.3.5 Weed and Pest Management

Weed control will be undertaken by a suitably qualified and experienced environmental weed contractor. The nature of weed control is iterative and as such the weed contractor will have the scope to address weeds on an as needs basis. Should weed

control be required, weeds will be sprayed with an appropriate herbicide or weeded by hand as necessary in accordance with the DoW's Herbicide use in Wetlands (WRC 2001).

Tree guards may be used on tubestock plants to protect from grazing by rabbits until established (approximately two years from planting). The replacement or repair of the guards during this time will be undertaken when required by the landscape contractor. After the establishment period, the tree guards will be removed.

4.4 Environmental Education

4.4.1 Signage

Education signs will be prepared and installed at a strategic point such as pathways and viewing areas, identifying the wetland and associated environmental characteristics, including an explanation of the importance of responsible environmental practices with regard to maintaining good water quality practices and illegal disposal of wastes.

4.5 Implementation and Contingency Measures

4.5.1 Monitoring

General inspections of the rehabilitation and landscaped areas will be made twice a year (preferably in summer and winter) until hand over to the City of Cockburn to search for signs of vegetation disturbance and vegetation condition and density. Should any of these occurrences be detected additional rehabilitation work will be undertaken in these areas to rectify the situation.

The rehabilitated wetland area will be monitored by a qualified botanist/landscape consultant. Monitoring will include assessment of:

- species present
- approximate percentage vegetation cover of native species and weeds
- planted vegetation survival rates
- photography at monitoring locations.

4.5.2 Revegetation Contingency Measures

The Key Performance Indicator (KPI) used to monitor revegetation success will be achievement of 70% establishment of planted density rates. Should the KPI be breached supplementary planting will be undertaken. The success of plants will be inspected annually for a two years until hand over to the City of Cockburn.

4.5.3 Implementation Schedule

The following table presents a provisional schedule of all programmed monitoring activities. The monitoring of physical parameters is flexible and is intended to occur in conjunction with other maintenance and monitoring activities.

Table 1: Implementation Schedule

Issue	Parameter	Action	Frequency	Time Frame	Responsibility
Water Quality Management	Education	Develop and install education (interpretative) signs at strategic locations.	Once	Completion of development	Developer
	Fertiliser Application (if required)	Visual Inspection of plants (i.e. colour of leaves) if required record fertiliser type and application rates.	As required	Until hand over to the City of Cockburn	Developer and contractor, thereafter City of Cockburn
Rehabilitation and Landscaping	Rehabilitation of wetland buffer	Confirm Vegetation Species lists and planting densities.	Once	Prior to subdivision earthworks or revegetation	Developer
		Develop a revegetation plan.	Once	Prior to subdivision earthworks	Landscape Consultant in association with the City of Cockburn and DEC
		Review the success of plantings in revegetated areas	Biannual	2 years until hand over to the City of Cockburn	Developer
		Install tree guard on tube stock	Once	When planting	Developer
		Remove tree guards	-	Once plants established (~ 1 to 2 years from initial plantings)	Developer
		Weed Control	Weeds sprayed with an appropriate herbicide or weeded by hand in accordance with the DoW's Herbicide use in Wetlands (WRC, 2001).	As required	Until hand over to the City of Cockburn
	Monitoring rehabilitation works	Establish four monitoring points within revegetated areas	Once	When revegetation is complete	Developer

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5.0 MANAGEMENT TECHNIQUES TO MINIMISE IMPACT OF MOSQUITOES

The following section describes management techniques which will be employed in the proposed Stage 2 development to help minimise and manage the risks associated with mosquitoes breeding in the surrounding environment.

The City of Cockburn currently conducts midge larval monitoring fortnightly during September to March for North Lake, Bibra Lake, Yangebup Lake, Lake Coogee and Market Garden Swamp and monthly for Kogolup Lake, Little Rush Lake, Manning Lake, Tea Tree Close and four constructed basins. Conductivity, pH, temperature, visibility and water depth are monitored at each sample point. Analysis of water samples includes filterable reactive phosphorus, organic phosphorus, nitrite/nitrate, organic nitrogen, Chlorophyll a, phaeophytin and colour.

Should midge larval densities exceed 4000 to 5000 per square meter the sites or areas of the wetland that recorded these densities will be considered for treatment with Abate®. This is applied to the wetland using a helicopter.

5.1 Vegetation Transport Corridors and Mosquito Buffers

The City currently has a policy of not supporting the re-zoning of subdivision of land for residential development within 500 m of the edge of any lake that is subject to potential midge infestation. The Policy also requires development between 500 metres and 800 metres of the lake to have restrictive covenants placed on the title of each new residential lot warning prospective purchasers that the land may be affected by midge infestation.

The City of Cockburn has been undertaking revegetation of Yangebup and Little Rush Lakes with a particular emphasis on the replacement of fringing vegetation between these wetlands and existing residential areas to act as a buffer to mosquitoes and midges. Revegetation has also commenced at other wetlands to reduce the possibility of midge problems.

Although native vegetation acts as a buffer between wetlands and residential areas, it can also function as a transport corridor for mosquitoes and midges if there is no

Terrestrial vegetation planted around a water body can serve to function as a transportation corridor for mosquitoes seeking a blood-meal. The vegetation protects mosquitoes from predators and can act as a transport path.

In order to disrupt the potential transport corridor, lots within the development will be separated from riparian vegetation by road. The lack of vegetation and provision of roads directly adjacent to individual residential lots will serve as a form of buffer to mosquitoes.

5.2 Street Lighting

Street lighting has the tendency to attract mosquitoes and result in mosquito aggregations. Consideration will be given within the development design to limiting street lighting along streets within the development which are not easily flushed with the sea breeze. The provision of additional lighting in non-residential areas may be used as a decoy to draw mosquitoes away from populated areas.

5.3 Drainage

Standing water within the infiltration basin will only occur during the wettest part of the year when temperatures are low and available sunlight is also restricted. These will both reduce the conditions suitable for mosquito breeding.

6.0 MONITORING

6.1 Pre-development

Six groundwater bores were established within the Stage 2 development and monitored during 2010–2011.

Pre-development groundwater monitoring parameters include:

- water levels
- water quality
 - in situ: pH, EC, temperature and DO
 - laboratory analysis of nutrients (TP, TN, FRP, NO_x-N, TKN, NH₃).

Refer to Appendix I for results of water quality monitoring program.

6.2 Post-development

6.2.1 Groundwater

Groundwater monitoring of a representative sample of bores will continue for a period of two years post-development.

6.2.2 Surface Water

Water quality within the REW wetland and infiltration basin will be monitored following the first flush for two years.

6.3 Performance Values

The post-development surface water and stormwater monitoring results will be compared to the baseline (pre-development) conditions. Ongoing quarterly groundwater monitoring continues on site. If any water quality parameters exceed the pre-development values by 20% or more for two consecutive sampling occasions, contingency measures shall be employed.

6.4 Reporting

The post-development results of the monitoring program will be compared against the pre-development data and reported annually to the City of Cockburn (CoC) and DoW and will be reviewed annually in conjunction with the CoC.

The report will provide details of any variations the development has had on the hydrological conditions and propose necessary contingency plans where required.

6.5 Contingency Plans

In an event where the post-development monitoring exceeds the performance values, the CoC and DoW will be notified and an investigation will be undertaken to determine the cause of the exceedance, the impacts and the required contingency measures.

Possible contingency measures may include:

- identification of the pollution source
- removal of the pollution source, if possible
- further soil amendment in infiltration areas
- increased planting of nutrient stripping vegetation in infiltration areas.

7.0 CONSTRUCTION MANAGEMENT

A Site Construction and Management Plan (CMP) will be completed prior to starting works and will include the following:

- acid sulfate soils and dewatering
- noise and vibration
- dust management
- construction waste management
- Aboriginal heritage
- training, including site induction
- communication with adjacent landholders.

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8.0 CONCLUSIONS AND RECOMMENDATIONS

Potential issues associated with the proposed development and adjacent wetland, infiltration and rehabilitation areas include water quality, drainage and mosquitoes:

- Mosquitoes are not considered to be an issue as the wetland and infiltration basin is only expected to have standing water for a portion of the year and most of this time does not correspond with the mosquito breeding season.
- The REW is a surface expression of the groundwater in this location. It is also listed as an EPP Lake. The drainage into the wetland is not expected to significantly alter the surface flows to the wetland, however the infiltration associated with the drainage design will assist in maintaining or restore the hydraulic regime of the wetland that has suffered from recent low rainfall and falling groundwater levels in recent years. As long as water is treated prior to entry into the wetland, drainage into the REW is likely to improve vegetation condition and encourage birds using lakes and wetlands in the area to also utilise the site, which in turn will encourage community interest and use of the site.

8.1 Roles and Responsibilities

Table 2: Roles and Responsibilities

Principals	Role	Responsibility	Time-scale
Monitoring	Surface Water Monitoring	Developer prior to hand over to City of Cockburn	Monthly during winter for a period of two years post-development.
	Monitoring at selected groundwater bores	Developer prior to hand over to City of Cockburn	Quarterly for a period of two years post-development.
	Revegetation	Developer prior to hand over to City of Cockburn	Two years post-development
Revegetation	Maintenance of drainage system	Developer prior to hand over to City of Cockburn	As required for a period of two years post-development.
	Fertiliser application		As required.
Fencing	Installation and repair	Developer prior to hand over to City of Cockburn	Two years post development

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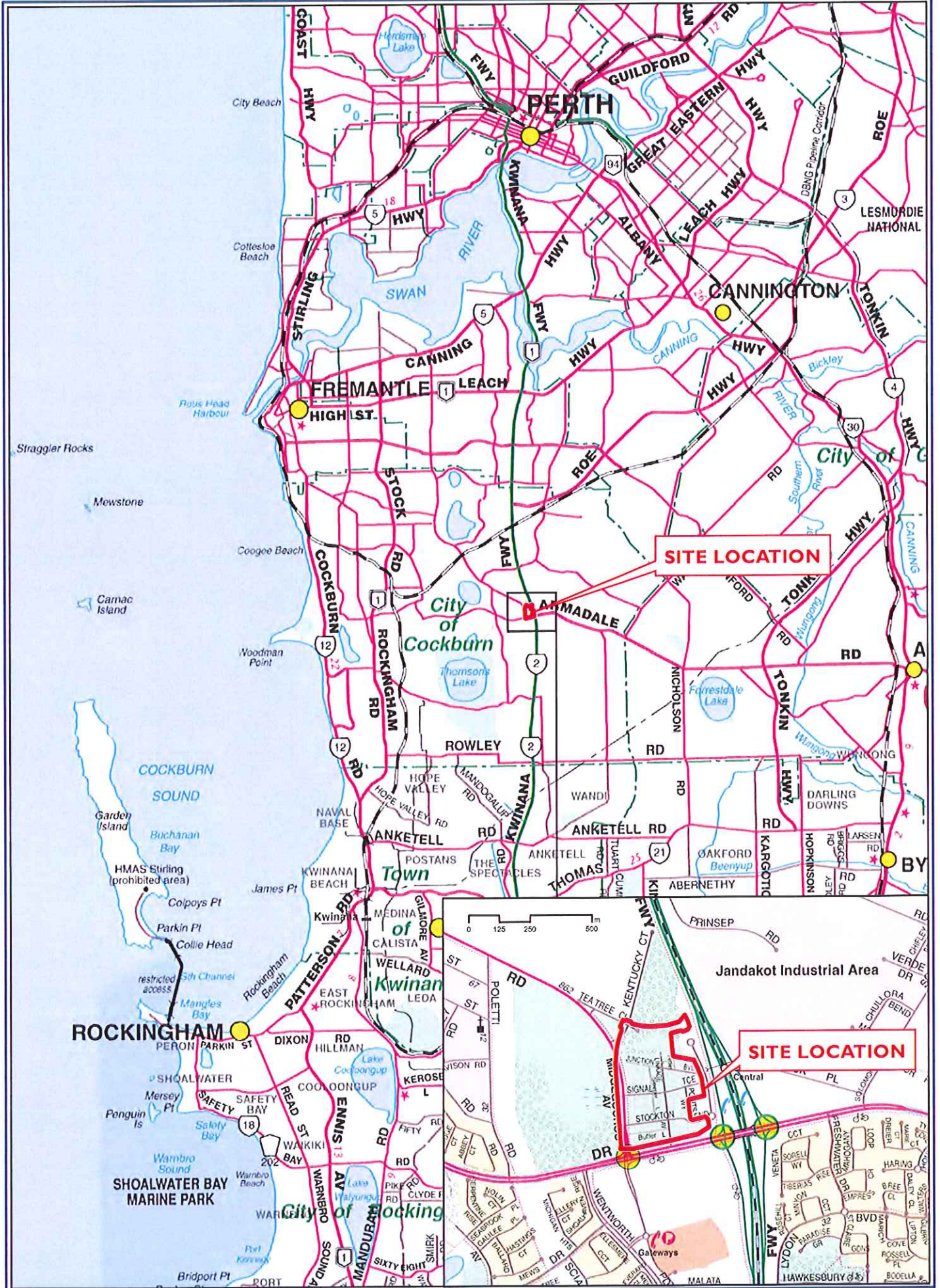
FIGURES

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RPS

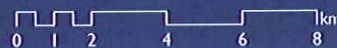


Figure 1

Site Location



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