Appendix J
Emplacement Local Water Management Strategy

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LandCorp

Hilltop / Emplacement Crescent Local Water Management Strategy

Volume 1

12 November 2012

Executive summary

This report is subject to, and must be read in conjunction with, the limitations set out in section 0 and the assumptions and qualifications contained throughout the Report.

GHD Pty Ltd was commissioned by LandCorp to prepare a Local Water Management Strategy for the Hilltop / Emplacement Crescent precinct of the Cockburn Coast urban redevelopment. LandCorp is proposing to sustainably develop the land for residential use.

The development located approximately 24 km south west of Perth and approximately 4 km south of Fremantle, within the City of Cockburn.

The Hilltop / Emplacement Crescent precinct area is approximately 20 ha in size and comprising the north eastern part of the Cockburn Coast structure plan area. The current zoning of the site supports the proposed subdivision development.

Water use

To reduce the annual water consumption in the development, in particular potable scheme water consumption, it will be necessary to be efficient in the use of water, and to use water that is fit-for purpose and appropriately sourced. Efficient water use will be up kept by following recommendations outlined in the water sustainability principle and Cockburn Sound Green Infrastructure recommendations. Fit-for-purpose water sources to be adopted will be scheme water, groundwater, and wastewater reuse.

Stormwater management

In accordance with the principals and objectives of this LWMS, the proposed development will need to maintain the pre-development stormwater discharge rates, and be protected from flooding in the 100-year ARI event. To this extent, the following stormwater management strategy is proposed:

1 year ARI event

- Runoff will be retained as close to source as possible within raingardens and bioretention areas;
- Runoff will be capture within rainwater tanks where possible, excess will be disposed of onsite via soakwells or other infiltration facilities;
- The use of permeable paving will be maximised to provide opportunities for infiltration at source.

5 year ARI event

- Runoff will be conveyed in underground pipe system designed to maximise infiltration utilizing bottomless pits and permeable joints to low point infiltration areas.

100 year ARI event

- Public open space will be designed to cater for surface overflow with habitable floors at least 300 millimetres above 100 year ARI flood levels.

Groundwater management

Groundwater quality and quantity will be at least maintained at a minimum and improved where possible for the entire Hilltop / Emplacement Crescent development site, in accordance with the principals and objectives of this LWMS. To meet these requirements the following groundwater strategy will is proposed:

- Soil amendment (where the tested phosphorous retention index is less than 10) within all stormwater infiltration areas and public open space;
- Infiltration will not be promoted in areas of known soil contamination;
- Xeriscaping to avoid the use of fertilisers; and
- Recommending a maintenance plan for the upkeep of the stormwater management system.

Next stage

The next phase of planning is the development of the Urban Water Management plan that will need to address the following:

- Additional information about irrigation, landscaping and POS, including water requirements, water sources, soil amendments;
- Additional information about geotechnical aspects of the site including phosphorus retention index testing;
- Flow rates and water levels at critical locations for the 100-year ARI event;
- Location, level and dimensions of drainage structures such as underground pipe system, low points for infiltration and soakwells;
- Imported wastewater program and necessary infrastructure upgrades;
- Management of subdivision works;
- Post-development monitoring program and a contingency action plan;
- Implementation plan, including roles and responsibilities;
- Guidelines for the irrigation and soil improvement for public open space are to be included within the urban water management plan.

Table of contents

Table index

Figure index

Appendices

Purpose of this report

To provide management strategies for stormwater, groundwater and water conservation within the Hilltop/Emplacement Crescent Local Structure Plan area.

Scope and limitations

This report: has been prepared by GHD for LandCorp and *may only be used and relied on by LandCorp for the purpose agreed between GHD and the LandCorp as set out in section 1 of this report.*

GHD otherwise disclaims responsibility to any person other than LandCorp arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer sections 5, 6, 7 and Appendix D of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by LandCorp and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has not been involved in the preparation of the Hilltop/Emplacement Crescent Local Structure Plan and has had no contribution to, or review of the Outline Development Plan *other than Hilltop/Emplacement Crescent Local Water Management Strategy. GHD shall not be liable to any person for any error in, omission from, or false or misleading statement in, any other part of the Hilltop/Emplacement Crescent* Local Structure Plan and Outline Development Plan*.*

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

1. Introduction

GHD Pty Ltd (GHD) was commissioned by LandCorp to prepare a Local Water Management Strategy (LWMS) for the Hilltop / Emplacement Crescent Local Structure Plan (LSP) of the Cockburn Coast urban redevelopment. The Hilltop / Emplacement Crescent LSP is one of three LSPs that define the Cockburn Coast urban redevelopment area.

The Cockburn Coast urban redevelopment is a 331 hectare (ha) site, with its centre located approximately 24 kilometres (km) south west of Perth and approximately 4 km south of Fremantle, within the City of Cockburn.

The Hilltop / Emplacement Crescent LSP area is an approximate 20 ha parcel of land situated within the north eastern section of the Cockburn Coast District Structure Plan (DSP). The proposed land use for the Hilltop/Emplacement Crescent LSP is residential, mixed use and local activity note, which is in line with the current zoning of the area.

1.1 Planning background

This LWMS has been prepared in accordance with the responsibilities for State Planning Policy 2.9: Water Resources (WAPC, 2004). The planning framework for land and water planning is illustrated in Figure 1.

The strategies presented in this LWMS are consistent with the following documents:

- City of Cockburn town planning scheme no. 3;
- City of Cockburn local planning strategy; and
- City of Cockburn guideline and standards for the design, construction and handover of subdivision within the municipality

1.2 Previous studies

Previously a number of studies have been conducted in support of the Cockburn Coast redevelopment including the Cockburn Coast District Water Management Strategy (GHD 2010c) and the Cockburn Coast Integrated Water Management Assessment (GHD, 2012b).

The aim of this local water management strategy is to combine present information and deliver design criteria and precinct water management strategies.

1.3 Principles and objectives

Local water management is a key component to water cycle management and should consider the integration of water supply, sewerage and stormwater while considering water-sensitive urban design principles.

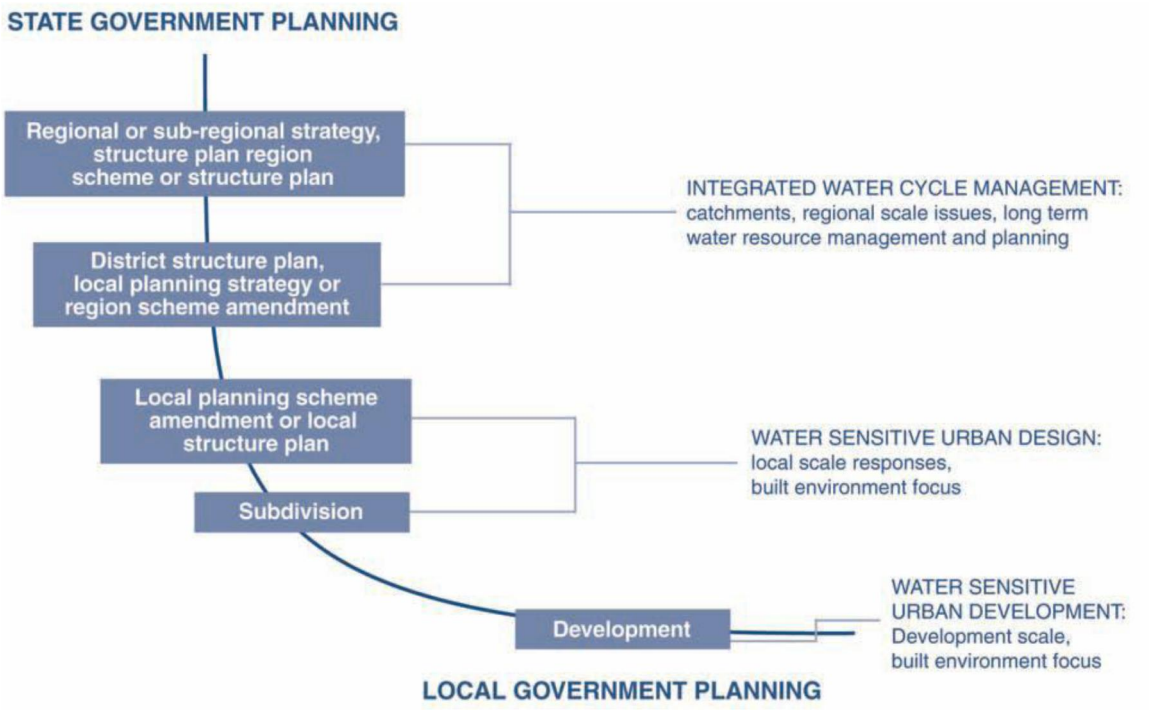

Figure 1 Planning framework for integrating the drainage planning with land planning

Source: Better Urban Water Management (WAPC 2008)

2. Proposed development

The proposed development is designed following the Cockburn Coast District Structure Plan 2009 prepared by the Western Australian Planning Commission (WAPC), detailing the planned land use and future development of the Cockburn Coast. The Hilltop / Emplacement Crescent development area is one of three phases in the Cockburn Coast Urban Redevelopment.

2.1 Land uses

The planned new land uses will complement existing local infrastructure to allow growth of new communities, economies, and activities beneficial to future residents and the wider community. The proposed development will be dominated by the following land uses: high and low rise residential, mixed use, and a road reserve. Less notable land uses will include public open space, medium rise residential, and terrace homes. The proposed land use and associated area in hectares, is summarised in Table 1.

The current land use is predominantly industrial and commercial, with some native bushland.

2.2 Public open space / landscaping

The Local Structure Plan for Hilltop/Emplacement Crescent provides large regions of Public Open Space (POS). As illustrated in Appendix B, the POS includes approximately 1.79 ha of Neighbourhood Park and Local Parks. Key features to these POSs is their east to west trending nature, which corrals stormwater drainage, and the presence of downstream infiltration basins abutting the street front to Cockburn Avenue. These designs aim to minimise stormwater runoff from crossing Cockburn Avenue.

Table 1 Hilltop / Emplacement Crescent land use

Land use	Area (ha)
Low density	0.403
High Density	10.957
Mixed use	4.77
Road reserve	2.18
Open Space	1.79
TOTAL	**20.1**

LEGEND

Local Structure Plan Boundaries

- Hilltop Emplacement LSP Area
- Power Station LSP Area
- Robb Jetty LSP Area

1:25,000 (at A4)

0 100 200 400 600 800 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

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LandCorp
Hilltop / Emplacement Crescent

Job Number 61-27019
Revision 0
Date 13 Sep 2012

Locality Plan

Figure 2

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Data source: Landgate 0.05m West Mosaic 2010 - 20110706, Roads - LGATE - 012 - 20110704; GHD: Local Structure Plan Boundaries - 20110221; GA: 250K Australian Topographic Series - 2006 Created by: jrutherford, cagilbert

3. Design criteria

Key objectives for the water management within the Hillside/Emplacement Crescent development area are detailed within the Cockburn Coast District Water Management Strategy (GHD 2009). The design criteria defined herein are adapted from those objectives, with consideration for recent investigation and obtainable targets.

3.1 Water conservation

Principle

To ensure management of the water within the development is wholly sustainable across all aspects of water and use is efficient.

The following criteria will be applied to support the intent of this principle:

- Consumption target for water of 80 kilolitres per person per year (kL/person/yr), including no more than 40 kL/person/yr scheme water;
- Potable water used outside of homes and buildings is to be minimised;
- All new fixtures and fittings are to be a minimum of 4 stars Water Efficiency Labelling and Standard Scheme (WELS) rated;
- The use of native plants is to be promoted, with native species constituting a minimum of 30-35% of total POS area.

3.2 Water quantity management

Principle

Maintain water discharge volumes and peak flows post-development, relative to pre-development conditions, unless otherwise established through determination of ecological water requirements for sensitive environments.

The following criteria will be applied to support the intent of this principle:

- Retaining all catchment runoff up to and including the 100-Annual Recurrence Index (ARI) events within the development area.

3.3 Water quality management

Principle

Quality will be maintained at pre-development levels (winter concentrations) and if possible, improve the quality of water leaving the development area to maintain and restore ecological systems.

To achieve the principle the following criteria will be applied:

- All surface and groundwater contained in the drainage infrastructure network will receive treatment prior to discharge to receiving environment consistent with the Stormwater Management Manual (DoW 2007).

3.4 Disease vector and nuisance insect management

To reduce health risks from mosquitoes, retention and detention treatments should be designed such that detained immobile stormwater is fully infiltrated in a time period not exceeding 96

hours, in accordance with the Department of Water (DoW) requirements, between the months of November and May.

Permanent water bodies are discouraged, but where accepted by DoW, should be designed to maximise predation of mosquito larvae by native fauna to the satisfaction of the local government on advice of DoW and the Department of Health (DoH).

3.5 Commitment to best management practices

In order to meet design criteria, a best practice hierarchy of principles will be implemented as follows:

- Place controls at or near the sources to prevent pollutants entering the drainage conveyance network and/or treat stormwater.
- Install in-transit measures to treat stormwater and mitigate pollutants that have entered the conveyance system.
- Install end-of-pipe controls to treat stormwater, mitigating any remnant pollutants prior to discharging to receiving environments.
- Utilise current discrete best practice water sensitive urban design measures for residential and commercial lot scales, and street scale.

Key design measures for each of these scales, include but may not be limited to, the following:

Residential lot scale:

  - Onsite retention;
  - Water and nutrient-wise landscaping;
  - Porous pavements;
  - Amended topsoils;
  - Rainwater tanks; and
  - Rain gardens and vegetated soakwells.

Commercial lot scale:

  - Landscaped infiltration structures; and
  - Hydrocarbon management and sediment traps.

Street Scale:

  - Landscaped infiltration structures;
  - Hydrocarbon management and sediment traps; and
  - Conveyance biofilter systems.

4. Pre-development environment

4.1 Study area

The Hilltop / Emplacement Crescent LSP area is located 0.5 km east of Cockburn coastline, approximately 24 km south west of Perth. The LSP area is bounded by Cockburn Road to the west, Rollinson Road to the north and Manning Reserve to the east. The site consists primarily of industrial and commercial use.

4.2 Climate

Cockburn Coast area has a Mediterranean climate with hot, dry summers and cold, wet winters. The average annual rainfall is 765 millimetres per year (mm/yr), of which 80% falls between the months of May and September. Local climate data is summarised below (BOM 2011):

- Mean Daily Maximum Temperature: 24.4 °C
- Mean Daily Minimum Temperature: 11.3 °C
- Annual Rainfall: 765 mm/yr
- Mean Annual Rain Days: 84.1

4.3 Topography

The Hilltop / Emplacement Crescent site is located on the western side of the Spearwood Ridge. Elevations range from 15 metres Australian Height Datum (mAHD) at the western border of the site to 40 mAHD at the eastern border, based on Light Detection and Ranging (LIDAR) measurements (Figure 3). The Spearwood Ridge peaks at approximately 50 mAHD just east of the site and is a key feature of the region. A small valley running north east to south west dissects the Hilltop / Emplacement Crescent site.

4.4 Geology and soils

Mapping by the Geological Survey of Western Australia indicates that the superficial geology at the Hilltop / Emplacement Crescent site is dominated by Tamala limestone, with Safety Bay calcareous sands present along the eastern boundary (Figure 4).

The Tamala limestone is characterised as a variably-cemented calcareous eolianite. The unit is generally karstic and often contains wide channels that increase the rate of water movement through the soil. Hydraulic conductivity is extremely high and is estimated between 100 m/day and 1000 m/day. The unit extends to a depth of -25 mAHD to -35 mAHD.

The Safety Bay calcareous sands present along the eastern part of the site are underlain by Tamala limestone, and consist of well sorted medium grained quartz and shell debris of eolian origin. Hydraulic conductivity of medium grained quartz is high and has been estimated at 8 m/day (Davidson 1995).

4.5 Acid sulfate soils

Mapping by the Department of Environment and Conservation (DEC) indicates that there is one area approximately 0.5 km east of the proposed development where there is a moderate to high risk of acid sulfate soils occurring within 3 m of the ground surface. This area is associated with Manning Lake in Beeliar Regional Park. There is no known risk of acid sulfate soils throughout the remainder of the Hilltop / Emplacement Crescent area.

LEGEND

Contours (5m)

Cadastre

Local Structure Plan Boundaries

Hilltop Emplacement LSP Area

Power Station LSP Area

Robb Jetty LSP Area

1:7,500 (at A4)

0 37.5 75 150 225 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

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Topography

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Date 13 Sep 2012

Figure 3

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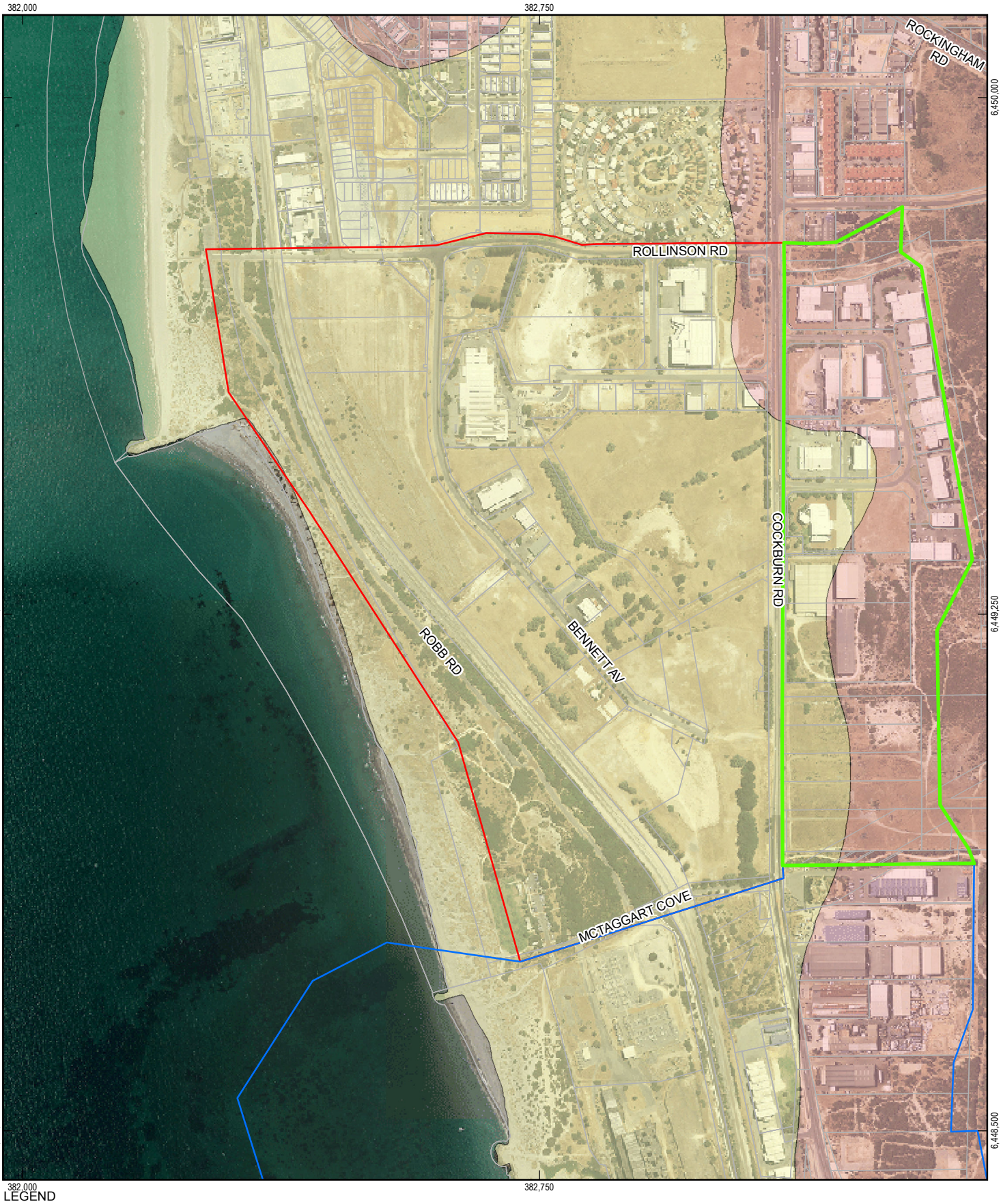
Data source: Landgate - Metro West Mosaic 2010 - 20110706, Roads - LGATE - 012 - 20110704, Contours - LGATE-015 - 20110530, Cadastre - LGATE-082 - 20110530; GHD Local Structure Plan Boundaries - 20110221.

Created by: jrutherford, cagilbert



LEGEND

Cadastre

Local Structure Plan Boundaries

- Hilltop Emplacement LSP Area
- Power Station LSP Area
- Robb Jetty LSP Area

Geology

- LS1 - LIMESTONE - pale yellowish brown, fine to coarse-grained, sub-angular to well rounded, quartz, trace of feldspar, shell debris, variably lithified, surface kankar, of eolian origin
- S13 - CALCAREOUS SAND - white, medium-grained, rounded quartz and shell debris, well sorted, of eolian origin
- S7 - SAND - pale yellowish brown, medium to coarse-grained sub-angular quartz, trace of feldspar, moderately sorted, of residual origin
- Sm2 - SILTY SAND - greyish brown, medium to coarse-grained, quartz, variable silt content

1:7,500 (at A4)

0 37.5 75 150 225 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

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Job Number	61-27019
Revision	0
Date	13 Sep 2012

Geology and Soils

Figure 4

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Data source: Landgate - Metro West Mosaic 2010 - 20110706, Roads - LGATE - 012 - 20110704, Cadastre - LGATE-082 - 20110530; GHD: Local Structure Plan Boundaries - 20110221, DOIR: Geology - 20110530. Created by: jrutherford, cagilbert

4.6 Aboriginal heritage

Preliminary assessment has revealed aboriginal heritage sites in and around the Hilltop / Emplacement Crescent site (Figure 5). A narrow path across the southern boundary of the Hilltop / Emplacement Crescent area is part of a much larger heritage area to the south east of the site.

Archaeological and ethnographic evidence suggest the Cockburn coastal area was utilised as a route and favoured camping ground, linking wetland and other sources throughout the Perth metropolitan area. Signs of artefacts were absent; however, this may be attributed to the dynamic nature of the sand dunes of the site.

4.7 Environmental assets

The Hilltop / Emplacement Crescent area is located adjacent to Bush Forever Site No. 247 (Manning Lake and adjacent bushland, Hamilton Hill/Spearwood) which covers 50.6 ha and is part of Beeliar Regional Park. The bulk of Beeliar Regional Park lies south east of the Hilltop / Emplacement precinct and is defined as a significant Environmentally Sensitive Area. GHD carried out a site survey and produced an ecological assessment report for the Hilltop / Emplacement Crescent area (GHD, 2012c).

4.7.1 Flora

The site is largely degraded, developed for industry and dominated by weeds (GHD 2012c). However a 2.96 ha patch of native vegetation in good condition is present where the site is adjacent to a corridor of bushland connected to Manning Park.

One vegetation type identified on the limestone ridge on the eastern side of the site has similarities to a DEC listed threatened ecological community (TEC). A vegetation survey in spring (when annual species are present) would be required to confirm whether the area is a TEC.

The site contains no plant taxa labelled as Endangered or Vulnerable. One weed species was identified at the site; Bridal Creeper (*Asparagus asparagoides*) (GHD 2012c). The Bridal Creeper is listed as a Priority 1 declared plant by the Agriculture Protection Board. Weed management during the construction phase will be required to prevent the spread of these plants.

4.7.2 Fauna

Carnaby's Black Cockatoos were observed at the site within the 2.96 ha area of native vegetation (GHD 2012c). Carnaby's Black Cockatoos are classed as Schedule 1 priority fauna by the DEC. This classification applies to fauna which are rare or likely to become extinct, and are in need of special protection. Since the patch of native vegetation is connected to a much larger bushland corridor it is unlikely that the foraging habitat is critical to the survival of the Black Cockatoos, however, it is recommended that clearing is minimised or avoided where possible (GHD 2012c).

LEGEND

Local Structure Plan Boundaries

- Hilltop Emplacement LSP Area
- Power Station LSP Area
- Robb Jetty LSP Area

- Environmentally Sensitive Areas
- Bush Forever Sites
- Heritage Council Sites

- Cadastre
- Black Cockatoo Habitat

1:7,500 (at A4)

0 37.5 75 150 225 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

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Heritage Sites and Environmental Assets

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Figure 5

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Data source: Landgate - MetroWest Mosaic 2010 - 20110706, Roads - LGATE - 012 - 20110704, Cadastre - LGATE-082 - 20110530; GHD: Local Structure Plan Boundaries - 20110221, Black Cockatoo HabitatTree - 20120528; DOP: Heritage Council Sites - 4001-003 - 20110530, Bush Forever Sites - 20120530; DEC: Environmentall Sensitive Areas - 20110530; Created by: jrutherford, cagilbert

4.8 Surface water

There are no surface water bodies within the Hilltop / Emplacement Crescent area. Surface water flows across the area towards the coast as a result of topography.

Runoff in the currently developed area is generally infiltrated on individual lots via soakwells or collected in the local piped drainage systems and infiltrated in drainage sumps at an individual street or collection of streets scale.

4.9 Groundwater

The study area is located within the Cockburn Groundwater Area (CGA), which is a 157 square kilometer (km^2) area located 30 km south of Perth and covers a coastal strip of 22 km. The CGA was proclaimed on 29 July 1988 under the provisions of the *Rights in Water and Irrigation Act 1914* (RIWI Act) in order to protect the long term viability of this resource.

4.9.1 Superficial Aquifer

Data from three GHD bores in the Hilltop / Emplacement Crescent area indicate groundwater elevation ranges between 0.6 mAHD and 0.7 mAHD (Table 2).

The Superficial Aquifer is recharged by direct infiltration of rainfall. Groundwater flows in an east-west direction, again with some localised variation.

Table 2 Groundwater levels of GHD bores (monitored June 2010)

Well ID	Depth to groundwater (mBGL)	Ground elevation (mAHD)	Groundwater elevation (mAHD)
MW3-1	16.319	16.987	0.668
MW3-2	20.839	21.495	0.656
MW3-3	10.536	11.173	0.637

Groundwater quality monitoring of the three GHD bores was conducted by GHD in April / May 2010, as part of the DSP area investigations (GHD 2010b). Laboratory results indicated that the analysed groundwater samples exhibited naturally elevated salinity and nutrient levels, most likely a result of the historic agricultural practices (Table 3). Groundwater samples collected from two bores in the Hilltop / Emplacement Crescent area reported of total nitrogen, total phosphorous and oxides of nitrogen at concentrations above Australia and New Zealand Environment and Conservation Council (ANZECC) (2000) inline water resource guideline values and long term irrigation water guidelines (DEC 2010) (GHD 2010b). Reported analysis of groundwater samples collected from all three bores indicated that zinc concentrations were present at levels that marginally exceed ANZECC (2000) inland waters guideline values.

The Department of Environment and Conservation's *Contaminated Site Series: Assessment levels for soils, sediments and water* (DEC 2010), specifies that for open space and domestic irrigation, the required assessment guidelines are the DEC Domestic Non Potable groundwater use. None of the bores in the Hilltop Emplacement LSP exceeded the DEC Domestic Non Potable groundwater use guidelines.

Table 3 Summary of available groundwater data

Parameter	Concentration
Total nitrogen	12 - 14 mg/L
Total phosphorous	0.04 – 0.06 mg/L
Electrical conductivity	940 – 1140 microsiemens per centimetre (µS/cm)
pH	7.4 – 7.5

4.9.2 Leederville Aquifer

The Leederville Aquifer exists between 100 m below ground level (BGL) and 150 mBGL. The aquifer is confined by the Kardinya Shale and Henley Sandstone members of the Osborne formation and is generally brackish to saline with total dissolved solids (TDS) ranging between 500 mg/L to 2000 mg/L in the upper strata and 3000 mg/L in the unit. The DOW reports that recharge to the Leederville Aquifer does not occur in the Cockburn region due to the Kardinya shale confining layer (DoW 2007).

4.9.3 Yarragadee Aquifer

Similar to the Leederville Aquifer, the Yarragadee Aquifer is confined by South Perth Shale at depths of approximately 450 mBGL to 500 mBGL and receives no recharge due to the confining Kardinya shale.

4.9.4 Groundwater allocations

The Leederville and Yarragadee Aquifers are entirely allocated within the CGA, making the Superficial Aquifer the only ground water source available for abstraction. An estimated 1.1 gigalitres per year (GL/yr) is available from this source in the Cockburn Coast Urban Redevelopment area on request.

4.10 Existing water and wastewater infrastructure

An active wastewater pumping station is located within the adjacent Robb Jetty LSP area. The pumping station conveys wastewater to the Woodman Point Wastewater Treatment Plant (WWTP).

The Water Corporation has advised that wastewater and potable water requirements of development will be met with minimal upgrades to existing infrastructure (Wood and Grieve, 2010). Potable water will be sourced from the Water Corporation's Integrated Water Supply Scheme from existing water sources and wastewater will continue to be treated at Woodman Point WWTP.

4.11 Historic land use and contamination

The Hilltop / Emplacement Crescent site has historically been used for agricultural purposes, and more recently for industry and commercial uses. Therefore, there is a risk of residual soil and groundwater contamination.

Although there are no registered DEC Contaminated Sites present in the Hilltop / Emplacement Crescent area, there are several situated to the northwest (Figure 6). A hydrocarbon plume of bunker oil has been identified within the superficial aquifer in the adjacent Robb Jetty LSP area.

LEGEND

- Groundwater Well Location
- Water Level (mAHD) (as at 13:16h on 09/07/2010)
- Cadastre
- Contaminated Site
- **Bunker oil plume**
  - Groundwater Impacted Area
  - Provisional 70m Exclusion Zone
- **Local Structure Plan Boundaries**
  - Hilltop Emplacement LSP Area
  - Power Station LSP Area
  - Robb Jetty LSP Area

1:7,500 (at A4)

0 37.5 75 150 225 300

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

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GHD

LANDCORP

SLIP ENABLER

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Hilltop / Emplacement Crescent

Groundwater Bores and Contaminated Sites

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Revision 0
Date 13 Sep 2012

Figure 6

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Data source: Landgate - Metro West Mosaic 2010 - 20110706, Roads - LGATE - 012 - 20110704, Cadastre - LGATE-082 - 20110530; DEC: Contaminated Site - 20110708; GHD: Local Structure Plan Boundaries - 20110221, Groundwater Well Location - 20100621, Bunker Oil Plumes - 20110712. Created by: jrutherford, cagilbert

5. Water use sustainability initiatives

5.1 Water conservation and efficiency

Principle

Achieve the sustainable management of all aspects of the water cycle within the development area to promote the most efficient use of potable water.

To achieve the above principle the following criteria will be applied:

- Consumption target for water of 80 kL/person/yr, including not more than 40 kL/person/yr scheme water;
- Potable water used outside of homes and buildings is to be minimised;
- All new fixtures and fittings are to be a minimum of 4 stars WELS rated; and
- The use of native plants is to be promoted, with native species constituting a minimum of 30-35% of total POS area.

Water efficiency is part of the "Business as Usual" approach from the Building Code of Australia (BCA) guidelines and is implemented through the use of technology and changing behaviour towards water use.

The Waterwise Display Village concept has been developed by the Water Corporation with the intent of initiating a water saving and efficiency process towards Waterwise developments. The Waterwise Display Village Criteria (Criteria), which has been expanded to include developments, aims to support the implementation of appropriate action to achieve best management water outcomes. The Criteria for designated Waterwise homes requires the installation of water efficient appliances with a minimum four star WELS rating.

The standards for in-house water use appliances to be adopted in Cockburn Coast are in line with the Waterwise Display Village concept which includes:

- All tap fittings must have at minimum a 4 stars WELS rating;
- All showerheads must have at minimum a 4 stars WELS rating;
- All sanitary flushing systems must have at minimum a 4 stars WELS rating dual flush; and
- Hot water heaters to be located within 5 m of major hot water using points.

5.1.1 Irrigation

The irrigation of POS must comply with the City of Cockburn's irrigation specifications and hydro-zoning of irrigation systems will be implemented. Soil amendment will be required in areas of POS with the exception of areas dedicated for drainage and infiltration purposes. In areas for drainage and infiltration, the phosphorus retention index is to be greater than 10. Design guidelines for the irrigation and soil improvement for POS are to be developed and then implemented in the development. The design guidelines for POS are to address:

- Soil amendment;
- Park design / plant selection;
- Water efficient irrigation systems and use patterns (e.g. hydro-zoning);
- Metering and reporting;

- Improvement to soil structure areas to reduce water percolation and assist in plant development; and
- Weather Stations linked to irrigation systems.

5.1 Water demands

GHD conducted an Integrated Water Management (IWM) assessment for the greater Cockburn Coast redevelopment (GHD 2012b) which identified the estimated water demands for the LSPs in the Cockburn Coast DSP as well as the potential fit-for-purpose water sources (discussed further in Section 5.4). The IWM assessment has been included as Appendix C to provide the assumptions and unit demands associated with the water demand assessment.

From the IWM assessment, the potable and non potable water demands for the Hilltop/Emplacement Crescent LSP were estimated and the results from this assessment are presented in Table 4 below.

Table 4 Hilltop/Emplacement Crescent estimated water demands (ML/year)

Land use	Potable	Non potable (in house)	Irrigation	TOTAL
Residential*	113.02	63.20	13.61	189.83
Commercial	3.89	2.27	0.32	6.48
TOTAL	**116.90**	**65.47**	**13.94**	**196.31**

* inclusive of residential components in the mixed use land use.

The estimated POS and road verge irrigation demands have been refined from the IWM assessment to reflect the proposed landscaping strategy for the Hilltop/Emplacement Crescent LSP. The revised estimated POS and road verge irrigation demands are presented in Table 5. These demands have been determined based on the following assumptions:

- Irrigation application rate of 7,500 kilolitres per hectare per year;
- Open space areas as presented in Appendix B;
- 60% of the total area local parks and neighbourhood parks will be irrigated;
- 10% of the road reserve will be irrigated verges; and
- 1734 dwellings with an expected occupancy rate of 2.0.

Table 5 Open space irrigation demands

POS Type	Total Area (ha)	Irrigation Area (ha)	Irrigation demand (kL/year)
Open Space^	1.79	1.07	8,058
Road Reserve	2.18	0.22	1,635
TOTAL	**3.97**	**1.29**	**9,693**

^ includes Local and Neighbourhood Parks and assumes 40% of the open space area will be irrigated

The estimated total water use assuming a waterwise development for the Hilltop/Emplacement Crescent LSP area is estimated as 206 ML/yr. Based on the estimated population for the Hilltop/Emplacement Crescent LSP, the per capita water demands will be in the order of 59 kL/person/yr.

5.2 Potable water

The potable water supply for Cockburn Coast will be provided from the Water Corporation's Integrated Water Supply Scheme from existing water sources with minor upgrades to existing infrastructure.

5.3 Fit-for-purpose

The potential fit-for-purpose water sources identified in GHD's IWM assessment for the greater Cockburn Coast redevelopment (GHD 2012b) are discussed in greater detail in the following subsections.

5.3.1 Rainwater

Collection and reuse of rainwater at a lot scale is constrained by storage requirements within a high density urban development. However, there are opportunities for rainwater tanks to be installed in lower density parts of the Hilltop / Emplacement Crescent LSP area, and for small scale rainwater storage and distribution systems to be used for multi-residential dwellings.

The use of this water is generally limited to domestic fit-for-purpose demand (e.g., toilets and washing machines) because rainfall does not occur during the irrigation season. On an annual basis, a 2 kL tank could supply approximately 36% of domestic non-potable water requirements.

It is recommended that the use of rainwater tanks is optional for the Hilltop / Emplacement Crescent LSP area.

5.3.2 Stormwater

Stormwater harvesting is limited by storage requirements and use is dictated by the seasonality of irrigation demands. The most efficient and effective option for managing and reusing stormwater within the Hilltop / Emplacement Crescent LSP area is infiltration of stormwater to the Superficial Aquifer at (or close to) source.

The calcareous sands prevalent in the Hilltop / Emplacement Crescent area are ideally suited to the promotion of infiltration at (or close to) source. This has the advantages of maintaining recharge into the Superficial Aquifer as well as minimising the need for drainage infrastructure.

Collection and storage of stormwater for reuse other than by aquifer storage is regarded as inefficient due to the need to construct large storages and water collection infrastructure.

5.3.3 Groundwater

The availability of groundwater reserves for licensed abstraction has been discussed in Section 4.9.4. There is approximately 1.2 GL/year available within the Superficial Aquifer for use by the Hillside/Emplacement Crescent LSP area. The greater Cockburn Coast redevelopment is likely to gain access to a limited proportion of this available resource (potentially only up to 10% or 120 ML/year). It is estimated that the irrigation demand for the Hilltop Emplacement LSP area will be approximately 10 ML/year and the total fit-for-purpose demand (ie open space irrigation, domestic irrigation and non-potable water uses) is estimated to be 89 ML/year. Therefore, the groundwater resource will be unable to meet the fit-for- purpose water demand, although it can support the open space irrigation demands for this structure plan area.

The estimated open space irrigation demand for the adjacent Robb Jetty LSP area is 41 ML/year. Combined with the Hilltop/ Emplacement Crescent open space demands of 10 ML/year, the total irrigation demand for the two local structure plans is estimated to be 51 ML/year. The Superficial Aquifer currently has sufficient available allocation to support both LSP areas.

5.3.4 Imported groundwater

Groundwater may be imported from the groundwater interception trench at the nearby Port Coogee development. This source could contribute 2.4 ML/day to the greater Cockburn Coast development during summer (GHD 2012b). Preliminary information indicates that the quality of this resource is adequate for irrigation. Further investigation will be required to establish in more detail the quality and quantity of water available from this source.

5.3.5 Wastewater

The Bennett Ave Main Pumping Station collects and conveys wastewater generated within the greater Cockburn Coast district structure plan area to the Woodman Point Wastewater Treatment Plant (WWTP).

Although the pumping station conveys a substantial quantity of wastewater, the cost of building infrastructure to extract, treat, store and distribute treated wastewater is prohibitive to implementing a local wastewater harvesting scheme.

5.3.6 Imported wastewater

Long term planning indicates the Water Corporation's aim to recycle 20% of treated wastewater from Woodman Point WWTP by 2030. Therefore the Hilltop / Emplacement Crescent development will contribute to this regional scale wastewater recycling plan.

5.4 Water source recommendations

The preferred option for irrigation water supply for the Hilltop/ Emplacement Crescent LSP is groundwater, sourced locally with the potential of sourcing from Port Coogee in the longer term. The estimated irrigation is approximately 10 ML/year and currently the superficial groundwater aquifer has an available allocation of 1090 ML/year.

Further discussions are to be held with the Port Coogee development to determine the possible arrangements for using the water from groundwater inception trench.

6. Stormwater management strategy

6.1 Hydrology

The Hilltop/ Emplacement Crescent LSP has been divided into 3 hydrologic catchments, with delineation primarily based on the grades of the natural surface and proposed roads as illustrated in Figure 7. The Hilltop/Emplacement Crescent LSP was analysed in conjunction with the full Cockburn Coast LSP project area comprising of 17 catchments.

Information was sourced from the Bureau of Meteorology to generate the Intensity Frequency Duration (IFD) curves and temporal patterns for the Cockburn coast area.

Developed 1-, 5-, 10- and 100-year ARI storm events were simulated for each catchment of the study area using the Storm Water Management Model (SWMM) hydrologic model within the InfoWorks CS hydraulic package. Adopted hydrologic and hydraulic parameters, along with a description of the InfoWorks model are listed in Appendix D.

Hydrographs and total runoff rates and volume were calculated to determine the limiting infiltration area for post development runoff. A Rational Method calculation in accordance with Australian Rainfall and Runoff (2001) was used to verify the peak discharge rates and volumes. The 10- and 100-year ARI pre-development peak flow rates for each catchment within the Hilltop/Emplacement Crescent LSP is presented in Table 6. Full details of Cockburn Coast project area catchment 10- and 100-year ARI flows are presented in Table 7. Catchment hydrographs for the 5-, 10- and 100-year ARI flows are also provided in Appendix D.

Table 6 Hilltop/Emplacement Crescent Development Peak Flows

Catchment	Catchment Area (ha)	5- Year ARI Flow Rate (m^3/s)	10- Year ARI Flow Rate (m^3/s)	100- Year ARI Flow Rate (m^3/s)
3	9.4	0.17	0.28	0.67
5	10.9	0.17	0.28	0.73
5a	7.3	0.14	0.23	0.56

Table 7 Cockburn Coast Development Peak Flows

Catchment	Catchment Area (ha)	5- Year ARI Flow Rate (m^3/s)	100- Year ARI Flow Rate (m^3/s)
1	13.2	0.23	0.69
1a	8.1	0.10	0.28
2	7.4	0.16	0.57
2a	8.9	0.19	0.70
2b	10.9	0.26	0.86
2c	4.5	0.15	0.42
3	9.4	0.17	0.67

Catchment	Catchment Area (ha)	5- Year ARI Flow Rate (m^3/s)	100- Year ARI Flow Rate (m^3/s)
4	14.1	0.32	0.95
4a	8.3	0.23	0.74
5	10.9	0.17	0.73
5a	7.3	0.14	0.56
6	7.9	0.17	0.56
7	7.5	0.20	0.66
7a	4.4	0.13	0.37
8	10.4	0.20	0.67
8a	7.0	0.14	0.51
External	30.4	0.14	0.50

6.2 Surface water quantity management

Development of existing brown field areas into commercial and high density residential typically results in a minor increase in the amount of impervious surfaces. The additional impervious surfaces however will limit the quantity of stormwater that can infiltrate into groundwater, and will cause a quicker hydrologic response to rainfall events.

The higher flow rates and larger runoff volumes have the potential to affect properties and the environment surrounding the subdivision. Therefore, measures need to be taken to counteract the effects of the additional impervious surfaces.

6.2.1 Principle

The greater Cockburn Coast development stormwater management principles to mitigate the effects of increase development are outlined below:

- Infiltrate all remaining catchment runoff up to the 1-year ARI event at source;
- Retain all residential lot runoff up to and including the 20 year ARI on site; and
- Retain all catchment runoff up to and including the 100-year ARI event within the development area.

The hydrological modelling of the Local Structure Plan was completed using the program InfoWorks and the runoff routing method of the Storm Water Management Model (SWMM). The modelling was conducted for the existing and proposed development scenarios to quantify peak stormwater runoff for the 1, 5, 10 and 100 year ARIs and a range of rainfall durations (10 minutes to 12 hours).

Results from the hydrological assessment were checked using the Rational Method to compare derived flows and runoff volumes.

6.2.2 Strategy

In accordance with the principals and objectives of this LWMS, the proposed development will need to infiltrate all catchment runoff and to protect infrastructure from flooding in the 100- year ARI event.

The stormwater system has been design for the residential lots retaining the 20 year ARI event and commercial land uses providing on-site retention and infiltration for all events up to and including the 24 hour 100 year ARI event.

On site storage should be sized in accordance with the following formula:

$$\text{Storage Volume } (m^3) = \text{Rainfall (mm)}/1000 \times \text{EIA}$$

Where EIA = Equivalent Impervious Area and Rainfall = Millimetres of rainfall Intensity for design storm (1 in 20 year for Res and 1 in 100 year for Commercial and Mixed use)

On-site infiltration is promoted due to the regions sandy permeable soil (8 m/day as reported in Section 4.4) and depth to groundwater (10 m BGL as reported in Section 4.9). Examples of onsite infiltration are:

- Combination with a rainwater tank, where the top section of the tank is reserved for detention, with a high-level outlet or bypass for flows exceeding the capacity of the tank;
- Above ground storage in gardens or courtyards, draining to a infiltration pit with a high-level outlet or bypass for flows exceeding the capacity of the garden or courtyard;
- Above ground storage tanks in driveways or car parks, draining to infiltration pit(s) with an with a high-level outlet or bypass for flows exceeding the capacity of the driveway or car park;
- Underground detention tanks located under driveways and car parks with a high-level outlet or bypass for flows exceeding the capacity of the tank.

As well as lots, the Cockburn Coast Hilltop / Emplacement precinct development area includes road reserve, rail corridor and open space. Runoff from these surfaces up to the 1-year ARI event will be infiltrated at or close to source via tree pits and other infiltration devices as approved by the City of Cockburn. Runoff from these surfaces exceeding the 1-year ARI event up to and including the 100-year ARI event will be conveyed via piped infrastructure to drainage basins located in POS regions within the structure plan area as shown in Figure 7.

Basin N3 will serve the northern third of the Hilltop / Emplacement Crescent LSP, basin N5 the central third and basin N5a the southern third. These basins are to be located within POS and will receive stormwater from the surrounding developed area including runoff from major roads.

The typically sandy soil types prevalent in the Cockburn Coast structure plan area are ideally suited to the promotion of infiltration at, or close to source. This has the advantage of maintaining recharge into the superficial aquifer, minimising the need for drainage infrastructure and maximising water quality.

The drainage structures including the detail for the basins (N3, N5 and N5a) are yet to be configured, however storage requirements are provided in Table 8 based upon infiltration rate of 1 m/day (42 mm/hour) with indicative basin sizing and top water level assuming rectangular shape provided Table 9.

Table 8 Storage volume required for 1, 5, 10 and 100 year ARI storm

Drainage Basin	Catchment Area (ha)	1 yr ARI (m^3)	5 yr ARI (m^3)	10 yr ARI (m^3)	100 yr ARI (m^3)
N3	9.5	55	500	800	2,350
N5a	7.3	65	470	500	1,500
N5	10.9	100	310	750	2,050

Note: 1 yr ARI volume represents a volume sized at 2% of the catchments connected impervious for water quality treatment to be located as close to source as possible.

Table 9 Basin Dimension

Drainage Basin	Side slopes	Maximum Depth (m) 5 year ARI	Maximum Depth (m) 10 year ARI	Maximum Depth (m) 100 year ARI	5 year ARI TWL Area (m^2)	10 year ARI TWL Area (m^2)	100 year ARI TWL Area (m^2)
N3	1:6	0.2	0.4	1.0	2,000	2,450	2,900
N5a	1:6	0.2	0.4	1.0	1,300	1,600	1,900
N5	1:6	0.2	0.4	1.0	1,900	2,200	2,500

Note: Top Water Level (TWL)

Area provided is indicative assuming a rectangular 1:6 side slopes basin and may be modified through landscape design

6.2.3 1 year ARI event

Runoff from all (residential and commercial) lots during the 1-year ARI event will be captured within rainwater tanks where possible, with the excess disposed of onsite via the use of soakwells or other infiltration facilities as approved by the City of Cockburn.

Road runoff from events up to the 1-year ARI event will be retained as close to source as possible within rain gardens and bioretention areas integrated into the urban form. The bioretention areas are to be sized at a minimum of 2 % of the connected impervious area for water quality purposes.

The use of permeable paving should be maximised to provide opportunities for infiltration at source.

6.2.4 5 year ARI event

Runoff from all (residential and commercial) lots during the 5-year ARI event will be captured within rainwater tanks where possible, with the excess disposed of onsite via the use of soakwells or other infiltration facilities as approved by the City of Cockburn.

Road runoff from events greater than 1-year ARI and up to 5-year ARI exceeding the capacity of the 1 –year ARI bioretention areas will be conveyed in an underground pipe system. The piped system should be designed to maximise infiltration through the use of bottomless pits and permeable joints. The piped system will discharge to infiltration basins integrated into public open space areas.

The basins will infiltrate within 1.5 days of the 5-year ARI storm event

6.2.5 10 year ARI event

Runoff from all (residential and commercial) lots during the 10-year ARI event will be captured within and disposed of onsite via the use of soakwells or other infiltration facilities as approved by the City of Cockburn.

Road runoff from events greater than 5-year ARI and up to 10-year ARI will exceed the capacity of the 1-year ARI bioretention areas and will be conveyed in an underground pipe system. The piped system should be designed to maximise infiltration through the use of bottomless pits and permeable joints. The piped system will discharge to infiltration basins integrated into public open space areas.

The basins will infiltrate within 2 days of the 10-year ARI storm event.

6.2.6 100 year ARI event

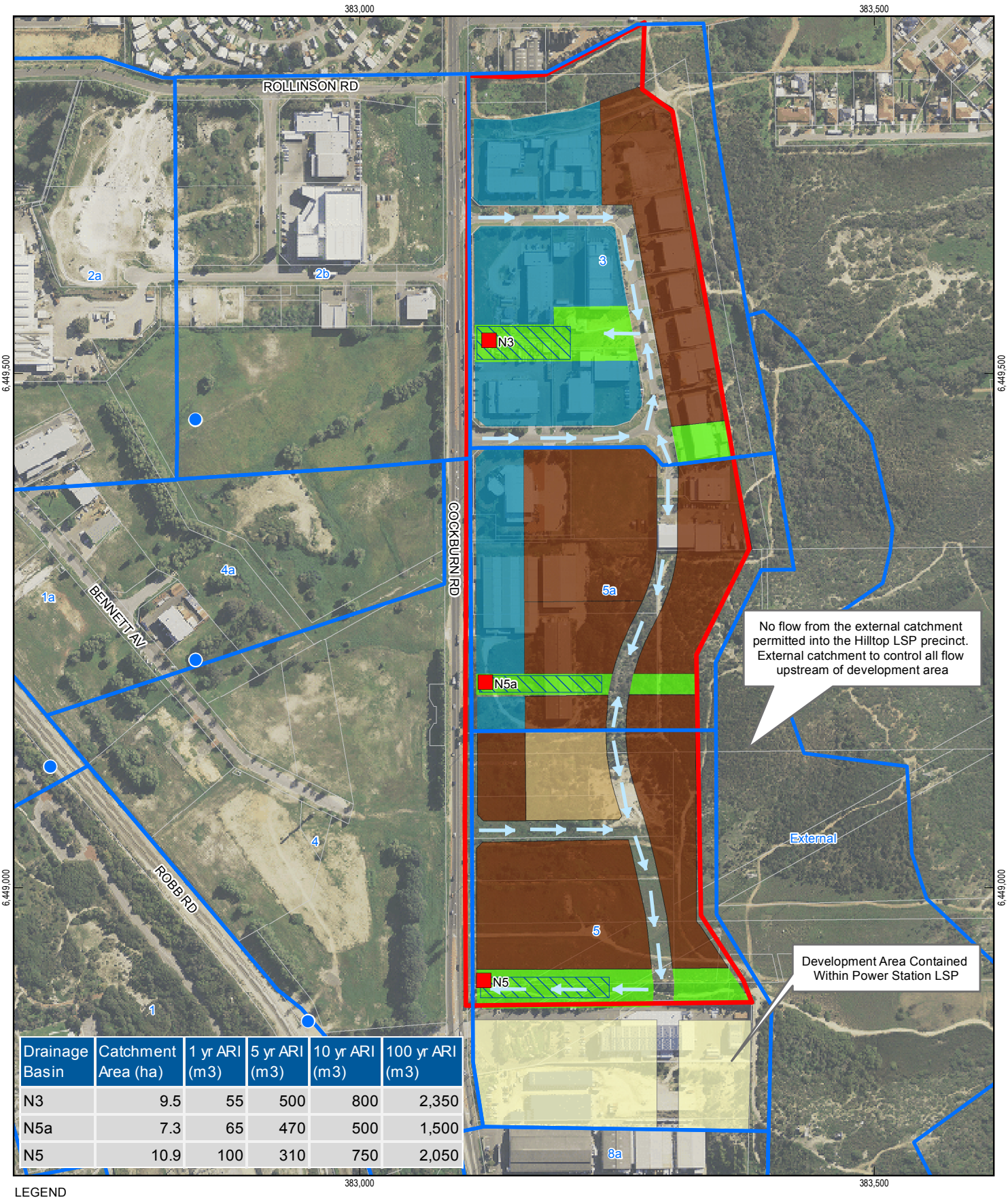
Runoff from all Commercial lots up to the 100-year ARI event will be captured within rainwater tanks where possible, with the excess disposed of onsite via the use of soakwells or other infiltration facilities.

For high density commercial lots where retention and infiltration within the boundary of the lot is not possible, retention and infiltration areas may be located underground within local public open space areas as close to source as possible in accordance with City of Cockburn development conditions.

Runoff from residential lots exceeding the capacity of the onsite detention system will overflow into the road reserves to be conveyed to the nearest infiltration basin or public open space which has been sized to accepted this volume of stormwater. Habitable floors will be set at least 500 mm above the 100-year ARI flood level at any basin location and 300 mm above road level.

Roads and public open spaces will be designed to cater for the surface overflow for more severe storms. Flow exceeding the capacity of the piped drainage system will flow within road reserves to the nearest infiltration basin or public open space.

The basins will infiltrate within three days of the 100 year ARI storm event.



Drainage Basin	Catchment Area (ha)	1 yr ARI (m3)	5 yr ARI (m3)	10 yr ARI (m3)	100 yr ARI (m3)
N3	9.5	55	500	800	2,350
N5a	7.3	65	470	500	1,500
N5	10.9	100	310	750	2,050

LEGEND

- Modelling Node
- Indicative Basin Location
- 100yr Flow Path
- Cadastre

Landuse

- Residential - power station LSP area
- Mixed use - residential/ commercial
- Public open space
- Residential - high density
- Residential - low density
- Indicative 100 Year Inundation Area
- Sub - Catchment

Local Structure Plan Boundaries

- Hilltop Emplacement LSP Area

1:5,000 (at A4)

0 25 50 100 150 200

Metres

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 50

N

LandCorp
Hilltop / Emplacement Crescent

Job Number 61-27019
Revision 3
Date 12 Nov 2012

Stormwater Management Strategy Figure 7

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Data source: Landgate - Metro West Mosaic 2010 - 20110706, Roads - LGATE - 012 - 20110704, Cadastre - LGATE-082 - 20110530; GHD: Local Structure Plan Boundaries - 20110221, Modelling Node - 20120725, Indicative Basin Location - 20120725, 100yr Flow Path - 20121030 - 20120725, Landuse - 20121030, Sub - Catchment - 20120730, Indicative 100 Year Inundation Area - 20121112; Created by: jrutherford, cagilbert, erice, mczekaj

6.3 Surface water quality management

6.3.1 Principle

Maintain water quality at pre-development levels (winter concentrations) and if possible, improve the quality of water leaving the development area to maintain and restore ecological systems.

It is proposed to adopt Water Sensitive Urban Design (WSUD) and Best Management Practices (BMPs) promoting retention, infiltration and treatment of events up to the 1 -year ARI events, in accordance with the Stormwater Management Manual for Western Australia (DoW, 2004-2007).

This will be achieved by ensuring that the 1 year 1 hour storm will be infiltrated at or close to source. Pollutant discharge is to be reduced through adopting a treatment train approach including:

- Non-structural measures to reduce applied nutrient loads;
- On-site retention of frequent rainfall events; and
- Bioretention structures/systems sized for treatment.

It is estimated that the stormwater treatment areas will need a footprint of at least 2% of the constructed impervious area.

6.3.2 Structural Measures

The choice of structural treatment measures varies across the study area to suit streetscape and POS landscapes.

The proposed drainage plans uses multiple soak wells, bio retention areas and basins to infiltrate the 1 year 1 hour ARI. The process of infiltration effectively filters the stormwater and is effective in the removal of particulate nutrients. To increase the potential of the infiltration device treatment media, such as Laterite is to be employed.

A bioretention system, which represents 2% of the total impervious area, will result in performance at the maximum possible reductions. The key WSUD structural measures to be incorporated into the design are:

- Biofiltration pockets: Wherever practical, these small biofiltration and infiltration systems will be incorporated into non-frontage verges (where they will not obstruct driveway crossovers) and road nibs.
- Vegetated basins: Biofiltration and infiltration systems in the form of vegetated basins will be incorporated into public open space areas.

6.3.3 Non Structural Measures

Non-structural measures to control and reduce discharge of contaminants are based on source control of stormwater. Non-structural source control can include:

- Actions that aim to change behaviour such as public awareness campaigns and community education;
- Strata management operations and maintenance activities such as street sweeping, waste management;
- Landscape maintenance and fertiliser use;
- Land use and management measures, such as sediment and erosion control during construction and permeable pavements;

- Develop landscaping guidelines for the proposed development area that recommend the use of appropriate native species in landscaping and provide advice on the responsible use of fertilisers and herbicides;
- Provide an effective waste-management plan for the area to ensure that litter and other waste does not collect in the drainage systems, including street sweeping; and
- Require all development construction projects, including road and infrastructure construction, to implement sediment and erosion control measures.

Non-structural measures have been shown to be cost-effective long-term methods of improving water quality and reducing contamination.

6.3.4 Best Management Practices

Table 10 outlines the WSUD Best Management Practices (BMP) for maintaining a high level of surface water quality.

Table 10 Best Management Practices

Best Management Practices	Definition of Recommended Action
Residential fertiliser	Use low water soluble fertiliser applied to sandy textured soils, applied sparingly to gardens and turf.
	Minimise lawn areas or plant an alternative lawn.
	Fertilise only when symptoms of nutrient deficiency occur (e.g. Yellowing).
	Use a complete lawn fertiliser containing nitrogen, phosphorus and potassium, if fertiliser is required.
	Apply fertiliser at the maximum individual application rate, which is 25 grams per square metre (g/m2) for couch grass and 12 g/m2 for kikuyu and buffalo grass.
	If fertiliser is required apply in spring or early autumn (September, October, November, March and April).
	Do not fertilise during summer or winter months.
	Do not over-water.
Full sewerage connection	Connect all new urban developments to sewerage. Build into approvals conditions by decision-making authorities for all new subdivisions and new homes to be connected to reticulated sewerage.
Soil remediation	Ensure all new urban developments in areas with sandy soils undergo soil remediation at the estate scale.
	At the lot scale blend or apply a layer of higher Phosphorous Retention Index (PRI) soil from grade to 50 cm beneath the finished ground level to provide increased phosphorus retention.

Best Management Practices	Definition of Recommended Action
	Use soil amendment materials such as yellow Spearwood sands, Karrakatta soils or brown loams.
	Take care to maintain soil permeability.
Water and nutrient sensitive principles	Decision-making authorities should take a lead planning role in incorporating best management practices including water-sensitive urban design principles, criteria and outcomes in its strategic land use planning, policies structure plans and subdivision conditions.
Water-sensitive urban design	Comply with environmental quality criteria should be incorporated in local planning policy.
	Ensure design complies with stormwater management policies.
	Apply water-sensitive urban design treatment trains.
	Prepare water management strategies.
	Undertake soil amendment.
	Ensure total phosphorus and total nitrogen import and export criteria are met.
	Meet the minimum percentage area of deep-rooted perennial vegetation.
	Impose building and landscaping covenants.
	Ensure sound construction and building site management.
Drainage reform	Modify drainage management practices to reduce in-channel sediment movement as opportunities arise.
	Manage drainage as part of the total water cycle with the dual objectives of optimising stormwater runoff and reducing nutrient flows into the rivers and streams.

6.4 Disease vector management

No permanent water bodies are currently planned for the Hilltop/Emplacement Crescent development area; therefore no disease vector management plan is required.

7. Groundwater management strategy

7.1 Glossary of Terms

Controlled groundwater level (CGL)

Controlled groundwater level is a groundwater level endorsed by DoW. Subsurface drainage may not be installed below the controlled groundwater level.

The actual level selected will vary according to availability of data and/or modeling results. Commonly, when a modeling approach is used, the rainfall record for a year with close to average rainfall for the current climate is run and the winter maximum groundwater level for this scenario becomes the controlled groundwater level.

Alternatively, where a historical groundwater record is available, the average of recorded maxima for a selected period of records that is representative of the current climate may be chosen.

Maximum groundwater level (MGL)

Maximum groundwater level is a groundwater level endorsed by the DoW. The actual level selected will vary according to availability of data and/or modelling results, but is commonly the maximum recorded groundwater level for a high rainfall condition.

Developments will be required to make the development surface level 1.2 m above the maximum groundwater level, if subsurface drainage is not installed.

Phreatic line

The phreatic line is the modified (post development) maximum groundwater level following the installation of subsurface drainage and is in fact an arc in between subsurface drainage lines. When subsurface drainage is installed the phreatic line becomes the level from which building floor level clearance to groundwater is measured termed Design Groundwater Level.

7.2 Groundwater Quantity Management

To protect housing from flooding and damage from groundwater, the building finished floor levels must maintain at least 1.2 m clearance from the predicted MGL.

Local investigations have determined the groundwater level to range from 3.0 to 12.9 mBGL (GHD 2010b). In light of this, adequate clearance to groundwater level is possible through with existing site levels. Areas of the site where the groundwater level is within 5 m of the surface are limited to the foreshore public open space.

CGL through a groundwater drainage system and the importation of fill for groundwater separation purposes are not proposed at this time. Groundwater is not considered a risk to property or infrastructure within the development and no specific groundwater management strategy is proposed.

7.3 Groundwater Quality Management

7.3.1 Principle

The environmental values of groundwater within, and surrounding, the Hilltop / Emplacement structure plan must be upheld. The objective is to maintain water quality at pre-development levels (winter concentrations) and if possible, improve the quality of water leaving the development area to maintain and restore ecological systems.

To achieve the above principle the following criteria will be applied:

- Ensure that all surface and groundwater contained in the drainage infrastructure network receives treatment prior to discharge to a receiving environment consistent with the Stormwater Management Manual (DoW 2007).

To ensure that the existing groundwater quality is maintained, the quality of the stormwater infiltration to groundwater will be maximised through:

- Adopting a treatment train approach to runoff, through the use of WSUD and BMPs such as permeable pavements, buffer strips, bioretention swales, rain gardens, biofiltration pockets, median swales, gross pollutant traps, and infiltration basins;
- Xeriscaping to avoid the use of fertilisers;
- Soil amendment (where the tested phosphorous retention index (PRI) is less than 10) within all stormwater infiltration areas and public open space;
- Infiltration will not be promoted in areas of known soil contamination;
- Recommending a maintenance plan for the upkeep of the treatment train; and
- Recommending a monitoring program is implemented during construction and post development to ensure that the management measures for stormwater quality are meeting the design objectives. Urban runoff is a significant source of nutrients and other contaminants that are discharged to the shallow aquifer. Runoff water quality from roads and other paved surfaces can be variable and is dependent on local soil types, land use and climate.

The quality of the stormwater infiltration will be maximised through:

- Soil amendment (where the tested phosphorous retention index (PRI) is less than 10) within all stormwater infiltration areas and public open space;
- Infiltration will not be promoted in areas of known soil contamination;
- Xeriscaping to avoid the use of fertilisers; and
- Recommending a maintenance plan for the upkeep of the stormwater management system.

Based on the above it is expected that there will be no additional inputs of nutrients and other pollutant into the groundwater as they should be contained in the upper soil layers of the swale and basins.

7.3.2 Nutrients

Past Land Uses

The previous land use of the proposed development was as industrial land. There is little information on the amount and type of fertilisers potentially used within the site, however, groundwater monitoring showing elevated nutrient levels in samples collected for laboratory analysis suggesting possible past application or spills.

Post Development Conditions

The areas of the proposed development which are impervious will be roads, car parks, foot paths, driveways and paving areas within each private lot, and roofs. For roadside bioretention swales and detention basins, native species planting without fertiliser inputs is recommended.

Vegetated, soil based biofilters have the potential to reduce:

- 95% of Total Suspended Solids (TSS);
- 85% of Total Phosphorus (TP); and
- 50% of Total Nitrogen (TN).

7.3.3 Other Pollutants

Past Land Uses

The previous land use of the proposed development was as industrial land. A plume of bunker oil has been identified within the superficial aquifer in the adjacent Robb Jetty area. The bunker oil is a dense viscous material and the plume is generally stable in nature and is not expanding or moving towards the ocean (GHD 2012a).

Post Development Conditions

It is suspected that development of the residential area will produce the following types of pollutants:

- Heavy metals, due to traffic activity in the residential area; and
- Hydrocarbons, also due to traffic activity in the residential area.

Road reserve runoff from residential developments contains heavy metals and hydrocarbons. Runoff from roads will be directed to the roadside bioretention swales for treatment.

The study, “The Impact of Stormwater Infiltration Basins on Groundwater Quality, Perth Metropolitan Region” (1993) by Appleyard on drainage sumps found that heavy metals and hydrocarbons were contained in the first 2 cm to 3 cm of the bottom of the sumps in this sandy catchment.

It can thus be said that sand is a good filter material for heavy metals and hydrocarbons from leaching into the groundwater, after being suspended in the bio retention areas.

Without further application of fertilisers and the ability of the swales system to retain heavy metals and hydrocarbons, it is expected that the proposed drainage strategy will reduce nutrients loads from the catchment and mitigate the risk of pollutants export from the development.

7.4 Impact on water dependent ecosystems

The only identified groundwater dependent ecosystem within the nearby vicinity is Manning Lake which is upstream of the Cockburn Coast development area and will therefore not be impacted.

8. Implementation framework

8.1 Monitoring

8.1.1 Pre-development monitoring program

Baseline groundwater levels and quality have been determined from existing data.

The site is sandy and within the area to be developed there is greater than 5 m depth to groundwater as determined from site investigations and regional bore records. The area where potential exists for groundwater to be within 5 m of the surface is limited to the coastal boundary outside of the Hilltop / Emplacement Crescent LSP area.

The existing site is currently industrial in nature and stormwater runoff receives no water quality treatment before direct infiltration to groundwater. The development will involve substantial improvements to stormwater management on the site by following water sensitive urban design principles and therefore is considered highly likely to improve groundwater quality.

Since it is predicted that the development will cause an improvement in surface and groundwater quality, groundwater is more than 5 m deep in the area and monitoring to address contaminated sites has been conducted, no additional pre-development monitoring is proposed.

8.1.2 Post-development monitoring

As there will be minimal impact on surface or groundwater from the development, and the depth to groundwater is greater than 5 m, no post development monitoring is proposed.

8.1.3 Contingency action plan

As there is no recommended monitoring program, no contingency action plan is proposed.

8.2 Next steps

The next stage of subdivision planning will require the development of an Urban Water Management Plan. This will include progressing conceptual designs to detailed designs, specifically the following issues will need to be addressed within the urban water management plan:

- Demonstration that the urban water management plan will meet the objectives and criteria stated in the local water management strategy;
- Demonstration of compliance with regulatory requirements, including required licences and approvals;
- Determining the infrastructure requirements and land required to fit the infrastructure for detailed design, including drainage and development requirements for stormwater and shallow groundwater management;
- Soil permeability and phosphorous retention testing to confirm soil amendment requirements;
- Detailed designs for the major/minor stormwater management system, including best management practices to achieve the water quality and quantity objectives given in this local water management strategy;
- Identifying finished floor level heights; and
- Operational and maintenance responsibilities and liabilities.

8.3 Roles and responsibilities

The efficacy of the proposed water management system will rely on its regular maintenance. The following operation and maintenance program is proposed:

- Removal of debris to prevent blockages from the stormwater system;
- Maintenance of the infiltration basins;
- Street sweeping; and
- Application of slow release/ low phosphorus fertiliser.

Table 11 sets out the roles and responsibilities for the actions outlined in the LWMS for the LandCorp development.

Table 11 Roles and Responsibilities

Role	Responsibility	Requirement
Construction and Building Site Management Plan	Contractor	Sediment and erosion control during construction.
Fit-for-purpose: Public awareness campaigns	Developer	Information packs, including educational information and operational timeframes for fit-for-purpose water relating to the use of groundwater and recycled water to be provided at settlement.
Non-Structural Controls: Public awareness campaigns	Developer	Sustainability information packs, including educational information regarding non-structural control measures, such as fertiliser application, native gardens, herbicide use, weed control and waste management, to be provided at settlement.
Design and Construction of Drainage System	Developer	Hand over to City of Cockburn at practical completion.
Structural Control Compliance: Drainage	City of Cockburn after Practical Completion	Too ensure lots meet requirements relating to onsite stormwater disposal. Drainage structures to be cleared biannually for a period of three years from practical completion and monitored to ensure functionality.

9. References

Australian and New Zealand Environment and Conservation Council (ANZECC) and Agriculture Resource Management Council of Australia and New Zealand (ARMCANZ) (2000), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality,* ANZECC, Canberra.

BoM, Bureau of Meteorology 2011. *Climatic Averages for Australian Sites.* Publicly available data prepared by the Bureau of Meteorology, Commonwealth of Australia.

Davidson, W. A. 1995, *Hydrogeology and Groundwater Resources of the Perth Region, Western Australia.* Geological Survey of WA. Bulletin 142, Department of Minerals and Energy

Department of Water, 2007. *Stormwater management manual for Western Australia*, Perth

Department of Environment and Conservation 2004, *Perth Groundwater Atlas*, Second Edition, Department of Environment, December 2004.

Department of Environment and Conservation (2010). *Assessment Levels for Soil, Sediment and Water,* Contaminated Sites Management Series, Department of Environment and Conservation, Land and Water Quality Branch, Perth, February 2010.

Edwards, Kevin, 1993. *Report of an Archaeological and Ethnographic Heritage Study in the Kwinana Industrial Area*

GHD 2009. *Cockburn Coast District Water Management Strategy*. Report for LandCorp

GHD 2010a, *Report for Cockburn Coast Detailed Site Investigation- Package 1 Lot 111 Bennett Avenue, North Coogee* Report for LandCorp

GHD 2010b, *Report for Cockburn Coast Detailed Site Investigation – Package 2, Former Abattoir Area, North Coogee* Report for LandCorp

GHD 2012a. *Report for Cockburn Coast Detailed Site Investigation – Bunker Oil Impact: Investigation and Risk Assessment*. Report for LandCorp

GHD 2012b. *Report for Cockburn Coast Redevelopment – Integrated Water Management Assessment.* Report for LandCorp

GHD 2012c. *Report for Hilltop/Emplacement Crescent – Ecological assessment*. Report for LandCorp

Government of Western Australia, 2007. *State water plan*.

Government of Western Australia, 2003. *State water strategy*.

Government of Western Australia, 1950. *Wildlife Conservation Act*.

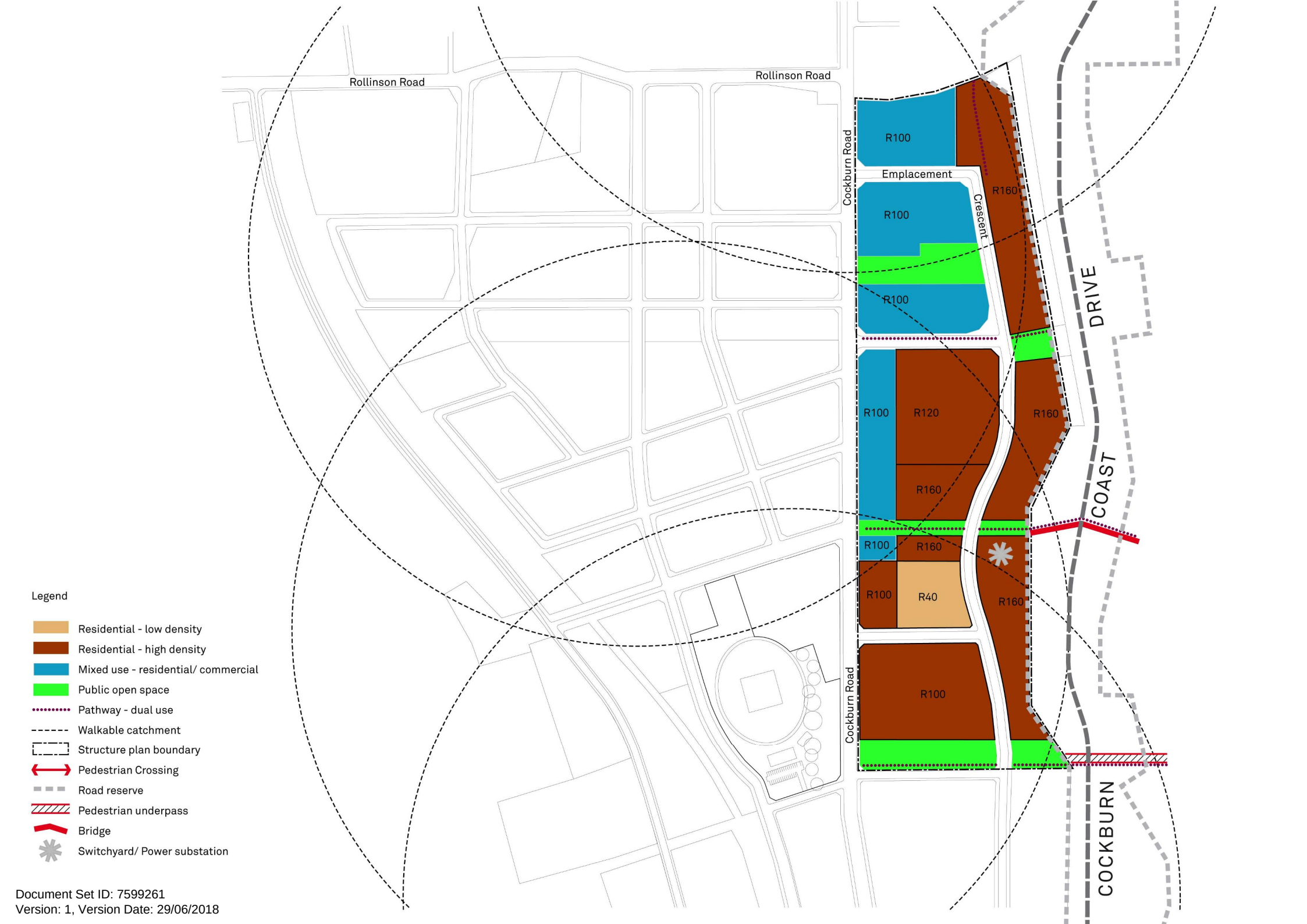
Parsons Brickerhoff 2011 *Cockburn Coast Green Infrastructure Study Implementation Strategy* Report for LandCorp

Western Australian Planning Commission, 2008. *Better urban water management*, Perth.

Western Australian Planning Commission 2004. *State Planning Policy 2.9: Water Resources*, Perth.

Appendices

Appendix A Local structure plan



Appendix B Landscape master plan

Appendix C Integrated Water Management Assessment

LandCorp

Report for Cockburn Coast Redevelopment

Integrated Water Management Assessment

February 2012

This Cockburn Coast Integrated Water Management Investigation *("Report"):*

1. *has been prepared by GHD Pty Ltd ("GHD") for LandCorp;*
2. *may only be used and relied on by LandCorp;*
3. *must not be copied to, used by, or relied on by any person other than LandCorp without the prior written consent of GHD;*
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To the maximum extent permitted by law, all implied warranties and conditions in relation to the services provided by GHD and the Report are excluded unless they are expressly stated to apply in this Report.

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- *were limited to those specifically detailed in section 1.3 of this Report;*
- *did not include GHD undertaking any site visits or testing at the site.*

The opinions, conclusions and any recommendations in this Report are based on assumptions made by GHD when undertaking services and preparing the Report ("Assumptions"), including (but not limited to):

- *currently available information at the time of issue of the report.*

GHD expressly disclaims responsibility for any error in, or omission from, this Report arising from or in connection with any of the Assumptions being incorrect.

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Contents

Table Index

Figure Index

Appendices

1. Introduction

1.1 Project setup

GHD were engaged by LandCorp to undertake an Integrated Water Management assessment (IWM) of the Cockburn Coast redevelopment (Cockburn). This IWM assessment is linked to the Cockburn Coast District Water Management Strategy (DWMS) (GHD, 2010) prepared for the Cockburn Coast district structure plan and this IWM report will present a detailed extension of the preliminary water balance provided within the DWMS.

1.2 What is IWM?

IWM is a strategy that brings together all facets of the water cycle (water supply, sewage management, water treatment and stormwater management) to achieve strong triple bottom line benefits.

Urban landscapes significantly alter the hydrological water cycle. IWM addresses this and works towards managing the urban water cycle with the hydrological water cycle to facilitate water efficiency.

1.3 Objective

Maximising water management in Cockburn represents a challenge to firstly ensure water efficiency and secondly to identify practical and accessible water sources to reduce total demand on scheme water. It is the objective of this exercise to:

- Quantify the pre- and post-development hydrological cycle;
- Identify water sources including alternative water harvesting options;
- Present a range of scenarios that quantify the water balance for Cockburn; and
- Recommend the urban water cycle configuration.

2. Cockburn Coast Redevelopment

2.1 Study area overview

The Cockburn Coast redevelopment (Figure 1) covers an area of approximately 130 ha and is located adjacent to the coast, extending north towards Rollinson Road, east to Manning Reserve and south to Port Coogee. The area has been divided into the following three local structure plan areas (Figure 1):

1. Robb Jetty;
2. Hilltop Emplacement; and
3. Power Station.

This IWM assessment has also been based on the three local structure plan areas and each area has been described in more detail in Section 5 to Section 7.

2.2 Land uses

The land use framework facilitates a diversity of residential, commercial and community oriented uses that complement the existing activities in surrounding areas, whilst bringing additional opportunities that may not currently be available.

The range of land uses and landforms that can be established through the concept plan will allow new communities, economies and activities to be developed to the benefit of existing and future residents and landowners, and the wider community. Proposed land use areas for the Masteplan are shown in Table 1.

Table 1 Cockburn coast project land use areas

Land Use	Area (ha)
Activity Centre	13.24
Commercial	0.13
Low rise residential	21.11
Medium rise residential	7.61
High rise residential	10.30
Terrace residential	2.23
Mixed Business	2.46
Mixed use	10.19
Public open space	17.48
Public purpose	1.50
Road reserve	45.45

2.3 Sustainability targets

As part of the district structure plan, a series of sustainability targets were developed and adopted, including a total water consumption and potable water consumption target of:

- 80 kL/person/year total water consumption with not more than 40 kL/person/year of potable water.

To meet the potable water consumption target, an alternative water source and servicing strategy should to be considered. The following table (Table 2) outlines three possible alternative water source servicing options ranging from the 'business as usual' option to a non drinking water system supplying all NDW uses including internal NDW uses. The development's potable consumption will depend on the servicing option implemented.

Table 2 Alternative water source servicing options

	Potable	In-house non potable uses	Domestic irrigation	POS irrigation
Business as Usual	IWSS	IWSS	IWSS	LB
Irrigation only NDW	IWSS	IWSS	NDW	NDW
Full NDW use	IWSS	NDW	NDW	NDW

IWSS = Integrated Water Supply Scheme (Water Corporation);

LB = Local groundwater bores;

NDW = A non-drinking water supply eg groundwater, treated wastewater, greywater through a third pipe

This IWM assessment will quantify the estimated water consumption for the Cockburn Coast redevelopment (for the ultimate scenario) and will determine if the sustainability target is to be met. The results of per capita consumption will be discussed in Section 0 and the potable consumption will be presented for each of the servicing options presented above.

Figure 1 Cockburn Coast concept plan

3. Environmental Characteristics

In undertaking an IWM assessment, it is necessary to understand the environment of the site as this has direct impact on the hydrological cycle. The following environmental characteristics are of particular importance and require detailed understanding to aid the IWM assessment:

- Climate / Topography;
- Soils / Geology; and
- Hydrogeology.

3.1 Climate and topography

The climate at Cockburn is described as Mediterranean. The average annual rainfall at nearby Fremantle is 765 mm, of which 80% falls between May and September. The rainfall characteristics will influence the timing and availability of both surface and groundwater at the site.

The topography varies within the study area. Located on the coast, Cockburn has both primary and secondary dune formations. Elevation of the land surface ranges from approximately 5 mAHD – 50 mAHD.

3.2 Soils and geology

The Cockburn Coast redevelopment area is characterised by Tamala Limestone of Quaternary age which outcrops inland on a ridge that runs north-south through the development area. This layer is highly permeable with hydraulic conductivities ranging from 100 m/d – 1000 m/d (Davidson 1995). The Tamala Limestone is overlain by Safety Bay Sand, which is fine to medium grained and has hydraulic conductivities of about 8 m/d (Davidson 1995). The hydraulic conductivities of surface soils within Cockburn limits surface water runoff and promotes infiltration of almost all water that falls on open areas.

An analysis of stratigraphic bore logs taken from registered groundwater bores located was undertaken. The analysis identified the Cockburn Coast area supports the prominence of Tamala Limestone and Safety Bay Sand as the main geological unit and the investigation also identified some potentially impermeable layers at depth which may act as a separation to the superficial groundwater aquifer.

The regional geology of the Cockburn Coast redevelopment area outlines the stratigraphic sequence that defines the various groundwater aquifers. The stratigraphy is summarised below in order of increasing depth:

Table 3 Cockburn geological stratigraphy

Stratigraphy	Max Thickness (m)	Lithology	GW Aquifer
Safety Bay Sand	24	Sand and shelly fragments	Superficial aquifer
Becher Sand	20	Sand, silt, clay and shell fragments	Superficial aquifer
Tamala Limestone	110	Sand, limestone, minor clay	Superficial aquifer
Bassendean Sand	80	Sand and minor silt and clay	Superficial aquifer
Rockingham Sand	70	Sand, silt and minor clay	Rockingham aquifer
Kardinya Shale Member	140	Shale, limestone, minor sandstone	Confining layer
Henley Sandstone Member	100	Sandstone and minor siltstone	Leederville aquifer
Leederville Formation	600	Sandstone, siltstone and shale	Leederville aquifer
Pinjar Member	150	Sandstone, siltstone and shale	Leederville aquifer
Wanneroo Member	450	Sandstone, siltstone and shale	Leederville aquifer
Mariginiup Member	250	Sandstone, siltstone and shale	Leederville aquifer
South Perth Shale	300	Shale, siltstone, minor sandstone	Confining bed
Gage Formation	350	Sandstone, siltstone and shale	Yarragadee aquifer
Yarragadee Formation	>2,000	Sandstone, siltstone and shale	Yarragadee aquifer
Cattamarra Coal Measures	>500	Sandstone, siltstone and shale	Yarragadee aquifer

3.3 Hydrogeology

The study area is located within the Cockburn Groundwater Area (CGA), which is a 157 km^2 area located 30 km south of Perth and covers a coastal strip of 22 km, extending approximately 7 km inland. The CGA was proclaimed on 29 July 1988 under the provisions of the *Rights in Water and Irrigation Act 1914* in order to protect the long term viability of this resource. The study area is located within the Kogalup Groundwater Subarea, which covers 5,065 ha. A summary of the groundwater aquifer characteristics beneath the Cockburn Coast development is provided below:

Superficial Aquifer

The Superficial Aquifer is an unconfined aquifer extending throughout the coastal plain with the water table typically close to the surface at topographic low points creating numerous wetlands. The Superficial Aquifer is recharged by direct infiltration of rainfall and is often expressed in coastal wetlands such as Manning Lake. The Superficial Aquifer has been measured at between 0 and 1 mAHD throughout the area, which corresponds to depths ranging between 3 m and 39 m below ground level (Perth Groundwater Atlas 2004). This thickness of the superficial aquifer can be calculated using the Ghyben-Herzberg relationship:

$$z = 40h$$

Where z = thickness of fresh groundwater below sea level; and
h = height of the water table above sea level

Assuming the end of summer groundwater level to be approximately 0.23 mAHD as indicated by Rockwater (2000) and the maximum recorded level was 1 mAHD, then it is estimated the thickness of the Superficial Aquifer will range from approximately 12 m – 40 m, with an average thickness of 30 m according to DoW (2007).

An analysis of the up-coning effect of saline water at a location 150 m inland of the coast was modeled by Rockwater (2000). Results indicated groundwater abstraction of 11,847 m^3/d could occur without up-coning of saline groundwater. These results indicate that there is potential for injection of fresh stormwater through Managed Aquifer Recharge (MAR) without the risk of mixing with saline water, provided this occurs at a safe distance from the coast.

Groundwater quality in the Superficial Aquifer is variable and ranges from < 130 mg/L to > 12,000 mg/L TDS, however this is commonly less than 1000 mg/L.

Leederville Aquifer

The Leederville Aquifer is confined beneath the Kardinya Shale and Henley Sandstone members of the Osborne Formation and occurs at depths of approximately 100 m – 150 m below ground surface with a thickness of around 200 m – 250 m (DoW 2007). Groundwater quality trends from 500 – 2000 mg/L TDS in the upper Leederville and deteriorates at depth to below 3000 mg/L (DoW 2007). Recharge in the Leederville Aquifer typically occurs from leakage from the Superficial Aquifer, with no direct connection to surface water features, however no recharge is reported to occur within the CGA due to the presence of the confining Kardinya Shale Member (DoW 2007).

Yarragadee Aquifer

The Yarragadee Aquifer is confined by the South Perth Shale at depths of approximately 450 m – 550 m below ground surface. Recharge occurs outside the CGA at the eastern edges of the Swan Coastal Plain in the absence of the South Perth Shale. Salinity levels typically range between 200 mg/L and 1000 mg/L (DoW 2007).

Groundwater Allocations

The three groundwater aquifers located within the Cockburn Coast study area are either at near of full capacity. These details were provided from DoW as recorded in July 2011 and are presented below:

Table 4 Groundwater allocations

GW Subarea	Aquifer Name	Allocation Limit (kL/yr)	Licenced + committed Allocation (kL/yr)	Groundwater Available (kL/yr)
Cockburn Confined	Perth – Leederville	1,350,000	1,500,000	0
	Perth Yarragadee North	5,150,000	5,555,689	0
Kogalup	Perth – Superficial Swan	11,460,000	10,488,084	810,711

The groundwater allocations are discussed further as a potential alternative water source in Section 10.

4. Water balance methodology

4.1 Overview

There are difficulties associated with the accurate quantification of water demands and water supply options when assessing total water balance for a given site. Usually the investigation of matching water demands with water supply options is conducted with a single catchment model. Rather than relying upon only one catchment scale model to calculate water demands and investigate how to match supply options, this study constructed catchment scale water balances by employing different catchment models according to site specifics within the study area.

4.2 Methods and Assumptions

In order to construct the development water balances, five separate models were used to determine the water demands, the soil-water mechanics of the study site (e.g. runoff, groundwater infiltration, evaporation, etc) and the quantity of the water supply sources used for the local structure plan area.

The five models employed were:

- Water Corporation's alternative water supply consumption tool (Consumption Tool);
- the Australian Water Balance Model (AWBM);
- the MUSIC stormwater model; and
- GHD's spreadsheet urban water demands model.

A brief description of the purpose of each model is provided in Table 5.

Table 5 Model summary

Model	Purpose
Water Corporation's alternative water supply consumption tool (Consumption Tool)	In house water demands Ex house water demands POS irrigation rates Verge irrigation rates
AWBM	Runoff from pervious areas
MUSIC	Runoff from impervious areas
GHD's spreadsheet urban water demands model	Integration of the models

Each of the land uses within the development area were divided into the following four categories for the purposes of estimating the runoff, infiltration or estimate demand for each area:

- Irrigation area;
- Pervious and un-irrigated area;
- Impervious (excluding residential roofs) area; and
- Residential roof area.

The runoff from the study area's impervious areas was determined for the pre-development (ie existing) scenario and the post-development (ie ultimate) scenario. The difference in pre and post development runoff volumes was assumed to be potentially available for possible stormwater harvesting options. For the pre-development scenario, an estimate of the developed area was determined using aerial photography and of this developed area, it was assumed from the aerial photos that 80% of the area was impervious.

In the post development scenario, the impervious and pervious areas were calculated by applying the coefficients outlined in Table 6:

Table 6 Model summary

Land use	Pervious coefficient	Impervious coefficient
Residential	0.6	0.4
Commercial / Mixed Use etc	0.2	0.8
Road	0.4	0.6

As aforementioned, the development water balance for each option was calculated by combining the outputs of four models. A summary of these models are given in the following sections.

Water Demands Model

A water demands spreadsheet model was developed by GHD to determine the water usage in the following categories:

- Residential;
- Schools;
- Commercial and Industrial;
- Public Open Spaces; and
- Roads

The model was based on the unit consumption rates published in the Water Corporation's Consumption tool and the unit demands adopted have been presented in Appendix A. The Consumption tool also provides specified unit consumption rates for differing land uses including commercial and office buildings. . For the purpose of this water balance, the commercial, mixed use, activity centre and mixed business land uses were assigned a corresponding land use category from the Water Corporation's Consumption Tool. An occupancy rate of 2.2 people per dwelling was adopted across the site to provide consistency with the district structure plan.

The estimated water consumption rates are provided in Table 7.

Table 7 Water balance assumptions

Land use	Adopted WC parameter	Occupancy	Water consumption estimate
Terrace homes	Traditional	2.2	-
Low rise residential	Cottage	2.2	-
Medium rise residential	Terraced	2.2	-
High rise residential	Apartment	2.2	-
Commercial	Shopping centre	N/A	1.08 kL/m^2 GLA/year
Mixed Business	Office building	N/A	0.80 kL/m^2 GLA/year
Mixed use	Office building	N/A	0.80 kL/m^2 GLA/year
Public open space	Passive and active	N/A	-
Road reserve	Verges	N/A	0.64 kL/m^2/year

The areas allowed for irrigation of the residential land uses were:

- 15% of the lot area for terrace houses; and
- 10% of the lot area for low rise, medium and high rise land uses for communal landscaping.

It was assumed that 2% of the total road area will be irrigated to allow for verge and streetscape irrigation. For the public open space, the areas were adopted based on the proposed landscape plan for the Master Plan area and from this, it was assumed that 1/3 of the area would be considered active open space (ie playing fields and turfed areas), 1/3 of the public open space area would be considered as passive open space (ie shrubs etc) and 1/3 of the open space would not be irrigated.

It is to be noted that the water consumption demands have only been calculated for the post-development (i.e. ultimate) scenario.

The water demands assessment assumed in-house water wise fittings were adopted to maximise water use efficiency. These are summarised below.

- All tap fittings and dishwashers must be minimum 4 stars WELS rated;
- Washing machines are to be a minimum of 4.5 stars WELS rated;
- All showerheads must be minimum 4 stars WELS rated;
- All sanitary flushing systems must be a minimum 4 stars WELS rated dual flush (6/3 or 4½/3); and
- Hot water heaters to be located within 5 m of major hot water using points.

AWBM

A spreadsheet version of the Australian Water Balance Model (AWBM) was used to model surface runoff and groundwater infiltration from the pervious, un-irrigated area of the proposed development. The AWBM is a catchment water balance model that relates runoff to rainfall and calculates losses from rainfall. The model uses a maximum of three (3) surface stores to reflect different soil types within a catchment. The water balance of each surface store is calculated independently of the others. When

runoff occurs from any store, part of the runoff becomes recharge of the base flow store if there is base flow in the stream flow. The surface runoff can be routed through a store if required to simulate the delay of surface runoff reaching the outlet of a medium to large catchment.

The study site was spatially analysed to determine geomorphological characteristics that influence drainage flow paths. Three catchments were delineated from the study area based on the local structure plan areas. AWBM was applied for the individual characteristics of each of these three catchments and the results were combined to gain an understanding of the entire study site. The runoff characteristics for the site were determined for the pre-development (ie existing) scenario and the post-development (ie ultimate) scenario.

MUSIC

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) was developed by the CRC for Catchment Hydrology. MUSIC provides the ability to simulate both quantity and quality of runoff from catchments ranging from a single house block up to many square kilometres, and the effect of a wide range of treatment facilities on the quantity and quality of runoff downstream.

Whilst MUSIC is designed for both pervious and impervious areas, it was only used to analyse stormwater generated from impervious areas only. The AWBM model was used in place of MUSIC for modeling pervious areas as it was deemed to have a higher level of accuracy given ability to model more than one soil type.

4.3 Approach

To allow easy integration into future planning processes, a water balance model was constructed for each local structure plan area. Each model was developed using the site specific geology and preliminary land use plans to provide runoff estimates, groundwater recharge estimates and required demands to determine the appropriate water use strategy for each structure plan area.

Total water demand outcomes are presented relevant to each local structure plan within Sections 5 - 7. A summary of each outcome is subsequently presented in Section 0, with reference to the three water source servicing options presented in Table 2.

5. Robb Jetty LSP

5.1 Site description

The Robb Jetty local structure plan area covers approximately 62 ha and bounded by Cockburn Road to the west, Rollinson Road to the north and sits north of the existing power station (Figure 1). Using the expected occupancy rates, the estimated population is 4,391.

The proposed ultimate land use within the structure plan area is described in Table 8.

Table 8 Robb Jetty LSP land use

Land use	Area (ha)
Activity Centre	4.11
Commercial	0.13
Low rise residential	13.94
Medium rise residential	1.52
Terrace homes	1.43
Mixed Business	2.46
Mixed use	2.55
Public open space	12.03
Public purpose	1.50
Road reserve	21.69
TOTAL	**61.36**

To determine the run off from the pervious areas using AWBM, the Robb Jetty LSP was assumed to be made up of 97% sand and 3% limestone.

There is a known bunker oil contamination source at the location of the existing historic chimney within the boundary of the proposed school. The contamination originates from a loss of bunker oil from a former underground storage tank at the boiler house of the abattoir which was formerly present at the Site. There have been several investigations undertaken around this area including:

- Report for Cockburn Coast Redevelopment Detailed Site Investigation, Package 2 Former Abattoir Area, North Coogee (GHD, November 2010); and

Report for Cockburn Coast Detailed Site Investigation, Historic Bunker Oil Impact: Investigation and Risk Assessment (GHD, September 2011)

Investigations of the bunker oil impact have identified that:

- Bunker oil contamination has impacted soil and groundwater from a depth of approximately 6.2 below ground level over a limited area (broadly circular to egg shaped area approximately 80m in diameter at the location of the historic chimney)

- The bunker oil impact is generally stable in nature and is not expanding or moving towards the Indian Ocean.
- Risks to relevant receptors are insignificant or can be addressed with relatively simple management measures

The recommended outcome of the site investigations have been to leave the area of bunker oil impact in situ and adopt appropriate management measures for development in the vicinity. These included measures to prevent disturbance within potential influencing distance of the bunker oil impact as summarised below:

- Groundwater abstraction (or recharge) within the interpreted extent of bunker oil impact (GHD September 2011) should be prevented.
- A provisional exclusion distance of 70 m radius for abstraction or recharge of groundwater should be applied beyond the interpreted extent of bunker oil impact (GHD, September 2011) for the protection of receptors and to minimise risk of mobilisation of impacted groundwater.
- The exclusion distance of 70 m radius is provisional as the influence that a groundwater abstraction bore may have on impact stability/migration potential depends on circumstances specific to the abstraction or recharge such as volume of groundwater to be abstracted, proximity, targeted strata and characteristics. Therefore any proposal to abstract or recharge groundwater at surrounding Lots 101, 102, 109, 110, 2109 and the southern half of Lot 2103 should specifically assess the potential for influence upon the bunker oil impact and the validity of the provisional exclusion zone to ensure plume stability is not compromised.

5.2 Water balance results

The table below presents the results from the pervious and impervious areas runoff in the pre- and post-development scenarios.

Table 9 Robb Jetty LSP Estimated runoff (ML/year)

		Runoff (ML/year)
Pre development	Pervious	6.75
	Impervious	51.69
Total pre development		**58.44**
Pre development	Pervious	2.31
	Impervious	242.65
Total post development		**244.96**
Total increase in runoff		**186.52**

The estimated water demands for the Robb Jetty LSP area are presented in Table 10.

Table 10 Robb Jetty LSP estimated water demands (ML/year)

Land use	Potable	Non potable (in house)	Irrigation	TOTAL
Residential*	140.39	79.69	7.57	227.65
School	2.61	1.74	5.80	10.15
Commercial	35.15	20.50	2.93	58.58
Public open space	-	-	76.99	76.99
Road reserve	-	-	2.78	2.78
TOTAL	**178.15**	**101.93**	**96.07**	**376.15**

* inclusive of residential components in the mixed use land use.

The estimated total water use assuming waterwise development the local structure plan area is estimated as 376 ML/yr. The per capita consumption rates have not been presented for the individual structure plan areas, rather the consumption rates are presented for the whole development in Section 0.

6. Hilltop Emplacement LSP

6.1 Site description

The Hilltop Emplacement local structure plan area covers approximately 22 ha and is bounded by Cockburn Road to the west, Rollinson Road to the north, and Manning Reserve to the east (Figure 1). Using the approximate occupancy rates, the estimated population is 2,068. The land use within the structure plan area is described in Table 11:

Table 11 Hilltop Emplacement LSP land use

Land use	Area (ha)
Low rise residential	4.90
Medium rise residential	1.10
High rise residential	4.53
Terrace homes	0.80
Mixed use	4.78
Public open space	1.22
Road reserve	4.14
TOTAL	**21.47**

To determine the run off from the pervious areas using AWBM, the Hilltop Emplacement LSP was assumed to be made up of 27% sand and 73% limestone.

6.2 Water balance results

The table below presents the results from the pervious and impervious areas runoff in the pre- and post-development scenarios.

Table 12 Hilltop Emplacement LSP Estimated runoff

		Runoff (ML/year)
Pre development	Pervious	1.41
	Impervious	51.83
Total pre development		**53.24**
Pre development	Pervious	0.41
	Impervious	105.70
Total post development		**106.11**
Total increase in runoff		**52.87**

The estimated water demands for the Hilltop Emplacement LSP area have been presented in Table 13.

Table 13 Hilltop Emplacement LSP estimated water demands (ML/year)

Land use	Potable	Non potable (in house)	Irrigation	TOTAL
Residential*	66.23	37.53	2.95	106.71
Commercial	15.94	9.30	1.33	26.57
Public open space	-	-	7.81	7.81
Road reserve	-	-	0.83	0.83
TOTAL	**82.17**	**46.83**	**12.91**	**141.91**

* inclusive of residential components in the mixed use land use.

The estimated total water use assuming waterwise development the local structure plan area is estimated as 142 ML/yr. As with the Robb Jetty precinct, the per capita consumption rates are presented for the overall redevelopment in Section 8.

7. Power Station LSP

7.1 Site description

The Hilltop Emplacement local structure plan area covers approximately 49 ha and bounded by ocean to the west, east of Manning Reserve and south of the Robb Jetty and the Hilltop/Emplacement structure plan areas (Figure 1). Using the approximate occupancy rates, the estimated population is 5,931. The land use within the structure plan area is described in Table 14.

Table 14 Power Station LSP land use

Land use	Area (ha)
Activity Centre	9.13
Low rise residential	2.27
Medium rise residential	4.99
High rise residential	5.77
Mixed use	2.86
Public open space	4.23
Road reserve	19.62
TOTAL	**48.87**

To determine the run off from the pervious areas using AWBM, the Power Station LSP was assumed to be made up of 54% sand and 46% limestone.

7.2 Water balance results

The table below presents the results from the pervious and impervious areas runoff in the pre- and post-development scenarios.

Table 15 Power Station LSP Estimated runoff

		Runoff (ML/year)
Pre development	Pervious	4.42
	Impervious	68.62
Total pre development		**73.04**
Pre development	Pervious	1.37
	Impervious	223.26
Total post development		**224.63**
Total increase in runoff		**151.59**

The estimated water demands for the Hilltop Emplacement LSP area are presented in Table 16.

Table 16 Power Station LSP estimated water demands (ML/year)

Land use	Potable	Non potable (in house)	Irrigation	TOTAL
Residential*	189.16	107.64	4.03	300.83
Commercial	66.31	38.68	5.53	110.52
Public open space	-	-	27.07	27.07
Road reserve	-	-	2.51	2.51
TOTAL	**255.47**	**146.32**	**39.14**	**440.93**

* inclusive of residential components in the mixed use land use.

The estimated total water use assuming waterwise development the local structure plan area is estimated as 441 ML/yr. The per capita consumption rates have been presented for the overall development in Section 8.

8. Overall development

To determine if the sustainability targets identified in Section 2.3 are likely to be met within the Cockburn Coast redevelopment, the total water consumption per capita for the development requires determination. The sustainability targets are:

- 80 kL/person/year total water consumption with not more than 40 kL/person/year of potable water.

In order to assess whether these targets can be met, the total water demands for the ultimate development must firstly be addressed and these are summarised below in Table 17.

Table 17 Cockburn Coast estimated water demands (ML/year)

Land use	Potable	Non potable (in house)	Irrigation	TOTAL
Residential*	395.77	224.86	14.56	635.18
Schools	2.61	1.74	5.80	10.15
Commercial	117.40	68.48	9.78	195.66
Public open space	-	-	111.87	111.87
Road reserve	-	-	6.11	6.11
TOTAL	**515.78**	**295.08**	**148.12**	**958.99**

The consumption per capita (2.2 people per dwelling) assessment is presented in Table 18 and is presented assuming the three NDW servicing options presented in Section 2.3.

From this table, it can be seen that the total consumption meets the sustainability target of 80 kL/person/year. However the potable consumption target of 40 kL/person/year will not be met in any of the non-drinking water servicing options. The best potable water consumption achieved will be approximately 42 kL/person/year if a full non drinking water scheme is implemented.

Suggested measures and strategies for minimising potable consumption further have been suggested as part of Section 9.

Table 18 Cockburn Coast water consumption summary

Total Water (kL/person/year)	Potable water in Business as usual (kL/person/year)	Potable use with an irrigation only NDW supply (kL/person/year)	Potable Water (with a full NDW supply) kL/person/year)
77.40	67.41	65.44	41.63

9. Water Conservation

The Cockburn Coast redevelopment has an objective to achieve the sustainable management of all aspects of the water cycle within the development and ensure that the use of potable water is as efficient as possible. The water consumption from the water efficient fittings and fixtures listed above has been taken into consideration during the preparation of the water balance.

A total water consumption target of 80 kL/person/yr, including not more than 40 kL/person/yr scheme water has been set in the DWMS. The development will be able to meet the total water consumption target, however is just over the potable consumption target if a full non drinking water scheme is implemented. The following sections outline possible measures which may be able to improve the potable water consumption per capita.

9.1 Water conservation and efficiency of use

Water efficiency is a critical element of the water management approach and is enabled through the use of technology and by changing behaviour to use less water. The Western Australian Government has introduced a range of measures to ensure that new houses built in Western Australia meet minimum standards for energy and water efficiency. The 5 Star Plus building standards introduced in September 2007 are now an addition under the Western Australian Appendix to the Building Code of Australia[1] (BCA).

The Waterwise Display Village concept has been developed by the Water Corporation to engage with developers to drive waterwise development. The Waterwise Display Village Criteria, which has been expanded to include whole developments, aims to ensure appropriate action is taken to achieve best management water outcomes. In addition to water use efficiency requirements outlined in the BCA, the Waterwise Display Village Criteria requires the installation of water efficient appliances and other water conservation strategies including for irrigation.

9.2 Waterwise In-building Practices

The developments within the Cockburn Coast Master Plan area will be required to adopt the following criteria (based on the Waterwise Display Village Criteria) in addition to the 5 Star Plus building standards. The waterwise requirements are:

- All tap fittings and dishwashers must be minimum 4 stars WELS rated;
- Washing machines are to be a minimum of 4.5 stars WELS rated;
- All showerheads must be minimum 4 stars WELS rated;
- All sanitary flushing systems must be a minimum 4 stars WELS rated dual flush (6/3 or 4½/3); and
- Hot water heaters to be located within 5 m of major hot water using points.

Estimates of demand for residential water consumption have assumed residential lots would meet these requirements. Although the water efficiency program is focussed on all customers including households,

[1] http://www.buildingcommission.wa.gov.au/bid/5StarPlus.aspx

industry and commerce, savings in water use have only been estimated in this study for residential demand. Predicting demand for commercial properties is much less certain.

Design criteria outlining these practices will need to be developed and implemented to ensure adoption.

9.3 Waterwise Irrigation Practices

Irrigation demands, both domestic irrigation and POS irrigation are the largest non-drinking water uses within the Cockburn Coast area. It is recommended that the developments within each of the local structure plans adopt the following criteria (based on the Waterwise Display Village Criteria). The Waterwise requirements related to garden design, soil improvement and irrigation.

The minimum required soil improvements within the study area will be the

- Use of a soil conditioner certified to AS4454 to a minimum depth of 150 mm for lawns and 300 mm for gardens;
- Mulching of gardens beds to 50 mm – 75 mm using mulch certified to AS4454.

Design guidelines for residential irrigation controllers are to be developed and included within the urban water management plan and the Waterwise Display Village Criteria should be referenced as a guide.

The irrigation of public open space must comply with any irrigation specifications that the City of Cockburn's irrigation specifications may have and hydrozoning of irrigation systems is recommended. Soil amendment is also recommended in areas of public open space with the exception of areas dedicated for drainage and infiltration purposes. In areas for drainage and infiltration, the phosphorus retention index will need to be greater than 10. Design guidelines for the irrigation and soil improvement for public open space are to be included within the future urban water management plans for subdivisions. The design guidelines should include areas of soil amendment, the use of water efficient irrigation systems and use patterns and park design and plant selection. The use of native plants is to be promoted, with native species constituting a minimum of 30-35% of total public open space area.

9.4 Recommendations

It is recommended that a Waterwise display village is developed as part of the Cockburn Coast redevelopment which encompasses all the required and desirable waterwise measures for the site. Design guidelines are also to be prepared and implemented for:

- The internal and external waterwise and water conservation initiatives; and
- Public open space design.

Engagement with prospective and new residents by the landowners, developers and the City of Cockburn is recommended which focuses on water efficiency within the Cockburn Coast redevelopment. It is further recommended that an ongoing program of education and feedback on irrigation water use as well as internal water use is established in conjunction with all stakeholders including the Water Corporation.

10. Water source options

There are several potential fit for purpose water source options available within the Cockburn Coast redevelopment area which are summarised below.

10.1 Rainwater

Collection and reuse of rainwater at a lot scale within rainwater tank systems can be constrained by storage requirements within a high density urban development. However, there are opportunities for rainwater tanks to be installed in terrace house/detached and low rise residential areas outlined in the concept plan. There are also opportunities for small scale rainwater storage and distribution systems to be used for multi-residential dwellings. The use of this water is generally limited to in-house fit-for-purpose demand (ie toilets and washing machines) because rainfall does not occur during the irrigation season and tank sizes to retain sufficient water for year round irrigation demands are likely to be excessive.

Prior to the enforcement of rainwater tanks, the implementation mechanisms will need to be determined. The *Cockburn Coast Green Infrastructure Study* (PB, April 2011) determined that the implementation of rainwater tanks across the developed was an order of magnitude higher in costs than the cost for recycling wastewater and stormwater. As such, rainwater tanks are not recommended for mandatory installation across the Cockburn Coast development and it will be up to the individual household to install these as desired.

10.2 Stormwater

Harvesting of stormwater from drainage infrastructure is similarly constrained by storage requirements and again its use may be limited by the seasonality of irrigation demands.

There is some scope to investigate the potential for stormwater harvesting for Aquifer Storage and Recovery (also known as Managed Aquifer Recharge, MAR). This involves injection of treated stormwater into a suitable groundwater aquifer to be later re-abstracted and used locally or distributed to the wider development area for use as a year round fit-for-purpose water source. Storage and treatment requirements for this type of scheme can vary significantly according to the quality and suitability of the receiving aquifer as well as the quality and availability of stormwater for harvesting. This process is regulated in Western Australia under the Department of Water's *Operational policy 1.01 - Managed aquifer recharge in Western Australia* (DoW, 2011). Under this policy, changes in land use that result in additional runoff and would typically increase the groundwater recharge are not considered MAR. In order to gain additional abstractable water it would be necessary to demonstrate that an excess exists and cannot be infiltrated at source.

At this site there is an increase in stormwater runoff in the order of 390 ML/year. As there is an increase in runoff from the development in the ultimate scenario which will need to be managed, the possible options for capturing this stormwater are though:

- Storage areas (eg lined basins or tanks) during the winter months for reuse in the summer months; or
- Infiltration of the additional runoff at source.

The typically sandy soil types which are prevalent in the Cockburn Coast district structure plan area are ideally suited to the promotion of infiltration at, or close to source. This has the advantage of maintaining recharge into the superficial aquifer as well as minimising the need for drainage infrastructure. The existing drainage systems in place within the study area are therefore limited to onsite soakage devices, small scale collection systems and traditional drainage sumps. As such there is little to be gained through aquifer storage and recovery and it is not recommended that this considered further at this time.

The storage of the additional stormwater runoff will require large areas set aside for the additional infrastructure. The storage tanks will require maintenance as will ensuring the quality of the stormwater is maintained at a fit for purpose level.

The most appropriate management of stormwater is infiltration at source or as close to source as practicable.

10.3 Groundwater

The availability of groundwater reserves for licensed abstraction has been discussed in Section 3.3 and there is approximately 811 ML/year available within the superficial aquifer in the Kogalup groundwater sub area. The Cockburn Coast redevelopment is likely to gain access to a limited proportion of this available resource. It is estimated that the fit-for-purpose (non potable) water demand for the structure plan area will be approximately:

- 295 ML/year non potable in house use;
- 24.4 ML/year irrigation (residential and commercial);
- 124 ML/year for POS irrigation (inclusive of school ovals and verge irrigation); and
- **443.4 ML/year in total.**

As such, while there is currently sufficient groundwater allocation available to cover these demands, it is unlikely an allocation will be granted for the total NDW water use. Department of Water typically only issue groundwater allocations for a five year period based on the estimated development's requirements (ie groundwater for construction or public open space irrigation) and after this period, the licence can be renewed or additional allocation sought.

The location of abstraction bores (or recharge) within the Robb Jetty LSP area will need to be carefully evaluated. As referred to in Section 5.1, there is a known bunker oil contamination source at the location of the existing historic chimney within the boundary of the proposed school (Figure 1).

Groundwater abstraction (or recharge) within the interpreted extent of bunker oil impact (GHD September 2011) should be prevented. A provisional exclusion distance of 70 m radius for abstraction or recharge of groundwater should be applied beyond the interpreted extent of bunker oil impact (GHD, September 2011) for the protection of receptors and to minimise risk of mobilisation of impacted groundwater.

The exclusion distance of 70 m radius is however provisional as the influence that a groundwater abstraction (or recharge) bore may have on impact stability/migration potential depends on circumstances specific to the abstraction. Therefore any proposal to abstract (or reinject) groundwater at surrounding Lots 101, 102, 109, 110, 2109 and the southern half of Lot 2103 should specifically assess the potential for influence upon the bunker oil impact and the validity of the provisional exclusion distance to ensure plume stability is not compromised.

As such, the location any bore proposed for the irrigation of the school oval will require consultation with a hydrogeologist to determine what the cone of depression from abstraction will be and if this has any potential to impact upon the plume. Possible alternatives for bore placement include but are not limited to:

- Construction in the far south east corner of the school site (however the potential impacts on the bunker oil plume from abstraction will need to be assessed by a hydrogeologist);
- Piping the water from bores located in open space areas adjacent to the site on the opposite side of Cockburn Rd in the Hilltop Emplacement LSP or north of the school site; or
- Irrigating the school oval through a reticulated third pipe scheme.

The irrigation of the school oval will need to be determined as part of the local structure planning process and any potential impacts on the bunker oil plume mitigated or eliminated.

10.4 Imported groundwater

Additional groundwater reserves imported from the groundwater interception trench at Port Coogee may be able to contribute 2.4 ML/day during the summer to help meet the irrigation demands of the district structure plan. Preliminary information indicates that the quality of this resource is sufficiently good to enable its use for irrigation. Further investigation will be required to establish in more detail the quality and quantity of water available from this source.

The City of Cockburn is also proposing to use some of this available water and there may be other potential users. To assess the further viability of using the imported groundwater further, the following will need to be undertaken:

- Establish the long term viability and operation length f the groundwater interception trench at Port Coogee;
- Identify the approximate quantity of water required using the project staging information and if any additional groundwater allocations are available;
- Discuss and agree the options of acquiring a portion of the water with the owners of the water; and
- Establish the required regulatory requirements (e.g. groundwater trading approval or groundwater allocation application may be required).

10.5 Wastewater

There is a substantial wastewater pumping station, Bennett Avenue pump station (Bennett Ave PS) within the study area which collects and conveys wastewater to the Woodman Point Wastewater Treatment Plant. This provides an opportunity for onsite wastewater harvesting for local distribution.

The current average daily inflow through the Bennett Ave Main PS is in the order of 7 ML/day (approximately 3 GL/year). Advice received from the Water Corporation suggests that the pump station will ultimately be upgraded to a 350 L/s capacity (approximately 30 ML/day or 11 GL/year). There is a substantial quantity of wastewater available from this pump station, however the cost of building infrastructure to extract, treat, store and distribute treated wastewater needs to be examined in detail and costed and a suitable service provider secured.

The current buffer around the Bennett Ave Main PS is 50 m, however it is indicated that this may need to be increased to 150 m (WGE, 2010). There is the possibility that any upgrade works required at the Bennett Ave Main PS to allow for distributed treated wastewater may be able to be accommodated within the increased buffer area. The feasibility of upgrading the Bennett Ave Main PS should be investigated further to establish the cost of upgrading and the potential recovery volumes.

The second option for recycling treated wastewater is from the Woodman Point wastewater treatment plant (WWTP). The Water Corporation's long term planning indicates an aim to recycle 20% of treated wastewater from the Woodman Point WWTP by 2030. The total volumes of treated wastewater from the Woodman Point WWTP are currently 44 GL/year (approximately 120 ML/day) with projected flows in 2030 of 74 GL/year (approximately 200 ML/day). It may therefore be preferable for the Cockburn Coast redevelopment to continue contributing its wastewater into this larger, regional scale recycling plan.

The final alternative for wastewater recycling is on site wastewater treatment and distribution. This would involve the construction of a site specific wastewater treatment facility that is independent of the Bennett Ave PS and would treat, store and distribute wastewater generated within the development only.

To determine the availability of treated wastewater to reuse on site, a simple monthly demand is presented in Figure 2 where the wastewater is reused for all irrigation purposes only and where the wastewater is reused for all fit for purpose use. This figure assumes that of the wastewater generated on site, 75% of the wastewater will be available for reuse.

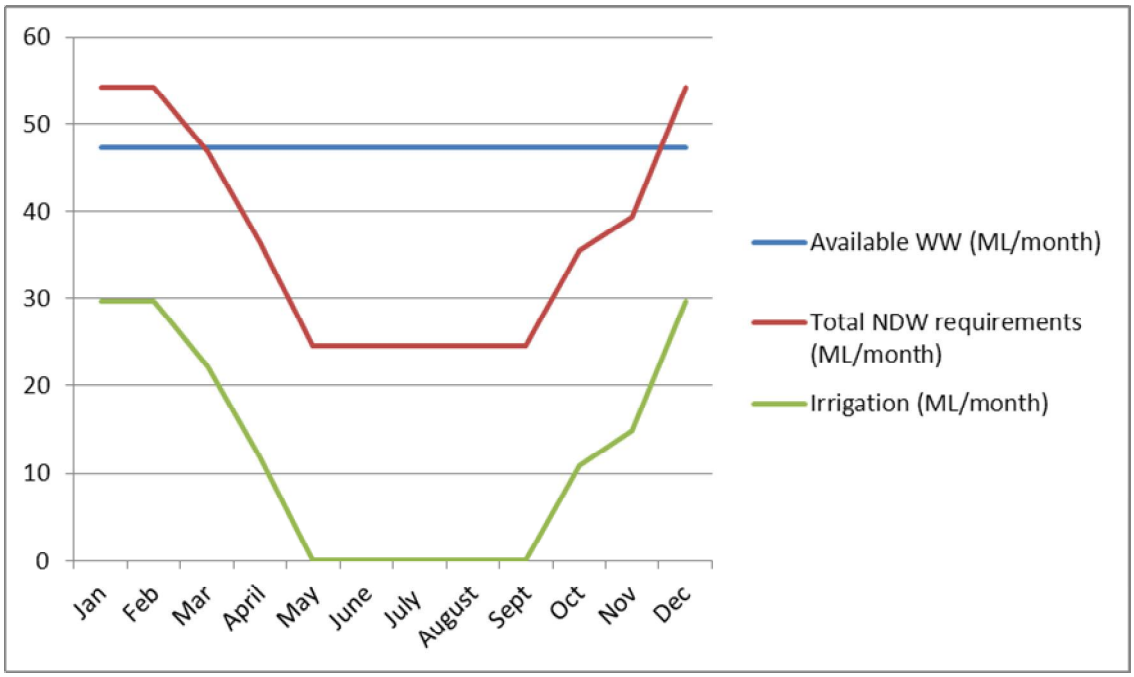


Figure 2 Wastewater availability

From Figure 2, it can be seen that there will be a surplus of wastewater during the winter months, regardless of which wastewater reuse servicing option is adopted. This excess would require either storage or disposal. If all non-drinking water uses were supplied by the treated wastewater, there will be a deficit of treated wastewater during the summer months. This deficit could be supplemented by storing some of the excess wastewater generated during the winter months or from an alternative water source.

At this stage of the development, the possibility of sewer mining and treatment at the Bennett Ave PS for local re-use is an option worth exploring further once more details are available regarding the timing of the upgrades.

10.6 Greywater

At the household scale, treated greywater is suitable for garden irrigation or infiltration in accordance with the Code of Practice for the Reuse of Greywater in Western Australia. Greywater can typically only be stored for up to 24 hours after which time there are significant impacts to water quality and subsequent risks to public health.

If greywater were to be used for domestic irrigation, the supply would be greater than the demand during the winter months. Alternative uses or disposal to the sewerage network would be required due to the reasons as described above.

Individuals may choose to install a greywater system for household irrigation and they will be responsible for adhering to the Code of Practice for Greywater Reuse in Western Australia. In this case the responsibility and costs for operation and maintenance are with the householder.

It is not recommended that greywater systems are mandated in the Cockburn Coast redevelopment area and it will be up to the individual householder to install the systems at their own discretion.

10.7 Water source recommendations

The following staged approach to implementing an alternative water source is recommended such that the development program is not impeded:

- Apply for groundwater allocation to allow for POS irrigation (and also construction) of the first stages;
- Commence discussions with groundwater inception trench owners to use part of this allocation;
- Allow flexibility in the local structure planning process to accommodate a reticulated NDW system; and
- Continue to investigate the possibility of wastewater recycling in the future based on upgrades to the Woodman Point WWTP.

11. Way forward

11.1 Summary

The integrated water management assessment has undertaken a high level water balance and demand assessment and found the following:

- A large amount (approximately 390 ML/year) of additional stormwater runoff will be generated in the ultimate scenario. While this is a possible water source, the recommended approach for managing this additional stormwater is to infiltrate into the groundwater using water sensitive urban design practices;
- The total water consumption for the site will be 960 ML/year, which equates to 77.40 kL/person/year. This per capita consumption meets the total water consumption sustainability target of 80 kL/person/year determined in the district structure plan; and
- The total potable consumption for the development ranges from 41.63 kL/person/year to 67.41 kL/person/year depending on which non drinking water servicing option is implemented. None of the calculated potable consumption rates will meet the potable sustainability consumption target of 40 kL/person/year outlined in the district structure plan.

11.2 Way forward and next steps

It is recommended that a staged approach is applied to taking forward the implementation of an alternative water source at the Cockburn Coast redevelopment. In the interim, the following is recommended:

- Apply for a groundwater allocation to allow for construction and establishment of the initial stages of development while an alternative water source is confirmed;
- Commence discussions with developers of Port Coogee for an allocation of groundwater from the groundwater inception trench. The Department of Water may also need to be involved to determine if an allocation is required for the use of this water; and
- Allow flexibility in the local structure planning process to accommodate a reticulated NDW system.

With respect to the localised bunker oil impact at depth in the vicinity of the historic chimney:

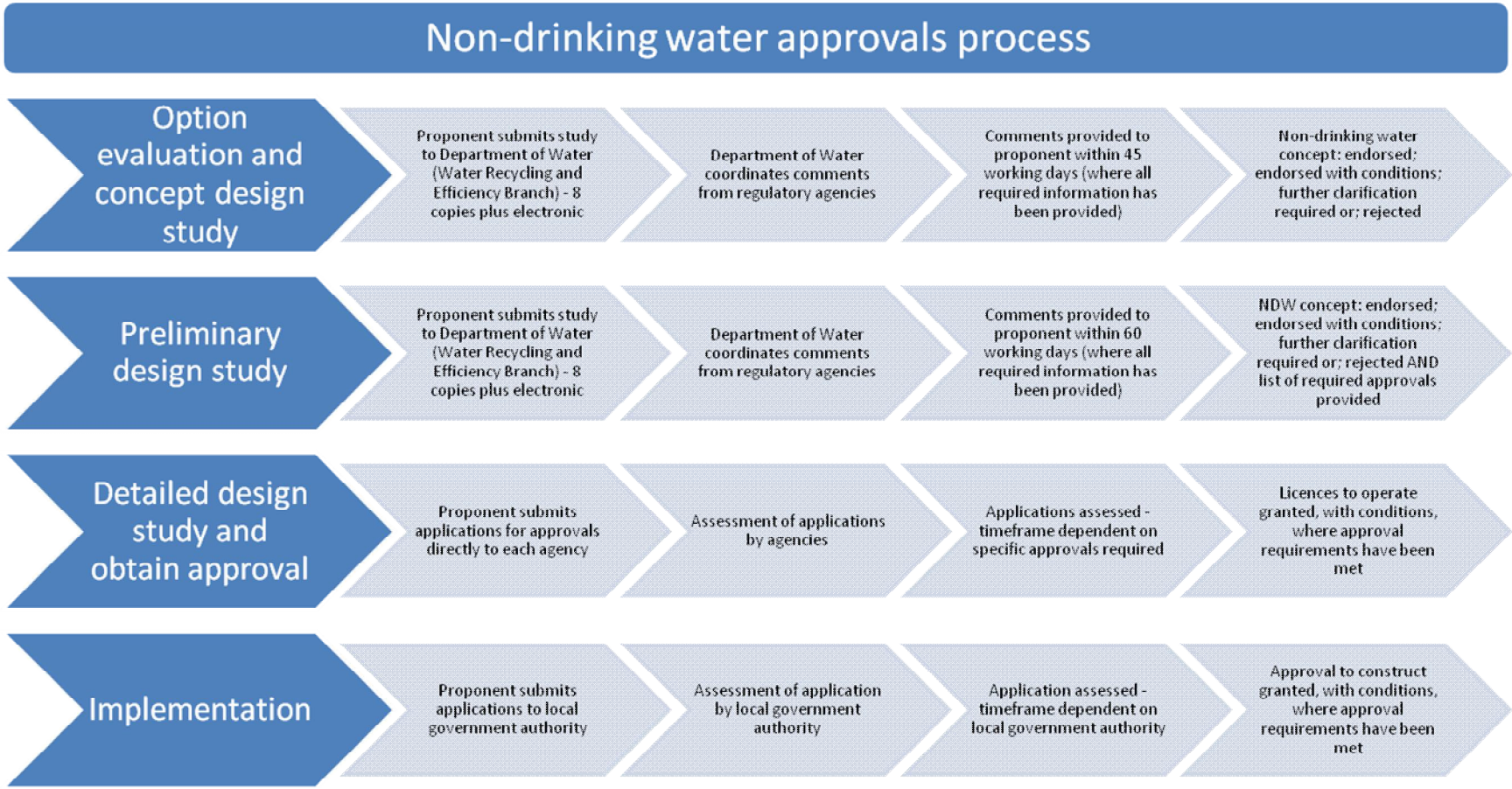
- No groundwater abstraction (or recharge) should be permitted within the interpreted extent of bunker oil impact in the vicinity of the historic chimney;
- No groundwater abstraction (or recharge) should be permitted within the provisional exclusion distance of 70m beyond the interpreted extent of the bunker oil impact (GHD September 2011);
- The exclusion distance of 70 m is provisional as the influence that a groundwater abstraction bore may have on impact stability/migration potential depends on circumstances specific to the abstraction or recharge such as volume of groundwater to be abstracted, proximity, targeted strata and characteristics. Therefore any proposal to abstract or reinject groundwater at surrounding Lots 101, 102, 109, 110, 2109 and the southern half of Lot 2103 should specifically assess the potential for influence upon the bunker oil impact and the validity of the provisional exclusion distance to ensure plume stability is not compromised.

- Prior to the construction of any groundwater bores within the exclusion distance surrounding the bunker oil impact in the Robb Jetty precinct, discussions are therefore to be held with a hydrogeologist to determine if the plume will be impacted.

For the longer term assessment of an alternative water source at Cockburn Coast, the following items should be considered:

- Undertake further discussions with the Water Corporation to determine the long term possibility of a regional wastewater recycling option;
- Assess and determine which non drinking water servicing option is most appropriate for the Cockburn Coast development;
- Undertake a cost benefit analysis for the preferred alternative water source and servicing strategy;
- Determine if a service provider is required and if so, assess potential service providers;
- Incorporate a waterwise display village into the initial stages of development to showcase the desirable water conservation initiatives; and
- Prepare design guidelines for the waterwise and water conservation initiatives and the public open space design.

Depending on the preferred alternative water source and servicing strategy, approval for the scheme may be required under the *Draft approvals framework for the use of non drinking water in WA* (DoW 2011). A summary of the approvals framework is provided as Figure 3. It is recommended that once a preferred water source has been established that discussions with the Department of Water are held to determine if the *Draft approvals framework for the use of non drinking water in WA* is applicable for the Cockburn Coast redevelopment.



Source: Department of Water, 2011

Figure 3 Draft non drinking water approvals framework

12. References

Davidson, 1995. Hydrogeology and groundwater resources of the Perth region. WA. GSWA Bulletin 142.

Department of Environment, 2004. *Perth Groundwater Atlas 2nd Edition*, 2004.

Department of Water, 2007. *Stormwater management manual for Western Australia*, Perth.

Department of Water. 2010 *Draft approval framework for the use of non drinking water in Western Australia.*

Department of Water. 2011 *Operational policy 1.01 - Managed aquifer recharge in Western Australia.*

GHD, 2010. *Report for Cockburn Coast District Structure Plan - District Water Management Strategy*. Prepared for LandCorp.

GHD, 2010. *Report for Cockburn Coast Redevelopment Detailed Site Investigation, Package 2 Former Abattoir Area, North Coogee*. Prepared for LandCorp

GHD, 2011. *Report for Cockburn Coast Detailed Site Investigation, Historic Bunker Oil Impact: Investigation and Risk Assessment.* Prepared for LandCorp

Government of Western Australia, 2007. *State water plan*.

PB, 2011. *Cockburn Coast Green Infrastructure Study*. Prepared for LandCorp

Water and Rivers Commission, 1997. *Perth Groundwater Atlas*.

Water Corporation H2Options Alternative Water Supplies for Perth Metro Area

Western Australian Planning Commission, 2009. *Cockburn Coast District Structure Plan.*

Wood & Grieve Engineers (WGE), 2010. *Report on Infrastructure for the proposed Cockburn Coast development.* Prepared for LandCorp

Appendix A

Water Corporation consumption parameters

WATER USAGE

1. Residential

1.1 Household Use	Estimate	Units	Source	Water Source	In-house/Ex-house	Notes
Garden Irrigation	0.002	kL/m^2/day	Water Corporation	Non-Potable (Irrigatio	Ex-house	10mm*9apps*8months/365.25days
Shower	0.050	kL/person/day	Diversity Australia	Potable (Drinking)	In-house	
Kitchen sink	0.008	kL/person/day	Diversity Australia	Potable (Drinking)	In-house	
Bathroom basin	0.006	kL/person/day	Diversity Australia	Potable (Drinking)	In-house	
Dishwasher	0.003	kL/person/day	Diversity Australia	Potable (Drinking)	In-house	
Bath	0.001	kL/person/day	Diversity Australia	Potable (Drinking)	In-house	
Laundry trough	0.004	kL/person/day	Diversity Australia	Potable (Drinking)	In-house	
Leaks	0.029	kL/household/day	Diversity Australia	Potable (Drinking)	Ex-house	
Pool	0.020	kL/household/day	Diversity Australia	Potable (Drinking)	Ex-house	
Spa	0.002	kL/household/day	Diversity Australia	Potable (Drinking)	Ex-house	
Car washing	0.002	kL/household/day	Diversity Australia	Potable (Drinking)	Ex-house	
Evaporative cooling	0.006	kL/household/day	Diversity Australia	Potable (Drinking)	In-house	
Other	0.004	kL/household/day	Diversity Australia	Potable (Drinking)	Ex-house	
Toilet	0.033	kL/person/day	Diversity Australia	Potable/Non-Potable (	In-house	
Washing machine	0.042	kL/person/day	Diversity Australia	Potable/Non-Potable (	In-house	

1.2 Household Type	Estimate	Units	Source	Notes
Traditional	2.736	Average # of Residents	2006 ABS Census	
Terraced	1.765	Average # of Residents	2006 ABS Census	
Cottage	1.814	Average # of Residents	2006 ABS Census	
Apartment	1.552	Average # of Residents	2006 ABS Census	
Lifestyle/Semi Rural	2.736	Average # of Residents	2006 ABS Census	

1.3 Irrigation Area	Estimate	Units	Source	Notes
Traditional	25	%	Water Corporation	
Terraced	25	%	Water Corporation	
Cottage	25	%	Water Corporation	
Apartment	22	%	Water Corporation	
Lifestyle/Semi Rural	12	%	Water Corporation	

2. Schools

2.1 School Size	Estimate	Units	Source	Notes
<100 Students	31.070	kL/Student/year	Water Corporation	
100 to 500 Students	8.710	kL/Student/year	Water Corporation	
501 to 1000 Students	7.060	kL/Student/year	Water Corporation	
>1000 Students	10.140	kL/Student/year	Water Corporation	
Irrigation	0.960	kL/m2/year		This is the midpoint between Active and Passive POS irrigation requirements.

2.2 School Non-Irrigation Water Usage Percentage

Parameter	Estimate	Units	Source	Notes
Drinking	60	%	Diversity Australia	Specify Drinking proportion and non-drinking is automatically calculated
Non-Drinking	40	%	Diversity Australia	
Potable Water Supply/Total Water Supply For Schools	100	%	Estimate	

2.3 Irrigation Area	Estimate	Units	Source	Notes
School	40	%	Water Corporation	

3. Commercial and Industrial

3.1 Entity Type	Constraint	Estimate	Units	Source	Notes
Shopping Centre	N/A	1.080	kL/m^2 GLA/year	Water Corporation	
Office Building	N/A	0.800	kL/m^2 GLA/year	Water Corporation	
Light Industrial	N/A	0.940	kL/m^2 GLA/year	Estimate	Mid point between Shopping Centres and Office Buildings
Hospital	≤300 Beds	185.820	kL/bed/year	Water Corporation	
Hospital	>300 Beds	269.350	kL/bed/year	Water Corporation	
Nursing Home	≤60 Beds	144.490	kL/bed/year	Water Corporation	
Nursing Home	>60 Beds	109.390	kL/bed/year	Water Corporation	
Hotel	≤250 Rooms	104.530	kL/room/year	Water Corporation	
Hotel	>250 Rooms	192.010	kL/room/year	Water Corporation	
Commercial Laundry	N/A	44834.400	kL/entity/year	Water Corporation	
Aquatic Centre	N/A	14600.000	kL/entity/year	Water Corporation	
Hospitality	N/A	570.180	kL/entity/year	Water Corporation	
Manufacturing	N/A	438.340	kL/entity/year	Water Corporation	
Other Sporting Facility	N/A	14600.000	kL/entity/year	Water Corporation	

3.2 Commercial Laundries	
Assumed kgs/week for Commercial Laundries	60,000
L/kg/week	14

3.3 Aquatic Centres	
Assumed visitors/day	500
L/visitor/day	80

3.4 Water Usage Percentage Entity Type	Irrigation	Drinking Water	Non-Drinking Water
Shopping Centre	5%	60%	35%
Office Building	5%	60%	35%
Light Industrial	5%	60%	35%
Hospital	5%	60%	35%
Nursing Home	5%	60%	35%
Hotel	5%	60%	40%
Commercial Laundry	0%	5%	95%
Aquatic Centre	5%	80%	15%
Hospitality	5%	80%	15%
Manufacturing	5%	80%	15%
Other Sporting Facility	5%	80%	15%

3.5 Potable Water Supply/Total Water Supply for Entity Type Entity Type	Percentage
Shopping Centre	100%
Office Building	100%
Light Industrial	100%
Hospital	100%
Nursing Home	100%
Hotel	100%
Commercial Laundry	100%
Aquatic Centre	100%
Hospitality	100%
Manufacturing	100%
Other Sporting Facility	100%

4. Public Open Spaces

4.1 Public Open Space	Estimate	Units	Source	Water Use
Public Open Space - Active	1.280	kL/m^2/year	Water Corporation	Irrigation
Public Open Space - Passive	0.640	kL/m^2/year	Water Corporation	Irrigation
Public Open Space - Amenity Drinking/Non-drinking ratio	0.50	%	Estimate	Drinking

4.2 Verges and Street Scaping	Estimate	Units	Source	Water Use
Verges	0.640	kL/m^2/year	Water Corporation	Irrigation
Street Scaping	0.640	kL/m^2/year	Water Corporation	Irrigation

WATER SUPPLY

1. Rainwater

1.1 Rainfall Collection	Estimate	Units	Source	Notes
Average Annual Rainfall	700	mm/year	Estimate	Metro area only
Rain correction	24	mm/year	http://enhealth.nphp.gov.au	For evaporation, roof wetting, etc
Efficiency factor	80%	%	Estimate	Conversion of rainfall to rain capture

1.2 Percentage of lot that is roofing	Estimate	Units	Source	Notes
Traditional	50	%	Estimate	
Terraced	50	%	Estimate	
Cottage	50	%	Estimate	
Apartment	50	%	Estimate	
Lifestyle/Semi Rural	25	%	Estimate	
Schools	10	%	Estimate	
Commercial & Industrial	25	%	Estimate	
Public Open Spaces, Roads & Verges	5	%	Estimate	

1.3 Percentage of roofing used for collection	Estimate	Units	Source	Notes
Traditional	100	%	Estimate	
Terraced	100	%	Estimate	
Cottage	100	%	Estimate	
Apartment	100	%	Estimate	
Lifestyle/Semi Rural	100	%	Estimate	
Schools	100	%	Estimate	
Commercial & Industrial	100	%	Estimate	
Public Open Spaces, Roads & Verges	100	%	Estimate	

TARGETS

Target	Target Level	Units	Source	Notes
Metropolitan Residential Average 07/08	105.4	kL/person/annum		
Development Estate Average	90	kL/person/annum		
Department of Water Irrigation Allowance	7500	kL/ha/annum		
Local Authority	7500	kL/ha/annum	Local Authority	
Infrastructure Planning Estimate (Water)	TBD		IPB	
Infrastructure Planning Estimate (Wastewater)	TBD		IPB	

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Appendix D Modelling

Modelling Discussion

GHD built an InfoWorks CS hydrologic and one-dimensional hydraulic model of the existing and proposed development, and simulated the model for a range of design storms. InfoWorks CS is a computer program for simulating catchment hydrology and one-dimensional flows in conduits and open channels. Data is input via GIS files, tables and a graphical user interface, and results are produced graphically and in GIS and tabular format.

The hydrology was simulated using the SWMM model, based on the parameters listed in Table 12, Table 13 and Table 14. These parameters are consistent with regional storm water modeling for the Serpentine area.

Modelling assumptions

- Catchment infiltration modelled at a constant rate of 6 mm/hour
- Basin infiltration modeled at a constant rate of 4 mm/hour
- All roads connected to bio retention system sized for the 1 year 1 hour storm (16 mm)

Modelling parameters

Table 12 InfoWorks model runoff surface properties

Runoff surface	Surface roughness (Manning's n)	Initial loss (mm)	Infiltration loss (mm/hour)	Fixed runoff coefficient
Developed Impervious	0.015	16	6	1
Pervious	0.03	10	6	1
Lot (Commercial)	0.015	1.5	6	0
Lot (Res)	0.015	16	6	1

Table 13 IFD data

Input	Value
2 yr ARI intensity	
1 hr	21.04
12 hr	4.25
72 hr	1.26
50 yr ARI intensity	
1 hr	35.96

12 hr	6.71
72 hr	2.19
Geographical factors	
F2	4.86
F50	17.18
Location skewness	
Zone	8

Table 14 InfoWorks model catchment properties for pre development scenario

Sub-catchment ID	Area (ha)	Vector slope (m/m)	Catchment dimension (m)	Impervious (%)	Pervious (%)	Soakage (%)
1	13.184	0.01	204.9	9.976	2.971	87.053
1a	3.498	0.007	105.5	24.08	75.92	0
2	7.361	0.01	153.1	13.669	8.882	77.449
2a	8.927	0.01	168.6	13.834	12.372	73.794
2b	10.923	0.01	186.5	19.713	7.474	72.813
2c	4.525	0.01	120	24.08	75.92	0
3	9.449	0.01	173.4	5.21	4.157	90.633
4	14.085	0.01	211.7	18.548	23.544	57.908
4a	8.327	0.01	162.8	25.686	0	74.314
5	10.857	0.01	185.9	8.096	9.035	82.869
5a	7.327	0.01	152.7	7.325	8.953	83.722
6	7.932	0.01	158.9	9.32	0.896	89.784
7	7.513	0.01	154.6	26.295	4.356	69.349
7a	4.434	0.01	118.8	23.454	6.321	70.224
8	10.381	0.01	181.8	11.059	7.699	81.243
8a	6.97	0.01	149	15.406	0	84.594
external	30.381	0.03	400	0	100	0

Appendix E Better Urban Water Management LWMS checklist

Checklist for integrated water cycle management assessment of local structure plan or local planning scheme amendment

1. Tick the status column for items for which information is provided.
2. Enter N/A in the status column if the item is not appropriate and enter the reason in the comments column.
3. Provide brief comments on any relevant issues.
4. Provide brief description of any proposed best management practices, eg. multi-use corridors, community based-social marketing, water re-use proposals.

Local water management strategy item	Deliverable	☑	Comments
Executive summary			
Summary of the development design strategy, outlining how the design objectives are proposed to be met	Table 1: Design elements & requirements for BMPs and critical control points	☑	Executive Summary
Introduction			
Total water cycle management – principles & objectives Planning background Previous studies		☑	Section 1
Proposed development			
Structure plan, zoning and land use. Key landscape features Previous land use	Site context plan Structure plan	☑ ☑	Section 2.1
Landscape - proposed POS areas, POS credits, water source, bore(s), lake details (if applicable), irrigation areas	Landscape Plan	☑	Section 2.2
Design criteria			
Agreed design objectives and source of objective		☑	Section 3
Pre-development environment			
Existing information and more detailed assessments (monitoring). How do the site characteristics affect the design?		☐	
Site Conditions - existing topography/ contours, aerial photo underlay, major physical features	Site condition plan	☑	Section 4.1 to 4.3
Geotechnical - topography, soils including acid sulfate soils and infiltration capacity, test pit locations	Geotechnical plan	☑	Section 4.4 and 4.5
Environmental - areas of significant flora and fauna, wetlands and buffers, waterways and buffers, contaminated sites	Environmental Plan plus supporting data where appropriate	☑	Section 4.7
Surface Water – topography, 100 year floodways and flood fringe areas, water quality of flows entering and leaving (if applicable)	Surface Water Plan	☑	Section 4.8
Groundwater – topography, pre development groundwater levels and water quality, test bore locations	Groundwater Plan plus details of groundwater monitoring and testing	☑	Section 4.9
Water use sustainability initiatives			
Water efficiency measures – private and public open spaces including method of enforcement		☑	Section 5.1
Water supply (fit-for-purpose strategy), agreed actions and implementation. If non-potable supply, support with water balance		☑	Section 5.4
Wastewater management		☑	Section 5.4
Stormwater management strategy			
Flood protection - peak flow rates, volumes and top water levels at control points,100 year flow paths and 100 year detentions storage areas	100yr event Plan Long section of critical points	☑ ☐	Section 6.2
Manage serviceability - storage and retention required for the critical 5 year ARI storm events Minor roads should be passable in the 5 year ARI event	5yr event Plan	☑	Section 6.2

Local water management strategy item	Deliverable	☑	Comments
Protect ecology – detention areas for the 1 yr 1 hr ARI event, areas for water quality treatment and types of (including indicative locations for) agreed structural and non-structural best management practices and treatment trains. Protection of waterways, wetlands (and their buffers), remnant vegetation and ecological linkages	1yr event plan Typical cross sections	☑ ☐	Section 6.2 Section 6.3
Groundwater management strategy			
Post development groundwater levels, fill requirements (including existing and likely final surface levels), outlet controls, and subsoils areas/exclusion zones	Groundwater/subsoil Plan	☑	Section 7.2
Actions to address acid sulfate soils or contamination		☑	Section 7.3
The next stage – subdivision and urban water management plans			
Content and coverage of future urban water management plans to be completed at subdivision. Include areas where further investigations are required prior to detailed design.		☑	Section 8
Monitoring			
Recommended future monitoring plan including timing, frequency, locations and parameters, together with arrangements for ongoing actions		☑	Section 8.1
Implementation			
Developer commitments		☑	Section 8.3
Roles, responsibilities, funding for implementation		☑	Section 8.3
Review		☑	Section 8.3

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