Cockburn Central East

Local Water Management Strategy

CW989900

Prepared for
City of Cockburn

28 July 2017

Cardno
Shaping the Future

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Executive Summary

The Local Water Management Strategy (LWMS) has been prepared by Cardno on behalf of the City of Cockburn in support of the development of the Cockburn Central East (CCE) precinct, located approximately 19 km south of Perth Central Business District.

The study area is approximately 108 ha in size and comprises:

> The area currently covered by the Solomon Road Structure Plan;

> Industrial zoned land boarding the Solomon Road Strucutre Plan (to the north); and

> Vacant land to the north of the CCTC.

City of Cockburn has commissioned the development of the CCE Structure Plan (and LWMS) due to the impending North Lake Road Bridge and Armadale Road deviation project. The Structure Plan area is also located in immediate vicinity of several development areas/precincts with adopted water management strategies which are to be consider as part of the LWMS.

The LWMS provides the framework for the application of total water cycle management to the proposed urban structure, consistent with Department of Water (DoW) principles of Water Sensitive Urban Design (WSUD) as described in the Stormwater Management Manual of WA (DoW, 2007). The preparation of the LWMS is consistent with the WAPC (2008) Better Urban Water Management framework and demonstrates the Study Area is capable of achieving appropriate water management outcomes with and commercial land use.

The LWMS has been developed to:

> Provide a stormwater management framework to support future commercial development proposed for the Study Area.

> Incorporate appropriate Best Management Practices (BMP) into the drainage systems that address the environmental and stormwater management issues identified.

The development proposes to be consistent with the objectives drawn up in the precinct in the Cockburn Central Activity Centre Strategy. The water management objectives for the site are to:

> Minimise the use of water within the development wherever possible;

> Retain and treat the first 15mm of rainfall event as close to source as possible;

> Retain flows up to the 1% AEP event in the existing wetland located in the central region of the Study Area.

> Minimise any changes to the underlying groundwater level and quality as a result of development.

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1 Introduction

1.1 Background

The Cockburn Central locality is set to become a major regional centre which is envisioned to house a vibrant mix of residential, commercial and recreational developments. The larger development encompassed under the Cockburn Central Activity Centre Strategy includes 10 distinct precincts, with 'Core Area' precincts including the Cockburn Central Town Centre, Cockburn Central West, Muriel Court South, Gateways Shopping Centre and Cockburn Central East. Works on Cockburn Central Town Centre and Gateways Shopping Centre have now predominantly been completed, while Cockburn Central West is under construction. Muriel Court South and Cockburn Central East remain in the planning and approvals process.

City of Cockburn (the City) has commissioned the development of the CCE Structure Plan (and LWMS) due to the impending North Lake Road Bridge and Armadale Road deviation project. Plate 1 illustrates the new alignment in the context of the wider Cockburn Central Activity Centre and the Solomon Road Structure Plan.

Plate 1: North Lake Bridge and Armadale Road deviation alignment indicated by Planning Control Area (City of Cockburn, 2016)

The Study Area is located in the City of Cockburn, approximately 19 km south of Perth CBD. Muriel Court (South), Town Centre and Cockburn Central West developments are located west of the Study Area, while the Gateways Shopping Centre development and residential precinct are to the south of the Study Area.

The Study Area is approximately 108 hectares in size and bound by Kwinana Freeway to the west, Cutler Road to the north, Wintergreen Crescent to the east and Armadale Road to the south.

While the structure plan study area relates to the entire Solomon Road industrial area, the intent at this stage is to propose land use changes to a portion of the study area close to the Freeway. The LWMS focuses on the white area identified within Plate 3. The remaining colour shaded areas currently propose no change.

Plate 2: Focus of the CCE SP – area highlighted in white "subject to future planning" (City of Cockburn, 2016)

1.1.1 Report Purpose

The City engaged Cardno to undertake the Local Water Management Strategy (LWMS) to address the requirements of the:

> Western Australian Planning Commissions (WAPC) Better Urban Water Management Framework (WAPC 2008);

> The associated Planning Bulletin 92 – Urban Water Management, and;

> The Department of Water Interim: Developing a Local water Management Strategy (2008).

For the area including:

> The area currently covered by the Solomon Road Structure Plan.

> Industrial zoned land bordering the Solomon Road Structure Plan (to the north).

> Vacant land to the north of the CCTC included to comprehensively look at drainage requirements for the deviation project and seeking to reduce impact on the town centre.

The context and extent of the CCE Structure Plan is shown in Plate 3.

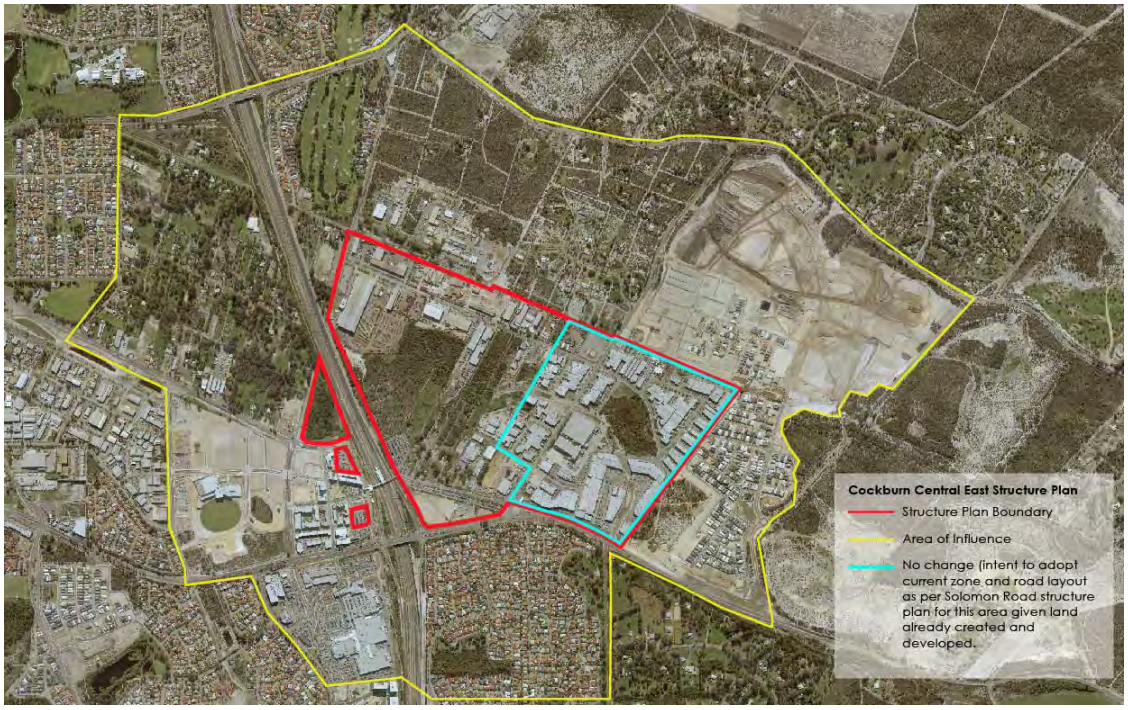

Plate 3: Project Area Context Plan (City of Cockburn, 2016)

The Structure Plan area is also located in immediate vicinity of several development areas/precincts with adopted water management strategies which are to be considered as part of the LWMS. To ensure drainage requirements are aligned and sufficient across the immediate district, the LWMS will also review and be informed by:

> Cockburn Central (Arterial) Drainage Study (2004) – David Wills and Associates Consulting Engineers;

> Cockburn Central West: LWMS (RPS, 2014) and subsequent UWMP (Essential Environmental, 2015);

> Muriel Court:

- Development Area 19 District Water Management Strategy (Cardno, 2008)
- LWMS (ENV Australia, 2011) and subsequent UWMP (details to be confirmed)

> Cockburn Central Town Centre water management strategies (details to be confirmed)

> The North Lake Road Bridge and Armadale Road deviation project

This Local Water Management Strategy (LWMS) is prepared by Cardno on behalf of the City of Cockburn in support of the development of Cockburn Central East (herein referred to as the Study Area), as required by the Better Urban Water Management framework (WAPC 2008).

1.2 Statutory Framework

A significant portion of the study area to the east of the Kwinana Freeway is zoned 'Industrial' under the Metropolitan Region Scheme (MRS) and 'Development' (Development Area 20 (DA 20)) under the CoC Town Planning Scheme (TPS). The Solomon Road Structure Plan is adopted for the area of DA 20, with land zoned as a mix of Light and Service Industry and Mixed Business.

1.3 Policy Framework

The LWMS has been prepared in accordance with *State Planning Policy 2.9: Water Resources (*Government of Western Australia, 2006) and uses the following documents to define its key principles and objectives:

- Stormwater Quantity Management Manual for WA (Department of Water, 2007)
- Better Urban Water Management (WAPC, 2008).
- Liveable Neighbourhoods Edition 4 (WAPC, 2009)

A summary of the guidance obtained through key design principles and objectives from these documents is provided in Table 1 and summarised below.

1.3.1 Stormwater Quality Management Manual for WA (DoW, 2007)

The Water and Rivers Commission, now the Department of Water (DoW), released *A Manual for Managing Urban Stormwater Quality in Western Australia* in 1998 to define Best Management Practices (BMP's) necessary to reduce pollutant and nutrient inputs to stormwater drainage systems. The Manual also provides guidelines for the incorporation of water sensitive design principles into urban planning and design, to promote the improvement of water quality from urban development.

The document was released to provide a guideline for best planning and management practices for use by Water and Rivers Commission, other State and Local Government Authorities and sectors of the urban development industry.

DoW completed a major review of the Manual in consultation with a working team comprising industry and government representatives, published in August 2007.

Principle objectives for managing urban water in Western Australian are stated as:

- Water Quality: To maintain or improve the surface and groundwater quality within the Study Area relative to pre-development conditions.
- Water Quantity: To maintain the total water cycle balance within the Study Area relative to the pre-development conditions.
- Water Conservation: To maximise the reuse of stormwater.
- Ecosystem Health: To retain natural drainage systems and protect ecosystem health.
- Economic Viability: To implement stormwater systems that are economically viable in the long term.
- Public Health: To minimise the public risk, including risk of injury or loss of life to the community.
- Protection of Property: To protect the built environment from flooding and waterlogging.
- Social Values: To ensure social, aesthetic and cultural values are recognised and maintained when managing stormwater.
- Development: To ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

1.3.2 Better Urban Water Management (WAPC, 2008)

The guideline document Better Urban Water Management (WAPC, 2008), focuses on the process of integration between land use and water planning and specifying the level of investigations and documentations required at various decision points in the planning process, rather than the provision of any specific design objectives and criteria for urban water management.

This LWMS complies with the BUWM process.

1.3.3 Liveable Neighbourhoods (WAPC, 2009)

The LWMS has been developed in accordance with regional and local principles and objectives of Integrated Urban Water Management (IUWM) established in the guideline document, Liveable Neighbourhoods (WAPC, 2009).

IUWM (also known as total water cycle management) is defined as promoting '*management of the urban water cycle as a single system in which all urban water flows are recognised as a potential resource and where the interconnectedness of water supply, stormwater, wastewater, flooding, water quality, waterways, estuaries and coastal waters is recognised*'.

IUWM also promotes water conservation measures, reuse and recycling of water and best practice in stormwater management.

The objectives in the LWMS are consistent with Liveable Neighbourhoods.

1.4 Previous Studies

Cardno completed a literature review of the documents below which are within the immediate vicinity of the Study Area.

1.4.1 Cockburn Central (Arterial) Drainage Study (2004) – David Wills and Associates Consulting Engineers;

The Cockburn Central Arterial Drainage Study was commissioned to assist the City of Cockburn to resolve technical issues associated with the provision of a stormwater drainage system, to service the Solomon Road Development Area and the Cockburn Central Development Area. This LWMS is located across Catchment Area 1 (existing Industrial land use area) and Catchment Area 2 (identified as 'subject to future planning, Plate 2) driven by the following principles:

> Lot filling to provide sufficient separation to the groundwater to promote infiltration;

> Catchments to use on site soakage as the primary disposal option

> The lot fill level shall be a minimum of 2.0 m above the Design Regional Control Groundwater level;

> All industrial lots are to retain storm events up to the 100 yr ARI critical event on site using a suitably designed soakage system;

> Mixed business and mixed use lots are to provide retention storage for the first 15 mm of rainfall from the gross lot area. Stormwater in excess of this volume shall be allowed to overflow into the Local Authority stormwater drainage system;

> The center line of road pavements within shall be a minimum 1.5 m clearance to the Design Regional Control Groundwater Level;

> Where possible, the basin should be integrated within Public Open Space (POS) to enhance the community use of the area.

The study suggested infrastructure may need to be installed beneath the Freeway to connect to the Cockburn Central West to control groundwater levels. Although not detailed within the preparation of the LWMS, it has been assumed this may ultimately need to be included. Due to the level of design currently available, the arrangement will be detailed within the proceeding UWMPs when greater site detail is available.

The Drainage Study has been used as a guiding document to inform the water management strategy criteria of the LWMS.

1.4.2 Cockburn Central West:

LWMS (RPS, 2014)

The Cockburn Central West Local Water Management Strategy was prepared for Landcorp to support the Local Structure Plan developed Cockburn Central West.

The key drainage strategy principles and criteria adopted for the document were:

> Permeability testing was undertaken by Douglas Partners and ranged between 27m/day to 147 m/day. The design permeability recommended was 43.2 m/day.

> All commercial and residential lots are required to collect and contain stormwater for infiltration using soakwells for up to and including the 100yr ARI event.

> The drainage system focuses on stormwater retention and infiltration at source via soakwells and underground stormtech cells.

> It was the intent to incorporate streetscape swales within road median strips and roadsides.

> Fully self-contained roadway drainage pit and pipe system with the capacity to infiltrate/convey the 5yr ARI.

> Pits located in the road reserve connected to shallow stormtech infiltration chambers sized to infiltrate events up to and including the 5yr ARI.

> Subdivision approvals and drainage design of Cockburn Central East rely on stormwater being discharged to the wetland in events that exceed the 5yr ARI event.

> The wetland includes the use of bio-filtration swales located on the perimeter of the wetland designed to treat the first flush.

The Central West LWMS does not impact on the Cockburn Central East LWMS but does demonstrate the use of similar criteria to address Better Urban Water Management.

The following shortfalls were noted:

> Modelling assumptions for sizing infrastructure is not provided to review.

> Bio-retention requirements around the wetland is questioned given that the Cockburn Central East and roads all contain event up to the 5yr within the road reserve.

UWMP (Essential Environmental, 2015);

Drainage design principles and requirements of the UMWP were adopted from the LWMS with the following differences:

> Treepits were based on a relatively low infiltration rate of 1.8 m/d (7 m/d mentioned later in the document) due to the relatively shallow depth to groundwater and possible clogging that can occur.

> Infiltration was assumed to be 2.5 m/day within the wetland and from the sides of the wetland as it intersects groundwater

> Stormtech cells sized based on 7 m/day infiltration rate.

The following shortfalls were noted:

> Detailed modelling information not provided.

> It is not clear what the adopted infiltration rates are based on.

> Not clear whether tree pits were sized on 1.8 m/d (section 6.2.1) or 7m/d (section 6.2.2).

> No runoff coefficients provided.

> Total volume generated and captured on site unknown.

1.4.3 Muriel Court

Development Area 19 District Water Management Strategy (Cardno, 2008)

The Development Area 19 DWMS built on from the Cockburn Central Arterial Drainage Study guided by the following principles:

> The 1 in 1 year ARI event shall be contained in a formalised area(s) or swale(s) and should be designed to infiltrate into the groundwater.

> Storm events above the 1 in 1 year may need to be detained in a formalised area(s), which could include a Compensating (Detention) Basin in order to meet maximum outflow criteria.

> A Groundwater Collection Basin(s), with the invert set a minimum 0.5m below the Design Regional Control Groundwater Level (DRCGL), may be adopted in POS to assist in setting the DRCGL. Where Groundwater Collection Basins are not adopted in POS, subsoil drainage or the use of the piped stormwater drainage network set at the DRCGL should be considered to assist in setting the DRCGL.

> Consideration should be given to lowering the base of Groundwater Collection Basin level in order to create a permanent water body and avoid the base becoming swampy in summer.

> The Groundwater Collection Basin(s) may also be used as a Compensating (Detention) Basin for large storm events, i.e. have a dual use.

> Maximum outflow for the Groundwater Collection Basin(s) should be set at 8 litres/second/impervious hectare of catchment area for the peak of the 5 year ARI event and 9.6 litres/second/impervious hectare of catchment area for the peak of the 100 year ARI event (to be checked at detailed design stage). • The 100 year ARI Top Water Level shall be a minimum 0.3m below the lowest lot level, unless otherwise set by Local Authority

> The road network may be used as an overland overflow path.

> Subsoil drains, where required, shall be set to the DRCGL and transport groundwater to the next down gradient Groundwater Collection Basin or the regional drainage network.

> Stormwater pipes should generally not be laid below DRCGL. If below DRCGL, the pipe network should be fully sealed.

> All manholes and gullies within the drainage system shall comply with City of Cockburn drainage details, with base extended a minimum 0.6m (where not below DRCGL). Bases to have a suitable filter material below manhole to act as a groundwater recharge point and groundwater collection point, particularly where set at the DRCGL.

> Where grade permits, the piped stormwater drainage network may be set to DRCGL with intake and outtake allowed at bases of manholes, possibly in conjunction with a small strip of subsoil drainage, grading down to the manhole. This would negate the requirement for subsoil drainage along road alignments.

> Saturated conductivity of 8.64 m/d adopted for site.

The document produced by Cardno BSD, while served its purpose at the time, was written prior to Better Urban Water Management (WAPC, 2008) with some philosophies now no longer supported by the City .i.e. creating a groundwater collection basin. The document should be utilized as a reference document only with a revision of design principles needing to be considered within LWMS documents.

LWMS (ENV Australia, 2011)

The LWMS for Muriel Court, built on design principles from the DWMS with some important changes:

> Principles and design were updated to be in Line with the (at the time) recently released Better Urban Water Management (WAPC, 2008); and

> No longer creating a groundwater collection basin with the inverts of bio-retentions set at Average Annual Maximum Groundwater Level (AAMGL) to reduce the period over which bio-retentions would be inundated.

The report did not provide an infiltration rate utilized for modelling purposes but rather developed an XPSWMM model and discharged to the district drainage based on flow rates derived in the DMWS.

1.5 Armadale Road Diversion and North Lake Road Bridge

Main Roads Western Australia (MRWA) have commenced design and drainage requirements for the Armadale Road deviation and North Lake Road bridge project. The current MRWA design provides a significant amount of drainage over an important town centre site – Lot 9500 Kentucky Court and within the Cockburn Central East Structure Plan Area.

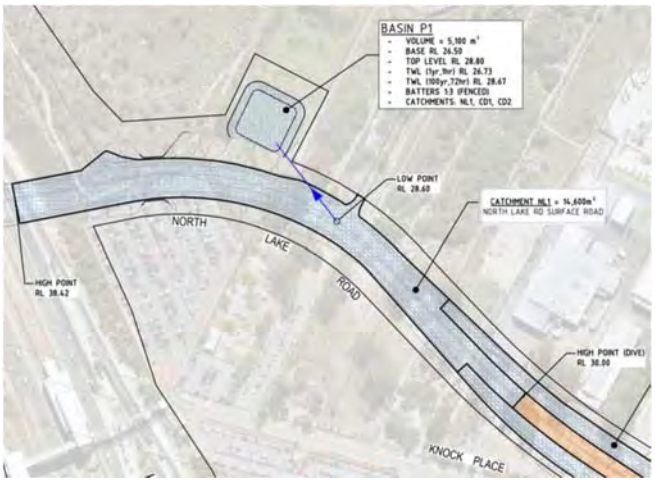

Plate 3 and 4: Concept Drainage Plans for Lot 9500 (left, MRWA 2016) and the CCE Structure Plan Area (right, BG&E 2017)

BG&E (2017) have prepared a 15% Design Report for the north Lake Road Realignment which identifies the following drainage:

> North Lake Road Bridge – built on a curve crest resulting in half the bridge draining to the west and half towards the east. No drainage infrastructure is proposed to be installed on the bridge with pit and pipe systems at the end of the bridge picks up stormwater flow.

> North Lake Road west – The proposed drainage connects into the existing City of Cockburn drainage network between Midgegooroo Avenue and the Kwinana Freeway.

> North Lake Road east – The proposed drainage is to a basin within Lot 9001 Knock Place. The basin (P1) is sized to cater for the 1% AEP event and takes into account drainage from the PTA carpark catchment. Basin P1 is described as being in a trapped low area with no identifiable, practicable overflow routes and therefore required sizing to contain the 1% AEP storm event. The area in which the basin is located has a high watertable limiting the ability to excavate a basin. The basin was sized utilising PC SUMP and assumed a 100% runoff from the road catchments and assumed permeability of 5 m/d and a clogged layer of 0.15 m/day. To cater for the 1% AEP 72 hr event, 6938 m^3 of storage is needed.

MRWA concept drainage designs are provided in **Error! Reference source not found.**.

2 Proposed Development

Cockburn Central East Structure Plan primarily consists of mixed business and light and service industry development (Plate 5) which will aim to achieve the objectives drawn up in the precinct in the Cockburn Central Activity Centre Strategy.

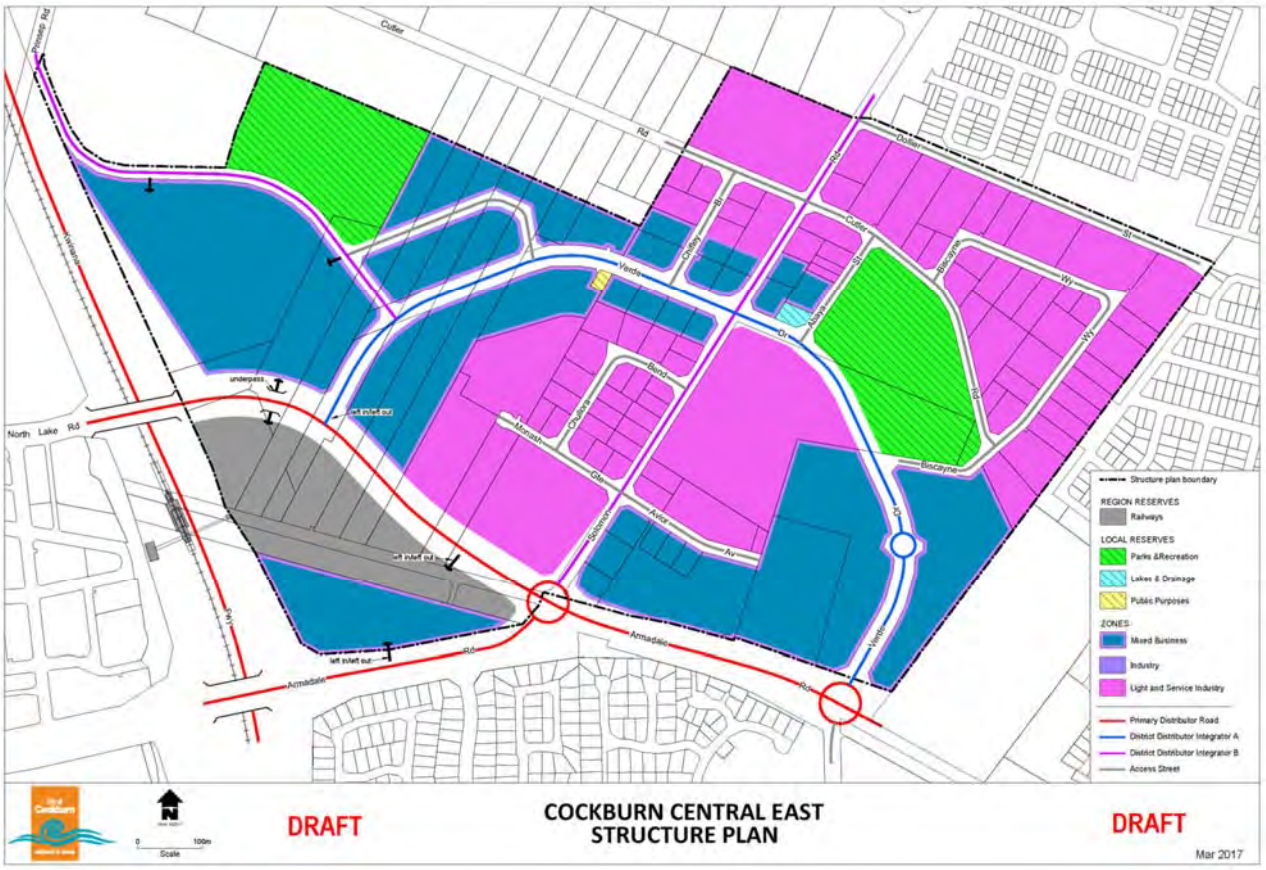

Plate 5 – Draft Cockburn Central East Structure Plan (City of Cockburn, 2017)

The developments within the precinct will be served by a road network which will be strategically connected to the regional road network, providing access to regional traffic and local traffic, enabling movement for business, freight, customers and residents. North Lake Road Bridge and extension planned by Main Roads which has also been incorporated within the Study Area.

The development will include functional landscaping which will serve both as amenity to local businesses and their customers while also providing drainage function to the precinct. The existing environmentally significant bushland (wetland) will be utilised as the primary drainage basin for the Study Area.

The main focus of the LWMS is to:

> Incorporate Main Road drainage design with proposed drainage infrastructure servicing Study Area; and

> Address drainage requirements of the Study Area, west of Solomon Road with the exception of the light and service industry which is already serviced.

2.1 LWMS Objectives

The LWMS Objectives and criteria how they are met are provided in Table 2-1.

Table 2-1 Summary of LWMS Principles and Objectives

Key Guiding Principles
• Facilitate implementation of sustainable best practice urban water management. • Provide integration with planning processes and clarity for agencies involved with implementation. • Minimise public risk, including risk of injury or loss of life. • Protect infrastructure and assets from flooding and inundation. • Encourage environmentally responsible development. • Facilitate adaptive management responses to the monitored outcomes of development.

Category	IUWM Objectives	LWMS Criteria
Surface Water Management	▪ Minimise changes in hydrology to prevent impacts on receiving environments. ▪ Manage water flows from major events to protect infrastructure and assets. ▪ Apply the Principles of WSUD. ▪ Adopt nutrient load reduction design objectives for stormwater runoff. Floodplain management and urban drainage.	▪ All surface water to be retained within the Study Area and infiltrated. ▪ First 15 mm of rainfall to be infiltrated at source where possible. ▪ Manage surface water flows from major events to protect infrastructure and assets from flooding and inundation. ▪ Use swales, living streams and ephemeral storage areas (buffers, POS, etc.) to attenuate and infiltrate surface water runoff.
Groundwater Management	▪ Manage groundwater levels to protect infrastructure and assets. ▪ Maintain groundwater regimes for the protection of groundwater-dependent ecosystems. ▪ Protect the value of groundwater resources. ▪ Adopt nutrient load reduction design objectives for discharges to groundwater.	▪ Managing and minimising changes in groundwater levels and groundwater quality following development. ▪ Sub-surface drainage (subsoils) and drainage infrastructure set at or above the groundwater design level, although existing inverts below this level may remain. ▪ Sub-surface drainage outlets must be free draining.
Water Conservation	▪ The State Water Plan target for water use of 100 kL/person/yr with no more than 60 kL/person/yr of scheme water. ▪ Develop a water conservation strategy. ▪ Progress water supply and sewage disposal strategy.	▪ Consumption target for water use of 100 kL/person/yr with no more than 60 kL/person/yr of scheme water. ▪ Irrigated areas will be watered at an average rate of 7500 kL/ha/yr. ▪ Consider alternative fit-for-purpose water sources where appropriate and cost-effective.
Monitoring and Implementation	▪ Adopt an adaptive management approach. ▪ Maintain drainage and treatment structures.	▪ Design methodology based on Water Sensitive Urban Design (WSUD) treatment train including: – Structural treatment measures (infiltration storages, bio-retention/treatment structures sized to minimum 2% of connected impervious area); and – Non-structural measures to reduce applied nutrient loads. ▪ Maintain groundwater quality at pre-development levels (median winter concentrations) and, if possible, improve the quality of water leaving the Study Area.

3 Pre-Development Environment

3.1 Site Locality

The Study Area is located in the City of Cockburn, approximately 19 km south of Perth CBD. Muriel Court (South), Town Centre and Cockburn Central West developments are located west of the Study Area, while the Gateways Shopping Centre development and residential precinct are to the south of the Study Area.

The Study Area is approximately 108 hectares in size and bound by Kwinana Freeway to the west, Cutler Road to the north, Wintergreen Crescent to the east and Armadale Road to the south. The Study Area encloses a large number of lots which are currently being used for mixed business and light industry, as well as a significant amount of undeveloped land.

3.2 Climate

The Cockburn area is characterised by a Mediterranean climate with warm dry summers and cool wet winters.

The long-term average annual rainfall from the Bureau of Meteorology's Jandakot Aero station (Site No. 009172) is 823 mm/yr (1973-2016). This average has decreased between 2006 to present to an average annual rainfall of 716 mm/yr, reflecting a 13% reduction compared to the long term average (BoM, 2016).

The average annual pan evaporation for Cockburn is 1850 mm (BoM, 2016).

3.3 Existing Land Use

The western portion of the Study Area is predominantly undeveloped land, designated as 'underutilised land' under the Cockburn Central Activity Centre Strategy. This area is referred to as the LWMS Drainage Area (Figure 1) for the purpose of this study.

The central and eastern portions of the Study Area consist of predominantly light industrial and commercial/showroom properties. A large carpark is located in the southern portion of the Study Area, with cleared undeveloped land situated at the southern bounds.

3.4 Topography and Soils

The topography of the Study Area is shown on Figure 2. The Study Area is generally flat with low lying regions in the central bushland areas. The southern region of the site between Kwinana Freeway and Armadale Road has a slope of 1.2% towards the centre.

3.5 Surface Geology

The Study Area is situated within the Swan Coastal Plain system underlain by Bassendean Sands. The Study Areas soil classification as described by Gozzard (1986) is shown in Figure 3.

Bassendean Sand (S8) described as very light grey at surface, yellow at depth, fine to medium-grained, sub-rounded quartz and moderately well sorted are found across the north-western extents of the Study Area as well as large swaths of the south-western, southern and eastern extents.

The central region of the study area, extending from the western to northern extents is mainly composed of Bassendean Sand (S10) which is as S8 as a relatively thin veneer over strong, blocky, brown silts and clays.

Parts of the north-western and north eastern extents are composed of sandy silt (Ms5) which are dark brownish grey silts, with disseminated fine-grained quartz sand, with firm, variable clay content.

Cardno hand augured three bores to the groundwater level or up to 2m depth in March 2017 as part of a site investigation (Figure 5). The lithology encountered is described below:

BH1

0 m to 0.2 m:	Sand, coarse, brown, dry
0.2 m to 2 m:	Sand, light grey, dry

BH2

0 m to 0.25 m:	Sand, black, medium to coarse, brown, rootlets present, loose, dry, poorly sorted.
0.25 m to 5 m:	Sand, light brown/grey, medium, sub-rounded, loose, dry, moderately sorted.
0.5 m to 1.5 m:	Sand, light brown, uncemented coffee rock, medium-fine grained, sub-rounded, loose, dry, poorly sorted.
1.5 m to unknown:	Pale brown sand, fine to medium grained, sub-rounded, loose, saturated, moderately sorted, smells like sulphur

BH3

0 m to 1.2 m:	Sand, light grey, fine to medium, well sorted, loose, sub-rounded, dry
1.2 m to 1.3 m:	Sand, black, heavily organic, fine, well sorted, medium dense, sub-rounded, wet
1.3 m to unknown:	Sand, dark grey, fine to medium, moderately sorted, loose, saturated.

The geology encountered is in general agreement with Gozzard (1986).

3.5.1 Permeability

Cardno carried out infiltration testing using the reverse auger method as described by Cocks (2007) on March 2017 at locations shown on Figure 5. The locations were chosen to represent areas where retention basins will likely be positioned.

Based on the results, an infiltration rate of 8.5m/day is recommended to be utilised to size drainage infrastructure. This allows for a 50% soil moderation factor and 50% clogging factor from the lowest permeability measured, 34 m/day.

Further details on infiltration testing can be found in Appendix C.

3.6 Acid Sulfate Soils

Mapping published by the Western Australian Planning Commission classifies the Study Area as mostly having a moderate to low risk of ASS occurring within 3 m of natural soil surface or deeper, with hotspots of high to moderate risk in the north-eastern and north-western portion of the Study Area. The ASS map is shown on Figure 4.

It is recommended that an Acid Sulphate Soil investigation be undertaken across the site prior to construction activities and if required an Acid Sulfate Soils and Dewatering Management Plan (ASSDMP) be prepared for the site prior to construction works.

3.7 Wetlands

Geomorphic Wetlands of the Swan Coastal Plain (DEC, 2012) indicate a Multiple-Use Wetland is present extending across the northern portion of the Study area. A Resource Enhancement Wetland is located in the eastern portion of the Study Area. Several other wetlands are located in close proximity to the Study Area as seen in Figure 4.

3.8 Surface Hydrology

3.8.1 Existing Surface Drainage

The Study Area is located in the Swan Coastal Plain and lies on the northern reaches of the Coastal Peel-Harvey catchment. There are no natural surface water drainage lines located within the Study Area.

The current developed commercial area currently drains to a drainage basin and also a central wetland for stormwater treatment and retention. Due to the Study Area being underlain by sandy soils, runoff from hardstand areas drain into these areas for infiltration and groundwater recharge.

3.9 Groundwater Hydrology

There are three aquifers of significance underlying the Study Area: each assigned the name of the major geological unit containing it. In order of depth from natural surface, they are:

> Superficial Aquifer (known as Jandakot Mound) (unconfined)

> Leederville Aquifer (Confined)

> Yarragadee Aquifer (Confined)

3.9.1 Superficial Aquifer

The superficial aquifer in this region is referred to as the Jandakot Mound, and extends approximately 522 km^2. The aquifer has a maximum thickness of 40 m and includes three formations which are, in order of increasing depth: Bassendean Sand, Gnangara Sand and Ascot Formation. Aquifer transmissivities range between 200 to 1000 m^2/d (Davidson, 1995).

The Bassendean Sand consists of fine to coarse grained, moderately sorted, sub-rounded to rounded quartz sand. The sand is highly permeable with horizontal hydraulic conductivity ranging between 10 to 50 m/d. In the Jandakot area where 'coffee rock' is present, limonite cement may reduce the horizontal hydraulic conductivity to less than 10 m/d (Davidson & Yu, 2008).

The Gnangara Sand is present beneath the Bassendean Sand and consists of pale-grey, fine to very coarse grained, very poorly sorted, sub-rounded to rounded quartz sand and feldspar (Davidson & Yu, 2008).

The Ascot Formation is present beneath the Gnangara Sand. The Ascot Formation consists of hard to friable, grey calcarenite with thinly interbedded sand commonly containing shell fragments near the base of the formation. Sands are fine to coarse and are poorly sorted and angular to rounded in shape (Davidson, 1995).

The Ascot Formation overlies the Kardinya Shale (part of the Osborne Formation) which is a confining bed, consisting of moderately to tightly consolidated, interbedded siltstones and shales (Davidson, 1995). Vertical fluctuations in the water table may be several metres and generally occur seasonally, consistent with Perth's winter-dominated rainfall pattern

Groundwater Levels

Perth Groundwater Map (DoW, 2017) indicates a minimum groundwater level at the site to range from 23 mAHD at the western end to 25 mAHD at the eastern end. Historical maximum groundwater levels (Water and Rivers Commission, 1997) range from of 25 mAHD at the western bounds to 27 mAHD at the eastern bounds. The adopted groundwater design contours for the site are the Maximum Groundwater Levels (1997) shown on Figure 5.

Table 3-1 below shows historic maximum and 10 year maximum water groundwater levels recorded in 4 DoW groundwater monitoring boreholes in close proximity to the Study Area. The locations of these boreholes is shown on Figure 5. Hydrographs for the boreholes can be found in Appendix D.

Table 3-1 DoW Borehole Groundwater Levels

DoW Borehole Ref.	Maximum Groundwater Level (mAHD)	10 Year Groundwater Level (mAHD)
61410232	25.7	24.4
61410239	27.4	27.3
6142525	24.8	24.8
61419704	26.8	26.2

Groundwater was encountered during infiltration testing at the Study Area in March 2017. The groundwater levels recorded during testing can be found on Figure 5.

Groundwater Quality

Groundwater data compiled for Hydrogeochemical Assessment of the Superficial Aquifer (DoW, 2010) was used to establish a pre-development groundwater quality. Table 3-2 below outlines water quality parameters for the Study Area as obtained from this document.

The values presented in the aforementioned document indicate favourable groundwater quality at the wider area in which the Study area is situated. JM19 is the closet Superficial Aquifer sampling point utilised in the report. Water quality values for this bore are provided in Table 3-2.

Table 3-2 Water Quality Data

Parameter	Value	JM19	Comment
Salinity	< 250 mg/L	234	Indicative of fresh water.
pH	5.1 – 6	5.69	Value typical for groundwater within Bassendean Sand.
HCO_3	< 50 mg/L	33.0	No significant bicarbonate present.
Total Hardness ($CaCO_3$)	< 100 mg/L	42.23	Value typical for groundwater in Bassendean Sand near crest of mound (in this case Jandakot Mound). Acceptable for use for domestic purposes.
Iron (Fe^{2+})	< 0.3 mg/L	0.20	No significant iron present.
Nitrate (NO_3^-)	< 10 mg/L	0.05	No significant leaching of fertiliser.
Phosphate (PO_4^{3-})	< 0.3 mg/L	-	No significant leaching of fertiliser and/or sewage.
Sulfate (SO_4^{2-})	< 50 mg/L	2.2	No significant Sulfate present.
Consumed Dissolved Oxygen (DO)	20.1 % - 40 %	44.63	Value indicative of “younger” groundwater.

3.9.2 Leederville Aquifer

The Leederville Aquifer is of Cretaceous age and consists of interbedded sandstone, siltstone and shales made up by the Mariginiup, Wanneroo and Pinjar Members and the Henley Sandstone Formation. The Leederville Aquifer is a major regional aquifer, from which large yields of fresh groundwater can be obtained. The groundwater in the Leederville Formation is confined with the potentiometric surface in this area at approximately ground level (Davidson, 1995).

3.9.3 Yarragadee Aquifer

The South Perth Shale underlies the Leederville Aquifer and acts as the confining bed between the Leederville and Yarragadee aquifers (Davidson, 1995). The Yarragadee aquifer is a major regional water resource of generally good quality water. South of Perth salinities vary between 1000 and 2000 mg/L. Dissolved iron levels are generally below Australian Drinking Water Quality Guidelines (Davidson, 1995).

3.10 Flora and Fauna

City of Cockburn commissioned Focused Vision Consulting Pty Ltd (FVC) to undertake a Level 1 Flora, Vegetation and Fauna Assessment of the CCE Structure Plan area. The assessment incorporated both desktop and field assessments with the key ecological values associated with the Study Area summarised by Focused Vision (2016) as:

- Several Threatened and Priority flora species were identified during the desktop review as potentially occurring at the site, although none were recorded during the assessment.
- None of the flora species recorded are of any conservation significance.
- Five intact vegetation communities and three degraded vegetation communities were described and mapped within the study area, consisting of four woodlands, two woodland/wetland vegetation types, one heath and one degraded community.
- Areas of Banksia woodland (vegetation communities BaEt and BaXp) are likely to be representative of the newly listed Commonwealth TEC; Banksia woodlands of the Swan Coastal Plain.
- Five fauna habitats, consisting of woodlands and woodland/wetlands, one open heath/scrub and degraded areas were described and mapped across the study area.
- Evidence of Threatened Black-cockatoos (Carnaby's Black-cockatoo and Forest Red-tailed Blackcockatoo) was recorded during the site survey, including a direct sighting of Forest Red-tailed Black-cockatoos overflying the site and evidence of both species feeding on native tree fruits.
- Evidence of the Priority 4 species, Southern Brown Bandicoot/Quenda was observed in the form of diggings and this species is likely to inhabit the areas of dense understorey within the Paperbark Woodland/Swamp habitat, as well as probably the Banksia Woodland habitat.
- Rainbow Bee-eater (*Merops ornatus*) was determined to have a moderate likelihood of occurrence in the study area, based on recorded sightings by GHD (2015) and the presence of potentially suitable habitat.
- The site supports a dampland classified as a Multiple Use wetland (UFI 5562).

3.11 Summary of Existing Environment

- The topography is generally flat with low lying regions in the central bushland area;
- The Study Area is situated within the Swan Coastal Plain system underlain by Bassendean Sands;
- An infiltration rate of 15m/day is recommended to be utilised to size drainage infrastructure based on permeability testing undertaken by Cardno;
- The majority of the Study Area has a moderate to low risk of ASS occurring within 3 m of natural soil surface or deeper;
- A Multiple-Use Wetland is present extending across the northern portion of the Study area and a Resource Enhancement Wetland is located in the eastern portion of the Study Area;
- The maximum groundwater level is typically greater than 2 m below the surface;
- No flora species recorded are of any conservation significance; and
- Five fauna habitats were mapped and there was evidence of Threatened Black-cockatoos and Southern Brown Bandicoot/Quenda.

4 Local Water Management Strategy

4.1 Water Balance

The water balance of the Study Area will be influenced by the frequency and intensity of rainfall and evapotranspiration. The Study Area has been considered on a regional scale with average annual estimates of rainfall, evaporation, transpiration and recharge.

Pre-development water balance assumptions:

> Rainfall based on the medium term (1985 – 2016) annual average for Jandakot of 823 mm.

> The balance of inputs is discharged as groundwater recharge.

Post development water balance assumptions:

> The balance of inputs is discharged as groundwater recharge.

Results of the water balance are presented in Table 4-1 below.

Table 4-1 Water Balance

Pre- Development		Use	Area (ha)	Quantity (mm/y)		Total kL/year	%
Inputs	**Rainfall**		108	823		888,800	100
					Input total	888,800	100
Outputs	Evapotranspiration	*Native Bushland*	35	400		140,000	16
		Mixed Business and Light Industry	73	200		146,000	16
	Superficial Aquifer recharge		-	-		602,800	68
					Output total	888,800	100
					Balance	0	

Post Development		Use	Area (ha)	Quantity (mm/y)		Total kL/year	%
Inputs	**Rainfall**		108	823		888,800	100
					Input total	888,800	100
Outputs	Evapotranspiration	*Native Bushland*	10	400		40,000	5
		Mixed Business and Light Industry	98	200		196,000	22
	Superficial Aquifer recharge		-	-		652,800	73
					Output total	888,800	100
					Balance	0	

4.2 Water Supply and Wastewater

Water supply to commercial buildings is to be via extension of the scheme water system. The project civil engineer will negotiate the extension of the system with Water Corporation.

Wastewater from commercial buildings will be removed via extension of Water Corporation's Sewer System. The project engineer will negotiate the extension of the system with Water Corporation.

4.3 Water Efficiency Measures

To achieve water efficiency targets, the following measures are proposed to reduce scheme water usage in the development:

> All buildings and public toilets are designed to include water efficient fixtures and fittings, such as dual flush toilets, flow control valves, spring loaded taps, etc.;

> Use of native plants in streetscapes to reduce the demand for water;

> Turf areas to be minimised (if any); and

> Use of fit-for-purpose groundwater resources for irrigation of vegetated areas.

4.3.1 Public Open Space

Consistent with the fit-for-purpose water use strategy, irrigation water needed for streetscapes will be sourced from a Superficial Aquifer groundwater supply. It is proposed irrigation water will be sourced from the nearest production bore with an allocation utilised from CoC's licence for establishment.

The irrigation system will be designed to water-wise standards with local native plants making up at least 50% of plantings.

4.4 Stormwater Management

A stormwater management strategy was developed as a part of this LWMS. The LWMS focuses on the CCE Structure Plan area highlighted in white "*subject to future planning*" shown in Plate 2 (City of Cockburn, 2016).

Drainage requirements of existing development outside of the LWMS Drainage Area has been previously completed under building and subdivisions approvals processes and has not been considered in the Local Stormwater Management Strategy.

4.4.1 Local Stormwater Management

The stormwater drainage system has been designed using a major/minor approach.

The major drainage system includes the use of roads, swales, drainage reserves, and the existing wetland to provide safe passage of stormwater runoff from major storm events greater than 10% AEP and up to the 1% AEP. The major drainage system is described below with the key elements of the drainage system shown in Figure 8.

Major Drainage System

Key points for the design of the major drainage system are as follows:

> Roads graded to direct flow overland to the lowest point in the catchment (the wetland). The ultimate road low point will be adjacent to the wetland, with overflow flood storage provided within the wetland.

> The wetland design aims to create flood storage in an informal manner, minimising formal drainage basin areas by using the existing low point;

> The wetland has capacity to store up to the critical 1% AEP in its natural state;

> 1% AEP event flows from the Transperth parking area (TPP) catchment will be stored at the TPP basin.

> All lot finished levels will have a minimum 0.3 m clearance above the estimated 1% AEP flood level in the road and wetland.

Minor Drainage System

The minor drainage system is defined as the series of swales, kerbs (flush or no kerb), pipes and gutters designed to convey runoff generated by minor storms up to and including the 10% AEP storm event. The minor drainage system incorporates a treatment train of best management practice (BMP) water quality structural controls such as vegetated swales that provide water quality treatment in the Study Area.

Key points for the design of the minor drainage system are as follows:

> Extensive use of roadside swales and central median swales to limit the use of pipes drains as far as practical.

> Kerb breaks and flush kerbing to be utilised around the wetland and swales to encourage overland flow;

> Where required, pipe drains sized to convey runoff from the 10% AEP storm event;

> Runoff from mixed business and light industrial lots for the first 15 mm of rainfall will be infiltrated in soakwells.

> Drainage treatment train of roadside swale, central median swales and raingardens for all roads with capacity to treat 15 mm of rainfall;

> Runoff from TPP for the first 15 mm of rainfall to be treated within a bio-retention zone in the TPP basin.

4.4.2 North Lake Road Bridge and Armadale Road Diversion

North lake Road Bridge and Armadale Road Diversion drainage calculations (as discussed in Section 1.5) have been considered in the context of the drainage infrastructure to be provide within the Study Area. Cardno and City of Cockburn have had preliminary discussions with Main Roads and have acknowledge the drainage requirements of Main Roads can be incorporated with the Study Areas drainage infrastructure.

The proposed design aims to:

> Consolidate Main Roads and the Study Areas drainage requirements.

> Remove sumps by utilising the existing wetland as a natural storage location.

> Refine drainage assumptions and catchments.

> Provide treatment for the first 15 mm of runoff.

The results of the discussion and the drainage requirements are captured in the assumptions below:

> Storage for the 1% AEP for the future North Lake Road within the Study Area, along with freeway off ramp (eastern side of the Freeway), will be provided within the proposed wetland storage. It is proposed that a treatment area will provided adjacent to the wetland to treat this runoff.

> Runoff from the planned overpass extending over Kwinana Freeway is assumed to drain into the Cockburn Central West drainage system (section 1.5).

> Runoff from the ramp on the western side of the Kwinana Freeway is to be stored in Lot 9500 Kentucky Ct (Figure 9). The drainage footprint is to be minimised as it is has been identified as an important town centre site by the City.

> PTA carpark to cater for its own drainage.

The required runoff volumes from the North Lake Road Realignment are presented in Table 4-2. These have been taken into consideration during design of the storage system for the Study Area shown in Figure 8.

Table 4-2 Assumptions and Storage Results for Critical Events

	Catchment Area (ha)	Runoff Coefficient	Required Treatment Area (m^2)
North Lake Road extension	2.84	0.8	455
Western on-ramp Ramp	0.4	0.8	65
1% AEP	Critical Storm Duration (hrs)		Runoff Volume (m^3)
North Lake Road extension	72		4,500
Western on-ramp Ramp	1		150
10% AEP	Critical Storm Duration (hrs)		Runoff Volume (m^3)
North Lake Road extension	72		2,860
Western on-ramp Ramp	1		95

More details on these catchments can be found on Figure 7 and Figure 8.

4.4.3 Surface Water Modelling

Surface water modelling was undertaken using MODRET, a stormwater infiltration and retention pond modelling software capable of simulating shallow groundwater conditions. Durations modelled ranged from 30 minutes to 72 hours, with the rainfall temporal pattern assumed to be spatially uniform across the catchment.

Post development modelling was undertaken to determine the capacity of the existing wetland which is to be retained, as well as to determine storage requirements for the proposed TPP catchment.

It was assumed that minor event runoff from the lots within the mixed business and light industry zone will be stored and infiltrated via soak wells on the lot level, while road runoff from within this zone will be treated via bioretention systems. It was assumed that the access road network within the mixed business and light industry zone will comprise 15% of the total area of this land use catchment.

The required treatment area sized at 2% of the impervious area for roads and parking areas. The areas required for the treatment of runoff for the 1 year 1 hr event are shown on Figure 8.

A catchment land use breakdown, along with the required treatment area is presented in Table 4-3 and shown on Figure 7.

Details and storage requirements of the critical 10% and 0.1% AEP detention storages area presented in Table 4-4 and shown on Figure 8. Concept designs for the basins are shown in Figure 9.

Table 4-3 Post-Development Catchment Land Use

Land Use (ha)		Runoff Coefficient	Total (ha)	Effective Impervious Area (ha)	Required Treatment Area (m^2)
Road		0.8	4.78	3.82	765
Mixed Business and Light Industry	Lots	0.6	14.58	8.74	N/A
	Access Roads	0.8	2.57	2.06	410
Wetland		0.1	4.73	0.47	N/A
Transperth Parking		0.8	6.14	4.91	980
Total Area (ha)		**-**	32.81	20.00	2155

Table 4-4 Post-Development 10% and 1% AEP Detention Storages

Catchment	LWMS Drainage Area Catchment	TPP Catchment
Contributing Catchment Area (ha)	26.67	6.14
Storage Method	Wetland	TPP Basin
Equivalent Impervious Area (ha)	14.58	4.91
Storage Invert	25.80	29.00
1% AEP		
Critical Storm Duration (hrs)	72	1
Storm Rainfall (mm)	206	47
Runoff Volume (m^3)	30,050	2,305
Top Water Level (mAHD)	26.75[1]	29.93
Water Level Rise (m)	0.95[1]	0.93
TWL Surface Area (m^2)	38,415[1]	1,990
Stored Volume (m^3)	20,710[1]	1,630
Stored Volume/Runoff Volume (%)	69%	71%
10% AEP		
Critical Storm Duration (hrs)	72	1
Storm Rainfall (mm)	126	26
Runoff Volume (m^3)	18,385	1,425
Top Water Level (mAHD)	26.35[1]	29.46
Water Level Rise (m)	0.55[1]	0.63
TWL Surface Area (m^2)	25,730[1]	1,745
Stored Volume (m^3)	8,182[1]	751
Stored Volume/Runoff Volume (%)	45%	53%

[1] Includes runoff volume from North Lake Road extension catchment.

The final configuration (i.e. side slopes) and exact location of the storage areas are dependent on final earthworks, drainage and road design levels for the Study Area. Drainage details will be refined further at the sub-division stage and reported in the relevant Urban Water Management Plan (UWMP).

The western end of the wetland has an overtopping elevation of approximately 26 mAHD, which is lower than the modelled top water level for the 1% AEP event. An earthen bund will be constructed along a small portion of the western boundary of the wetland to prevent overtopping. This is subject to a detailed survey of the wetland confirming the elevations at the boundary of proposed storage area to be documented within the Urban Water Management Plan.

4.5 Groundwater Management

The objectives of groundwater management for the Study Area are to:

> Manage groundwater levels to protect infrastructure and assets,

> Maintain groundwater regimes for the protection of groundwater dependent ecosystems,

> Protect the value of groundwater resources, and

> Adopt nutrient load reduction design objectives for discharges to groundwater.

The UWMP will assess a post-development groundwater level. Subsoils will be installed where required to ensure sufficient clearance to lot finished levels and operation of soakwells creating a controlled groundwater level (CGL).

Finished levels will become available at detailed design stage. Figure 10 shows indicative areas which may require subsoil drainage based on depth from natural surface to MGL.

The drainage management criteria for determination of lot finished levels shall be:

> Lot finished levels less than 1.8m from the MGL will require subsoil drainage.

> Lot finished levels lot finished levels shall be a minimum 1.0 m above estimated CGL. CGL is to take into account subsoil drainage inverts and estimated level of groundwater mounding between subsoil pipes.

All subsoil outlets are to be free draining either via direct discharge to a treatment zone or into the street drainage system which has a free outfall which enters a treatment zone.

4.6 Water Quality Management

The effective implementation of the structural and non-structural controls as part of the urban development will enhance water quality from the Study Area as a result of the land use change.

Non-structural source controls to reduce nutrient export from the site will focus on reducing the need for nutrient inputs into the landscape. The following strategies are proposed;

> Local endemic species are to be used in the wetland, vegetated and drainage areas; and

> Street sweeping and rubbish collection co-ordinated with the CoC.

Structural source controls are proposed to compliment the non-structural source controls and provide a complete stormwater treatment train. The following structural controls are considered appropriate for the Study Area;

> The use of vegetated treatment zones within swales and the wetland.

> Open bottom manholes.

> Gross Pollutant Traps to capture larger pollutants.

The minimum specifications for all bio-retention systems (swales and storages) are presented in Table 12.

TABLE 1: MINIMUM SPECIFICATIONS FOR BIO-RETENTION SYSTEMS

Item	Specification
Amended soil media (DoW, 2011)	• Minimum 500 mm thick. • Hydraulic Conductivity, k_{sat} = 3 m/day. • PRI ≥ 10. • Light compaction only. • Infiltration testing of material prior to installation and again once construction is complete. On-going testing as per the monitoring program.
Plant selection, planting density and distribution	• Species and densities to be in accordance with the Vegetation Guidelines for Stormwater Biofilters in the South-West of Western Australia (Oversby et al., 2014).

The bio-retention systems should be sized to function correctly with a saturated hydraulic conductivity, k^{sat}, of 3 m/day. Recent research conducted by the Facility for Advancing Water Biofiltration (FAWB, 2008) indicates that the desired k_{sat} is in the range of 2.5 to 7 m/day, to fulfil the drainage requirements as well as retain sufficient moisture to support the vegetation. The FAWB (2008) research also specifies that for vegetated systems some clogging will occur in the first few years until the vegetation is established. Once the plants are established, the roots and associated biological activity maintain the conductivity of the soil media over time.

It should be recognised that data currently guiding the design of bio-retention systems is only recent and largely based on laboratory testing. The specifications provided in this document should be considered as the best available information at the time. Some flexibility in the specifications will be required as the knowledge base increases.

4.6.1 Typical Bio-retention swales

Bioretention swales are swales that have a bioretention system installed in the base and therefore provide both treatment and conveyance functions. The vegetated swale component provides conveyance (and retardation of flow) and pre-treatment of the stormwater through the removal of coarse to medium sediments as the flow passes through the vegetation. The bioretention system, often placed at the end of the swale, removes finer particulates and associated contaminants through fine filtration, extended detention treatment and some biological uptake. Bioretention swales are limited to flows that are not excessive as this will result in scouring of the filter media.

A typical layout of a bioretention swale is shown in Plate 1 below:

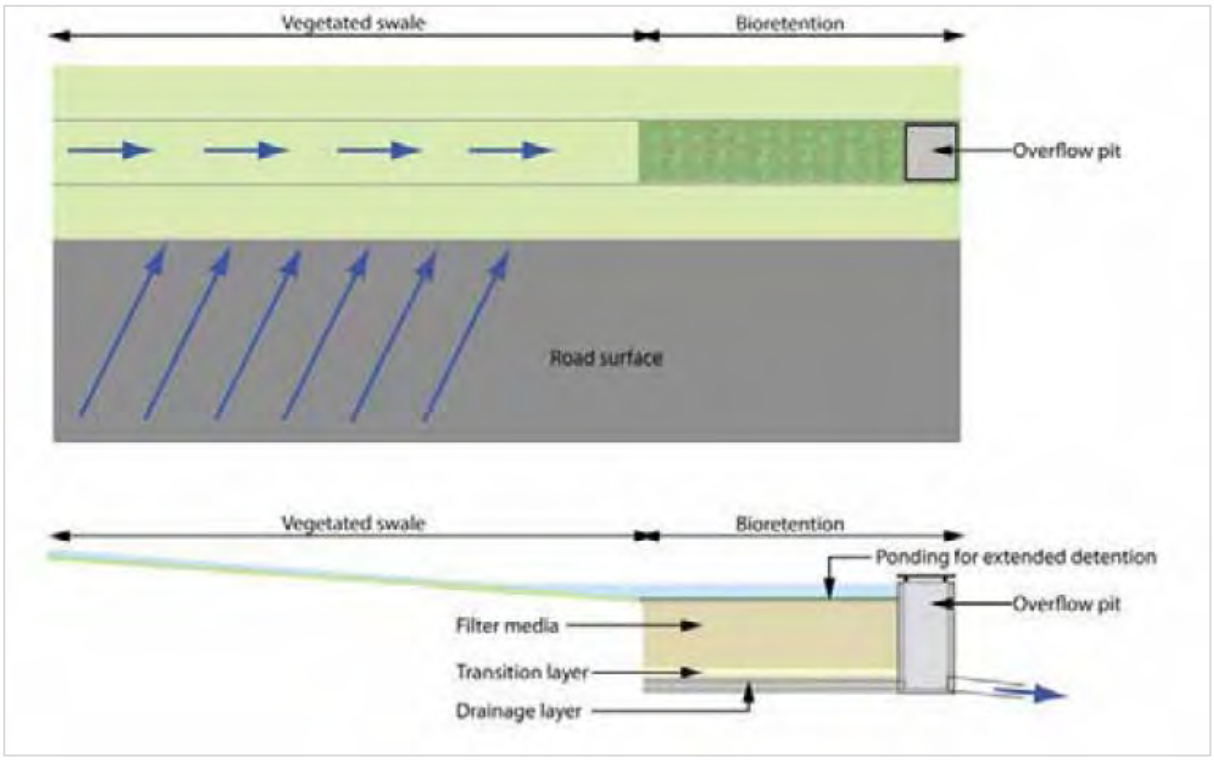

Plate 1 Typical Bioretention Swale Layout

4.6.2 Land Use Change Nutrient Impacts

The UNDO (Urban Nutrient Decision Outcomes) decision support tool (DoW, 2016) has been used to help quantify the nutrient inputs for the post-development scenario. The UNDO tool analyses inputs for Total Phosphorus and Total Nitrogen only. The calculation is provided in Appendix E.

With the implementation of the proposed structural and non-structural controls, a reduction of 85% for Phosphorus and 65% for Nitrogen is achieved compared to urban development without WSUD. These estimates correspond to a reduced Phosphorus input of 0.15 kg/yr and a reduced Nitrogen input of 2.04 kg/yr.

5 Implementation

5.1 Urban Water Management Plan (Subdivision)

Processes defined in Better Urban Water Management (WAPC, 2008) require an Urban Water Management Plan (UWMP) at subdivision stage. With an approved LWMS, a UWMP is required as a condition of subdivision and prior to any subdivision activities.

Specific items that should be addressed in the UWMP are:

- Design of treatment structures, vegetated swales and dry/ephemeral storages as outlined in the Stormwater Management Manual (DoW, 2007);
- Refinement of the final configuration (storage side slopes etc) and exact location of the detention storage areas dependent on final earthworks, drainage and road design levels for the Study Area;
- Confirmation of infrastructure needed to be installed beneath the Freeway to connect to the Cockburn Central West to control groundwater levels;
- Confirmation of groundwater design levels; and
- Confirmation of subsoil location and levels.

5.2 Construction Management

5.2.1 Temporary Storage

If construction of stormwater basins and a connection to future storage areas are not completed as part of Staged works, temporary storages will need to be provided to ensure sufficient drainage is provided for constructed areas.

5.2.2 Sediment Control

Construction will occur in a manner consistent with the approved Erosion and Sediment Management plan submitted to the CoC by the appointed civil contractor.

Final landscape works for the bio-retention storages will not be completed until the developer has finalised civil construction. It is expected that the majority of sediment movement from construction of residential lots will be contained in side-entry pit manholes and GPT's immediately upstream of the vegetated treatment basin. Any sediment reaching the bio-retention storages can be removed prior to landscape works.

5.2.3 Dewatering

Dewatering may be required for some elements of construction. Given the depth of construction, dewatering will only be in the Superficial Aquifer.

Prior to the commencement of any dewatering, the construction contractor will apply for and obtain from DoW a "Licence to Take Water". All dewatering will be carried out in accordance with the conditions of this licence. Where possible, construction will be timed to minimise impacts on groundwater and any dewatering requirement.

If elevated levels of nutrients are found in the groundwater, dewatering will be managed on-site or discharged through the sewer to prevent untreated discharge to drains or surface water bodies.

5.2.4 Acid Sulphate Soils

Management of Acid Sulphate Soils (ASS) will be addressed as a separate process to the urban water management document approvals process (LWMS/UWMP).

ASS will be investigated and managed in accordance with the applicable Department of Environment Regulation (DER) Acid Sulphate Soil Guideline Series and requirements of dewatering licences as they arise.

5.3 Stormwater System Operation and Maintenance

The operation and maintenance of the drainage system will initially be the responsibility of the developer, ultimately reverting to the local authority, City of Cockburn.

The surface and subsoil drainage system will require regular maintenance to ensure its efficient operation. It is considered the following operating and maintenance practices will be required periodically:

- Removal of debris to prevent blockages.
- Street sweeping to reduce particulate build up on road surfaces and gutters.
- Maintenance of vegetation in Bio-retention Systems/ Storages as outlined in the UWMP.
- Cleaning of sediment build up and litter layer on the bottom of Storages as specified in the UWMP.
- Undertake education campaigns regarding source control practices to minimise pollution runoff into stormwater drainage system.
- Checking and maintenance of subsoil drainage function.

Table 5-1 Maintenance Schedule for Drainage Infrastructure

Item	Maintenance Interval			
	Monthly	Quarterly (3 monthly)	Biannually (6 monthly)	As required
Street Drainage				
Street sweeping.			✓	
Eduction of sediment and rubbish in manholes.			✓	
Eduction of sediment and rubbish in GPT.		✓		
Inspection of subsoil drainage and removal of any blockages.				✓
Removal of debris to prevent blockages.		✓		
Vegetated Treatment Zones				
Removal of weeds	✓			
Inspect for erosion.			✓	
Assess health of vegetation. Remove dead plants and replace where necessary.				3 times per year
Inspect for standing water 1 week after rainfall events.				✓
Remove excessive sediment build-up.				✓
Use of slow release/low P fertilisers in turf areas			✓	

5.4 Monitoring Programme and Contingency Planning

The monitoring program has been designed to allow a quantitative assessment of hydrological impacts of the proposed development.

The post-development monitoring program is designed to operate over a 3 year period. The program will be reviewed periodically to verify suitability and practicality. Modifications may be required as data is collected to increase or decrease the monitoring effort in a particular area or alter the scope of the programme itself.

The post-development monitoring locations proposed are:

> Monitor groundwater levels and quality for 3 pre-development groundwater sites for comparison to pre-development data; and

A summary of the proposed monitoring program and reporting schedule is shown in Table 5-2, with the frequency of water quality target review and the contingency action plan detailed in Table 5-3.

All sampling is to be conducted according to Australian Standards and all water quality sample testing will be conducted by a NATA approved laboratory.

5.4.1 Reporting Mechanisms

The preparation of annual monitoring reports is to be arranged by the developer and submitted to the DoW and CoC for review. The report will compare the monitoring results with the design criteria and performance objectives to determine what, if any, further actions may be necessary with contingency measures detailed in Table 5-3 in accordance with the proposed reporting schedule detailed in Table 5-2.

Table 5-2 Monitoring Schedule and Reporting

Monitoring Type	Location	Method	Frequency, Timing & Responsibility	Parameter	Reporting	Responsibility
Groundwater Level	5 monitoring sites	Electrical depth probe or similar.	Monthly for 3 years by Developer	Water Level (mAHD)	Annual reports to be provided by the developer for a period of 3 years. Reports will be submitted to DoW/council within 3 months of completion of the reporting period.	Developer
Groundwater Quality	5 monitoring sites	Pumped bore samples.	Quarterly for 3 years by Developer (typically Jan, April, July, Sept).	In-situ: pH, EC, temp Lab: TN, TKN, NO_X, Ammonia, TP, FRP, selected metals		
Surface Water Quality	2 monitoring sites u/s and d/s of vegetated system	Collected grab samples or rising stage sampler.	3 times per year while flowing for 3 years.	In-situ: pH, EC, temp Lab: TN, TKN, NO_X, Ammonia, TP, FRP, selected metals, TSS		

Table 5-3 Contingency Planning

Monitoring Type	Criteria for Assessment	Criteria Assessment Frequency	Contingency Action
Groundwater Level	Groundwater levels not to exceed the estimated phreatic line by more than 300 mm.	After monitoring occasion	1. Review design and operation of subsoil and stormwater drainage system. 2. Perform maintenance as required.
Groundwater Quality	Nutrient concentrations in shallow bores should not exceed 20% of the maximum recorded pre-development level.	Annual review of water quality targets	1. Identify and remove any point sources. 2. Consider reinforcement of Community Education/Awareness program. 3. Review operational and maintenance (e.g. fertilising, cleaning) practices. 4. Consider alterations to POS areas including landscape regimes and soil amendment. 5. Consider modifications to the stormwater system. 6. Consider initiation of community based projects.
Stormwater Quality	Assess performance of vegetated detention storages in nutrient reduction. (Water quality discharging from the Study Area aims should not exceed 20% of the maximum recorded pre-development level.).		

5.5 Responsibilities and Funding

Table 5-4 Summary of Responsibility of Funding

Management Issue	Responsibility and Funding	
	Developer	Local Council
Negotiations with groundwater licence holders for transfer of water allocation	✓	
Construction of the planted swales	✓	
Construction of detention storages	✓	
Construction of irrigation system	✓	
Construction of street drainage	✓	
Street drainage defects liability period • 12 months (period between a successful Practical Completion Inspection and a defects inspection with written confirmation of City acceptance): • Ongoing (from notification of City acceptance):	✓	✓
Planted swale defects liability period • 12 months (period between a successful Practical Completion Inspection and a defects inspection with written confirmation of City acceptance): • Ongoing (from notification of City acceptance):	✓	✓
Detention storage defects liability period • 12 months (period between a successful Practical Completion Inspection and a defects inspection with written confirmation of City acceptance): • Ongoing (from notification of City acceptance):	✓	✓
Management of Stormwater Storage Landscaping • 2 years (period between a successful Practical Completion Inspection and a successful handover meeting with written confirmation of City acceptance): • Ongoing (from notification of City acceptance):	✓	✓
Irrigation system management • 2 years (period between a successful Practical Completion Inspection and a successful handover meeting with written confirmation of City acceptance): • Ongoing (from notification of City acceptance):	✓	✓
Post-development monitoring • Monitoring over a 3 year period, commencing immediately after the Practical Completion of the development:		✓
Street Sweeping • Period up to the successful Practical Completion of civil works. • Ongoing (from notification of City acceptance):	✓	✓

6 References

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Local Water Management Strategy

FIGURES

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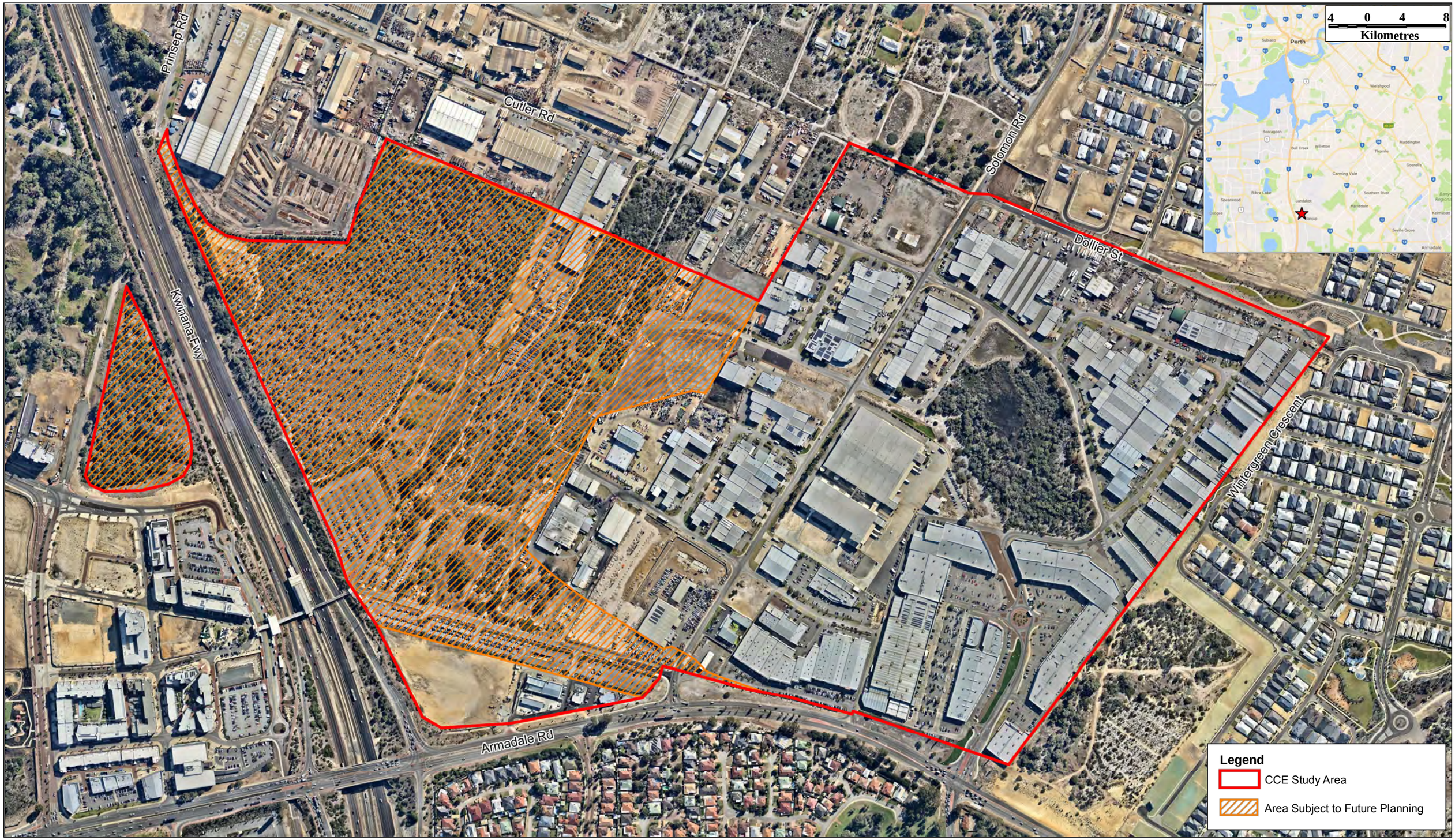

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Metres

Aerial imagery by nearmap.com

Cockburn Central East
Local Water Management Strategy
Figure 1
Location Plan

Cardno
Shaping the Future

Map Produced by Cardno WA Pty LTd
Date: May 2017
Coordinate System: MGA 94 Zone 50
Project: CW989900
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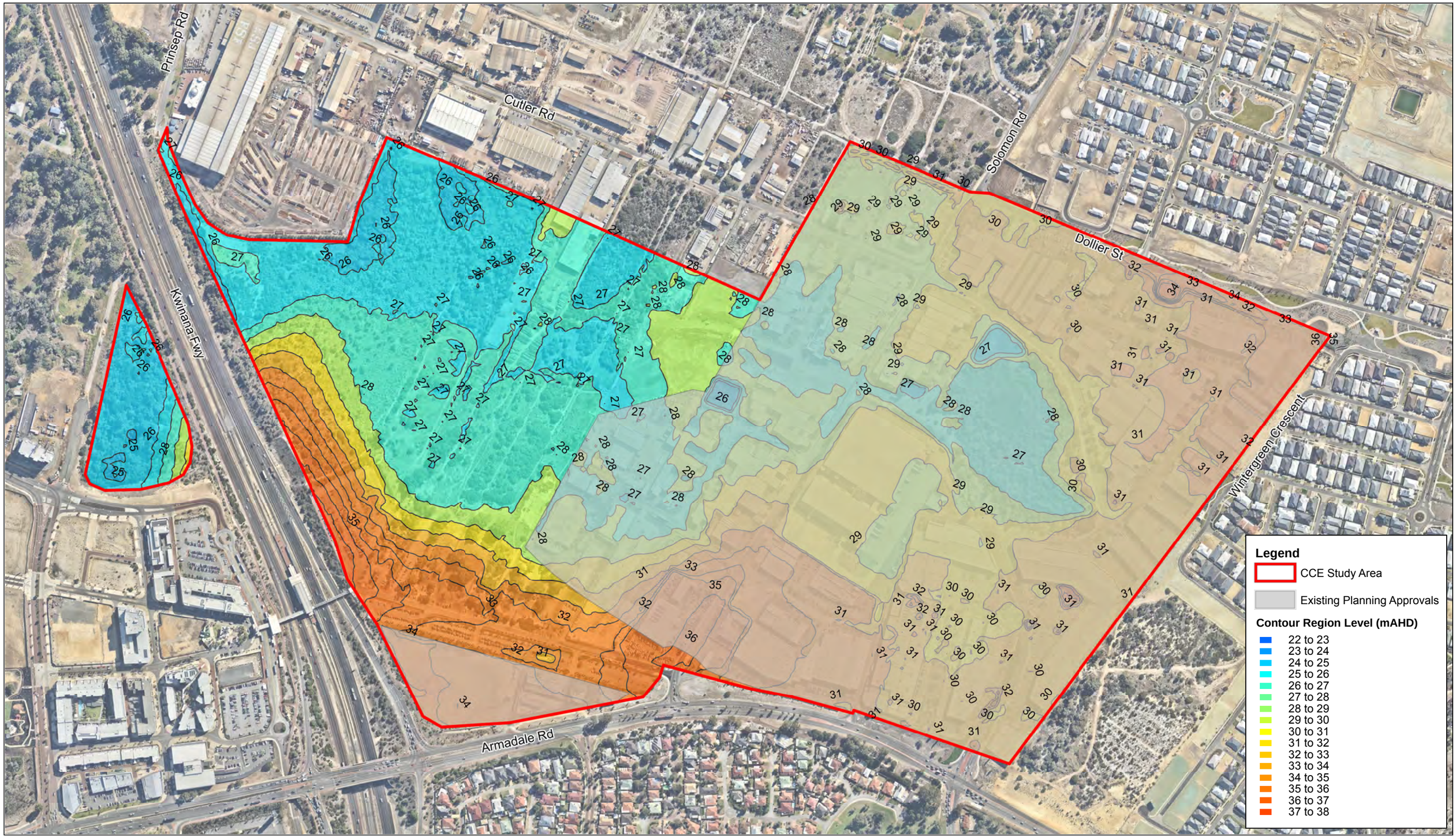

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Aerial imagery by nearmap.com

Cockburn Central East
Local Water Management Strategy
Figure 2
Topography

Cardno
Shaping the Future

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Date: May 2017
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Project: CW989900
Map: CW989900_City_of_Cockburn_Cockburn_Central_East_LWMS\5_Technical\Water\Drawings\Mapinfo_Workspaces\Landscape_Layouts\Figure2_Topography.wor

Prinsep Rd
Cutler Rd
Solomon Rd
Dollier St
Wintergreen Crescent
Kwinana Fwy
Armadale Rd
Ms5
S10
S8
Ms5

Legend

- CCE Study Area
- Existing Planning Approvals
- S8 - SAND - very light grey at surface, yellow at depth, fine to medium-grained, sub-rounded quartz, moderately well sorted, of eolian origin.
- S10 - SAND - as S8 as relatively thin veneer over strong, blocky, brown silts and clays.
- Ms5 - SANDY SILT - dark brownish grey silt, with disseminated fine-grained quartz sand, firm, variable clay content, of lacustrine origin.
- Cps - PEATY CLAY - dark grey and black, soft, variable organic content, some quartz sand in places, of lacustrine origin.

N

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Metres

Aerial imagery by nearmap.com

Cockburn Central East
Local Water Management Strategy
Figure 3
Surface Geology

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Map Produced by Cardno WA Pty LTd
Date: May 2017
Coordinate System: MGA 94 Zone 50
Project: CW989900
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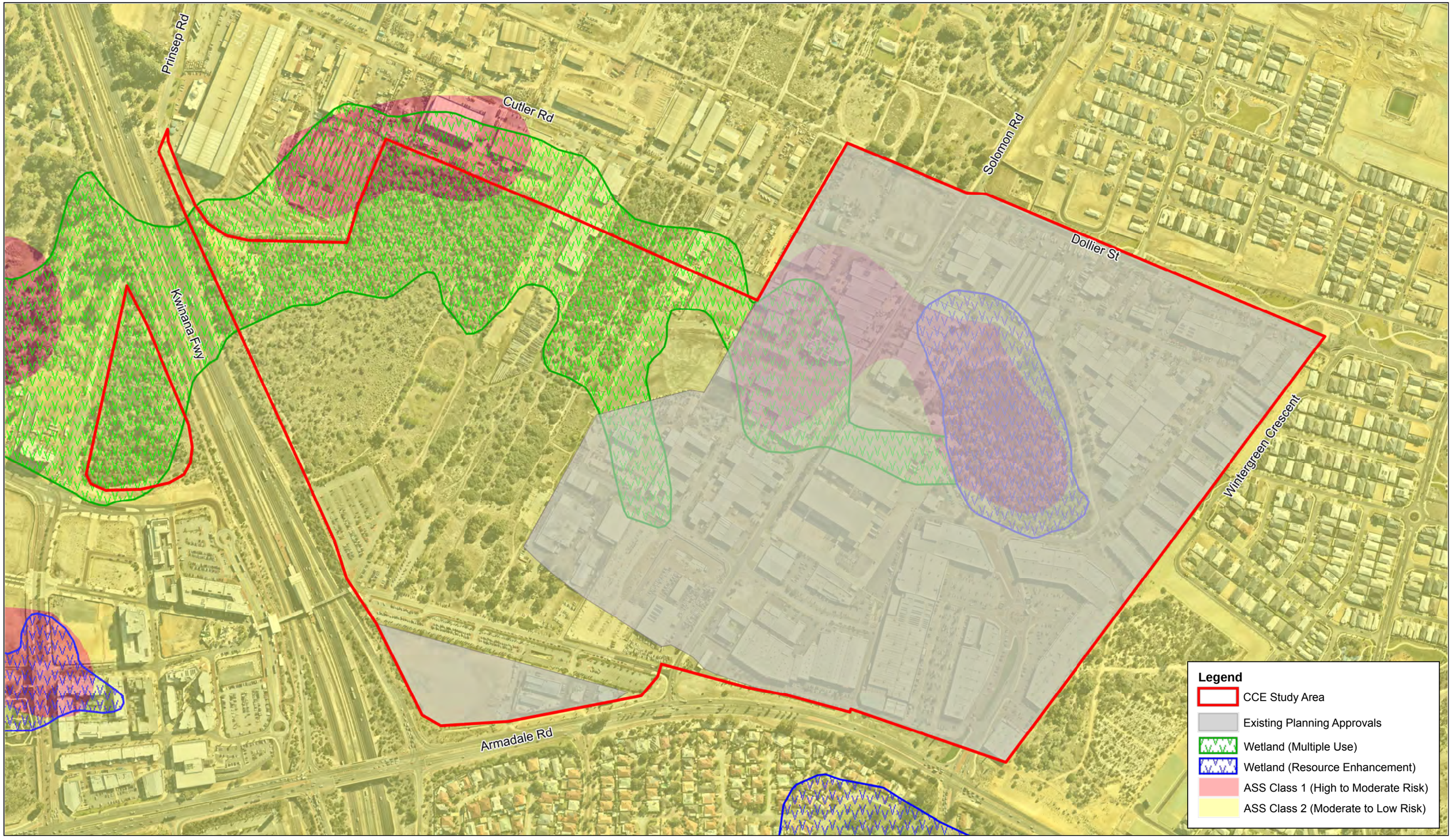

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Metres

Aerial imagery by nearmap.com

Cockburn Central East
Local Water Management Strategy
Figure 4
Wetlands and Acid Sulfate Soils

Cardno
Shaping the Future

Map Produced by Cardno WA Pty LTd
Date: May 2017
Coordinate System: MGA 94 Zone 50
Project: CW989900
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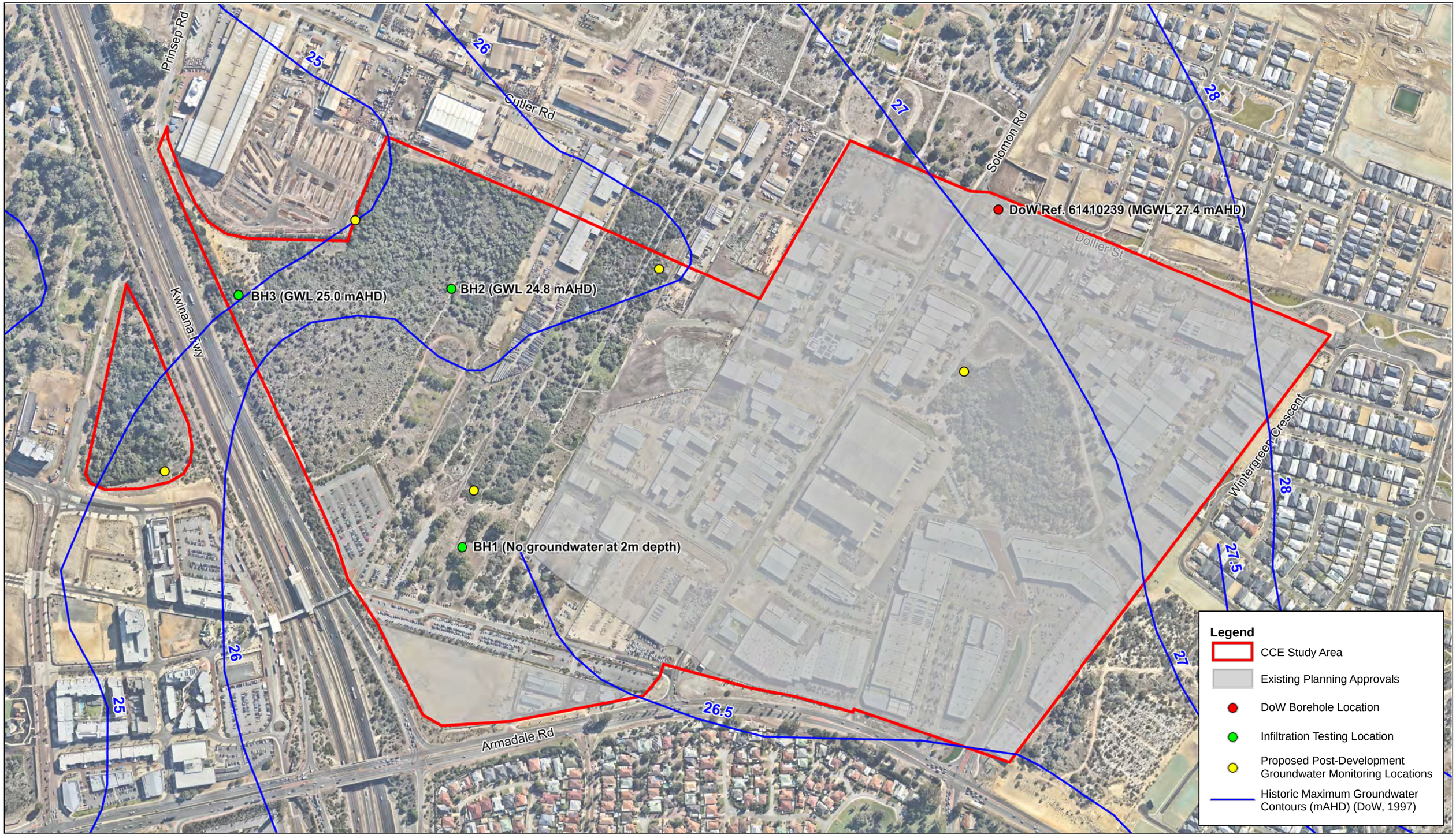

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Metres

Aerial imagery by nearmap.com

Cockburn Central East
Local Water Management Strategy
Figure 5
Groundwater

Cardno
Shaping the Future

Map Produced by Cardno WA Pty LTd
Date: May 2017
Coordinate System: MGA 94 Zone 50
Project: CW989900
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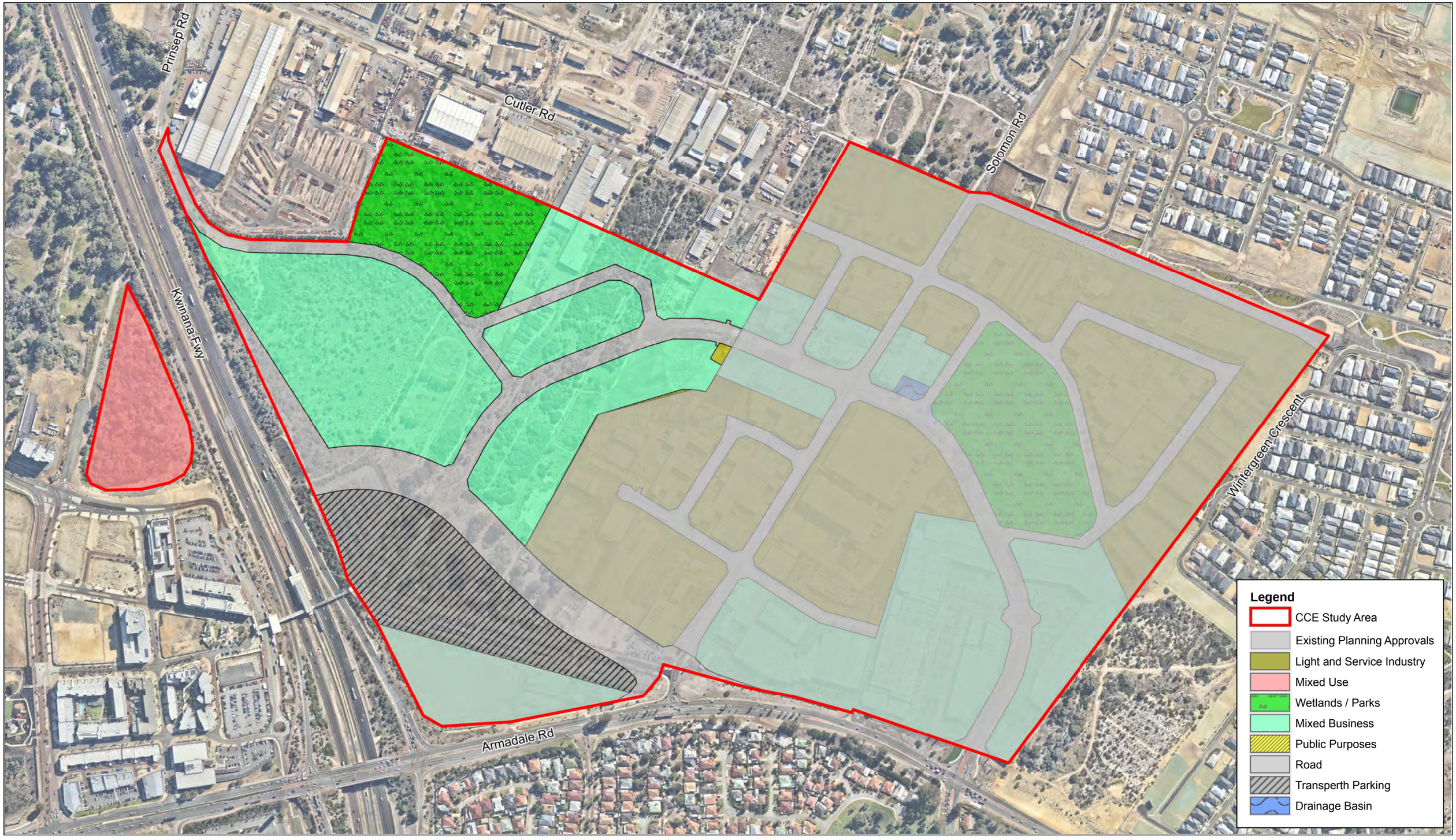

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Metres

Aerial imagery by nearmap.com

Cockburn Central East
Local Water Management Strategy
Figure 6
Land Use

Cardno
Shaping the Future

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Date: May 2017
Coordinate System: MGA 94 Zone 50
Project: CW989900
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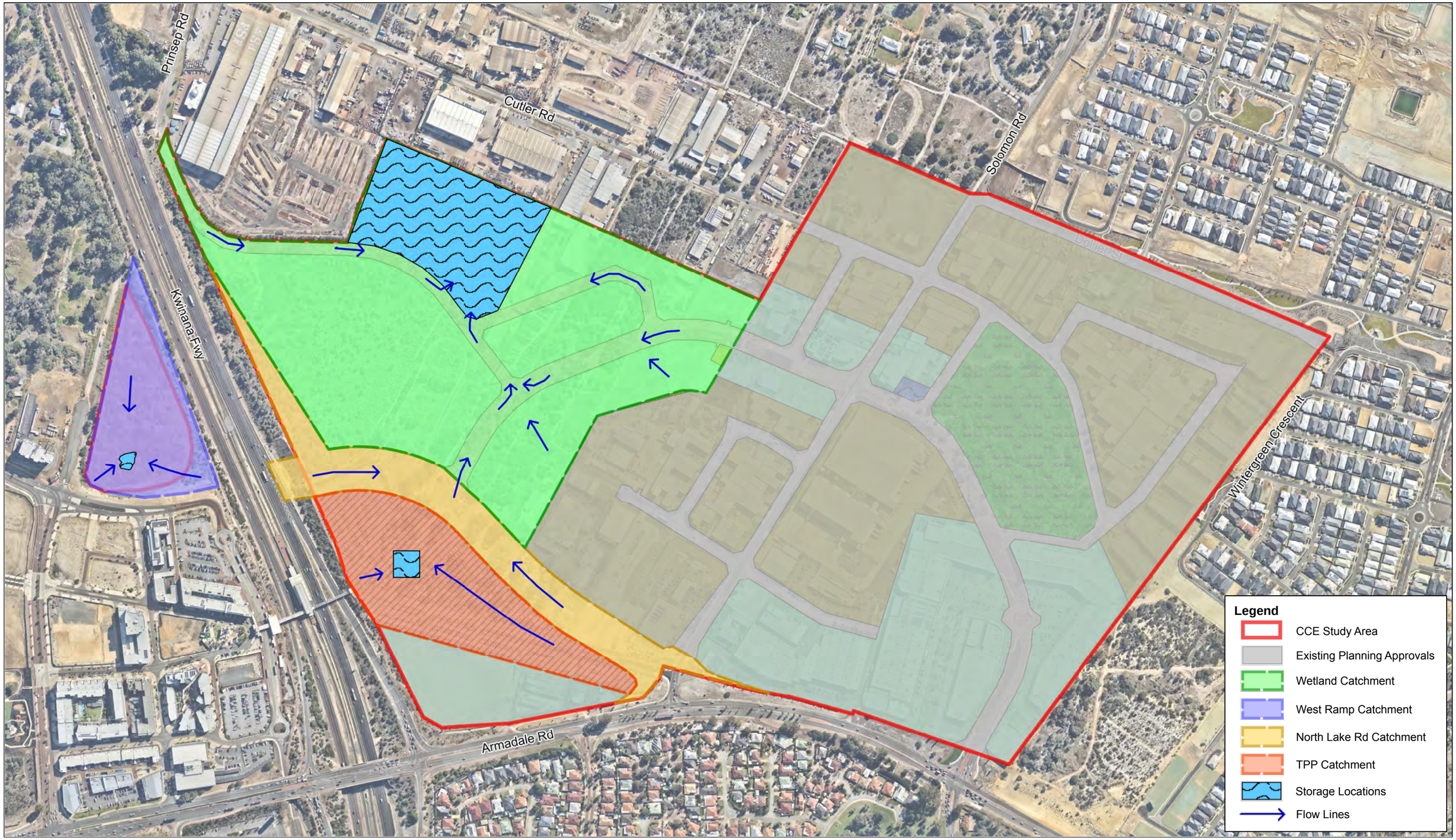

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Metres

Aerial imagery by nearmap.com

Cockburn Central East
Local Water Management Strategy
Figure 7
Catchments

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Shaping the Future

Map Produced by Cardno WA Pty LTd
Date: May 2017
Coordinate System: MGA 94 Zone 50
Project: CW989900
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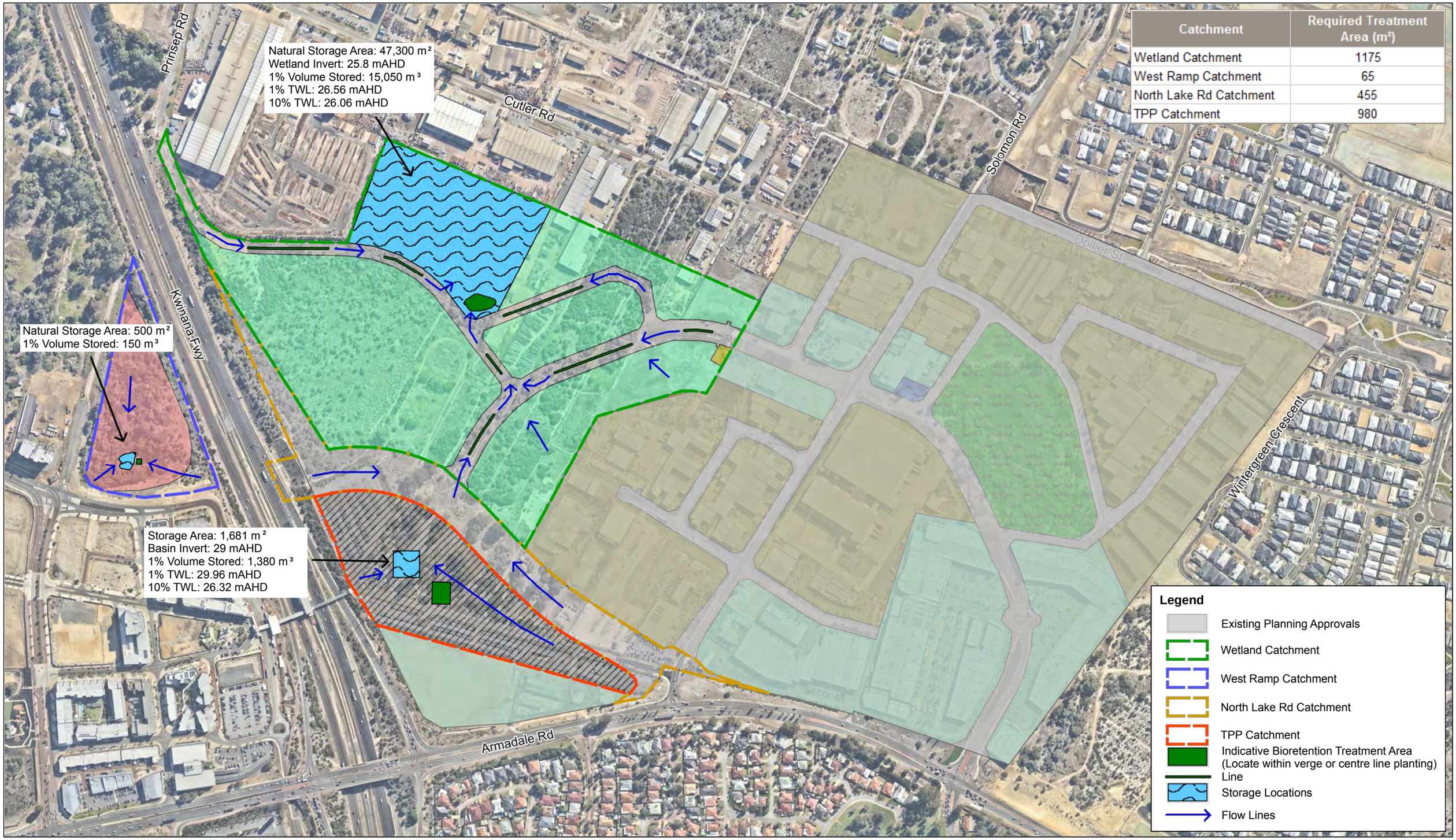


Catchment	Required Treatment Area (m²)
Wetland Catchment	1175
West Ramp Catchment	65
North Lake Rd Catchment	455
TPP Catchment	980

N

150 0 150 300 450

Metres

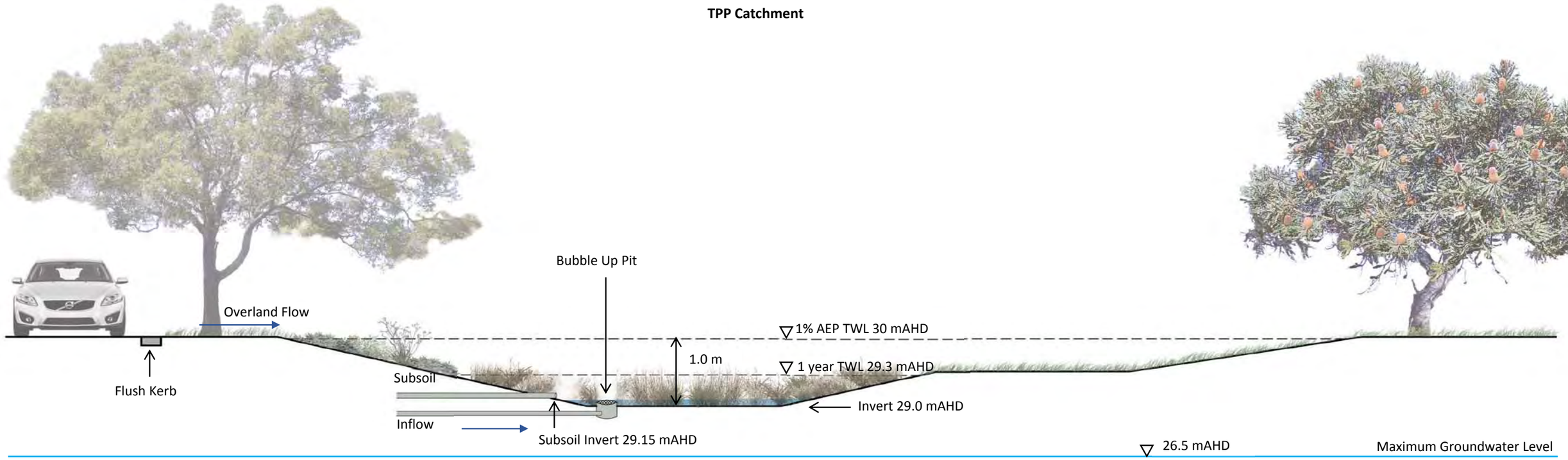
Aerial imagery by nearmap.com

Cockburn Central East
Local Water Management Strategy
Figure 8
Drainage Strategy

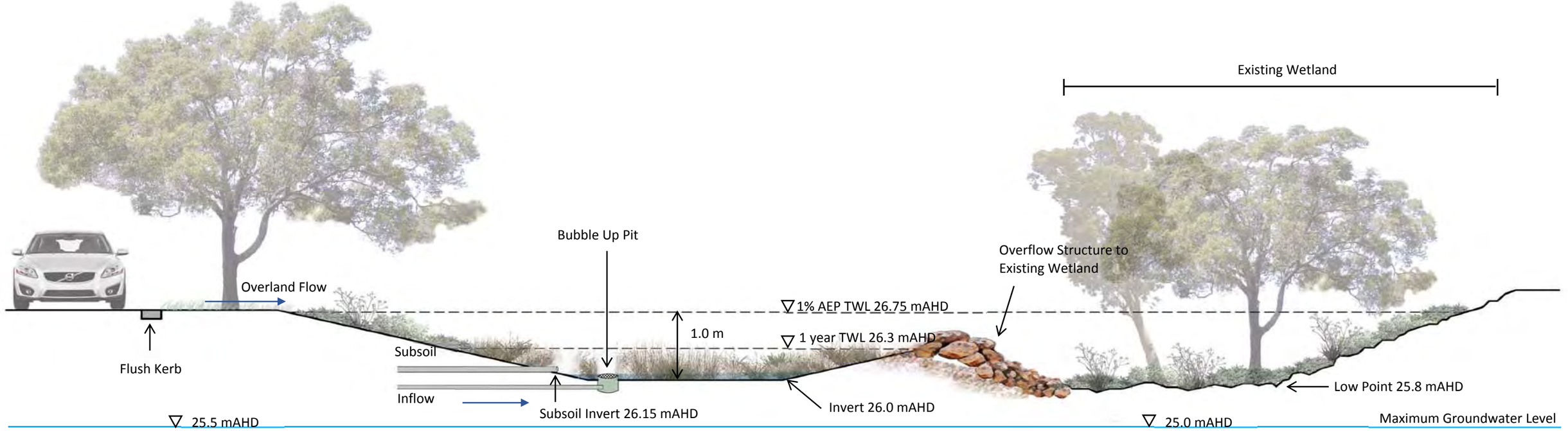
Cardno
Shaping the Future

Map Produced by Cardno WA Pty LTd
Date: May 2017
Coordinate System: MGA 94 Zone 50
Project: CW989900
Map: CW989900_City_of_Cockburn_Cockburn_Central_East_LWMS\5_Technical\Water\Drawings\Mapinfo_Workspaces\Landscape_Layouts\Figure8_Drainage_Strategy.wor

TPP Catchment



Wetland Catchment



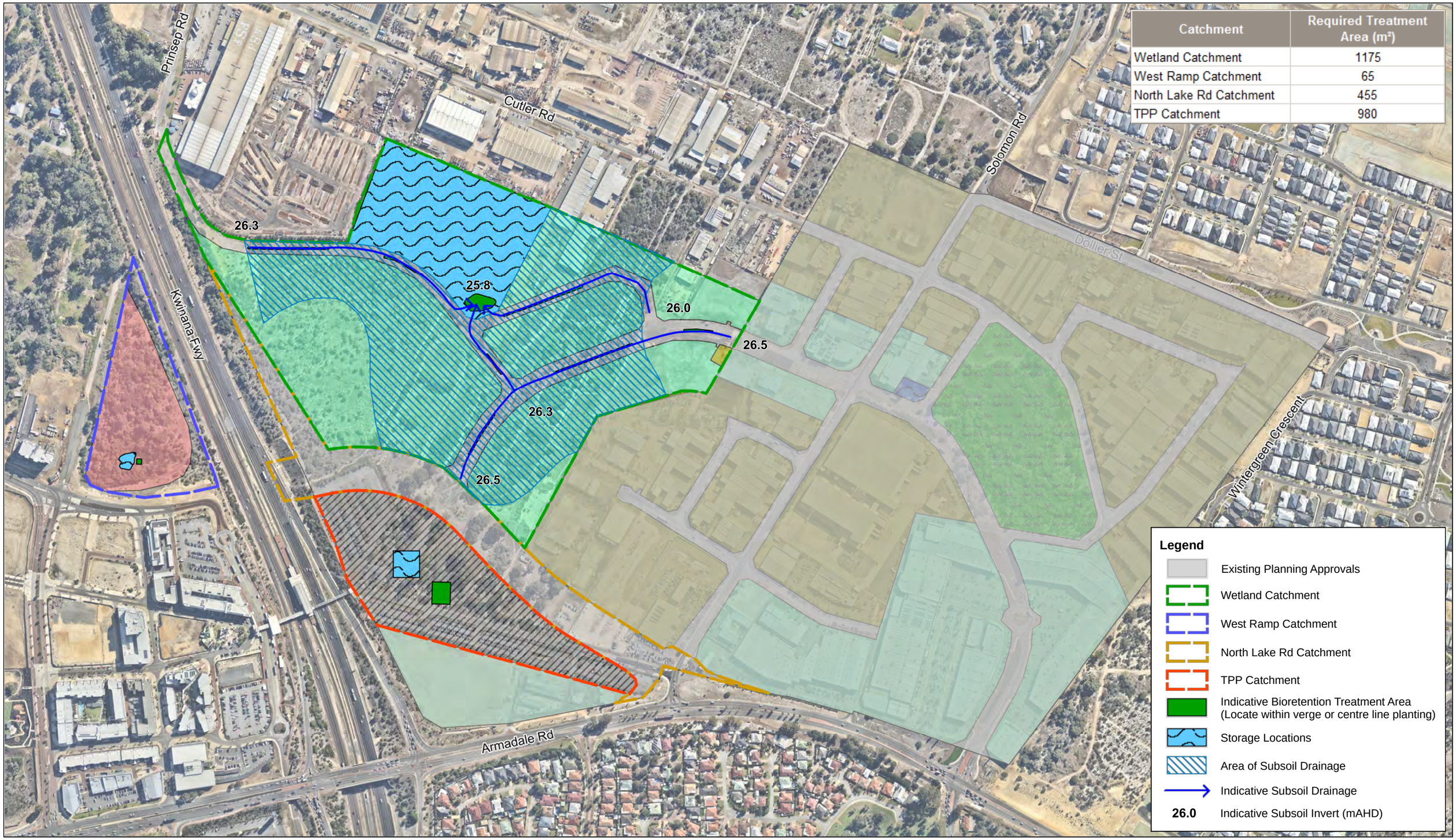
Cockburn Central East
Local Water Management Strategy
Figure 9
Concept Basin Cross Section

Cardno
Shaping the Future

Drawing Produced by Cardno WA Pty Ltd
Date: July 2017
Project: CW989900
Drawing: CW989900_City_of_Cockburn_Cockburn_Central_East_LWMS\5_Technical\Water\Drawings\PDF\Figure_9.pdf

***Note: Drawing not to scale**

Catchment	Required Treatment Area (m²)
Wetland Catchment	1175
West Ramp Catchment	65
North Lake Rd Catchment	455
TPP Catchment	980



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Metres

Aerial imagery by nearmap.com

Cockburn Central East
Local Water Management Strategy
Figure 10
Groundwater Management

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Map Produced by Cardno WA Pty LTd
Date: May 2017
Coordinate System: MGA 94 Zone 50
Project: CW989900
Map: CW989900_City_of_Cockburn_Cockburn_Central_East_LWMS\5_Technical\Water\Drawings\Mapinfo_Workspaces\Landscape_Layouts\Figure9_Groundwater_Management.wor

Local Water Management Strategy

APPENDIX A

DOW LWMS CHECKLIST

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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	☑	
Introduction			
Total water cycle management – principles & objectives Planning background Previous studies		☑	Section 2.1
Proposed development			
Structure plan, zoning and land use. Key landscape features Previous land use	Site context plan Structure plan	☑ ☑	Figure 1 Figure 6
Landscape - proposed POS areas, POS credits, water source, bore(s), lake details (if applicable), irrigation areas	Landscape Plan	☐	N/A
Design criteria			
Agreed design objectives and source of objective		☑	Table 2-1
Pre-development environment			
Existing information and more detailed assessments (monitoring). How do the site characteristics affect the design?		☑	Section 3
Site Conditions - existing topography/ contours, aerial photo underlay, major physical features	Site condition plan	☑	Figure 2
Geotechnical - topography, soils including acid sulfate soils and infiltration capacity, test pit locations	Geotechnical plan	☑	Figure 3 and 4 section 3.5
Environmental - areas of significant flora and fauna, wetlands and buffers, waterways and buffers, contaminated sites	Environmental Plan plus supporting data where appropriate	☑	Figure 4
Surface Water – topography, 100 year floodways and flood fringe areas, water quality of flows entering and leaving (if applicable)	Surface Water Plan	☑	Figure 8
Groundwater – topography, pre development groundwater levels and water quality, test bore locations	Groundwater Plan plus details of groundwater monitoring and testing	☑	Figure 5
Water use sustainability initiatives			
Water efficiency measures – private and public open spaces including method of enforcement		☑	Section 4.3
Water supply (fit-for-purpose strategy), agreed actions and implementation. If non-potable supply, support with water balance		☑	Section 4.3
Wastewater management		☑	Section 4.2
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	☑ ☐	Figure 7 N/A
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	☑	Figure 7

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	☑ ☑	Figure 7 Section 4.6.1
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 4.5
Actions to address acid sulfate soils or contamination		☑	Section 5.2.4
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 5.1
Monitoring			
Recommended future monitoring plan including timing, frequency, locations and parameters, together with arrangements for ongoing actions		☑	Section 5.4
Implementation			
Developer commitments		☑	Section 5.5
Roles, responsibilities, funding for implementation		☑	Section 5.5
Review		☑	Section 5.5

Local Water Management Strategy

APPENDIX B

MRWA CONCEPT DESIGN DRAWINGS

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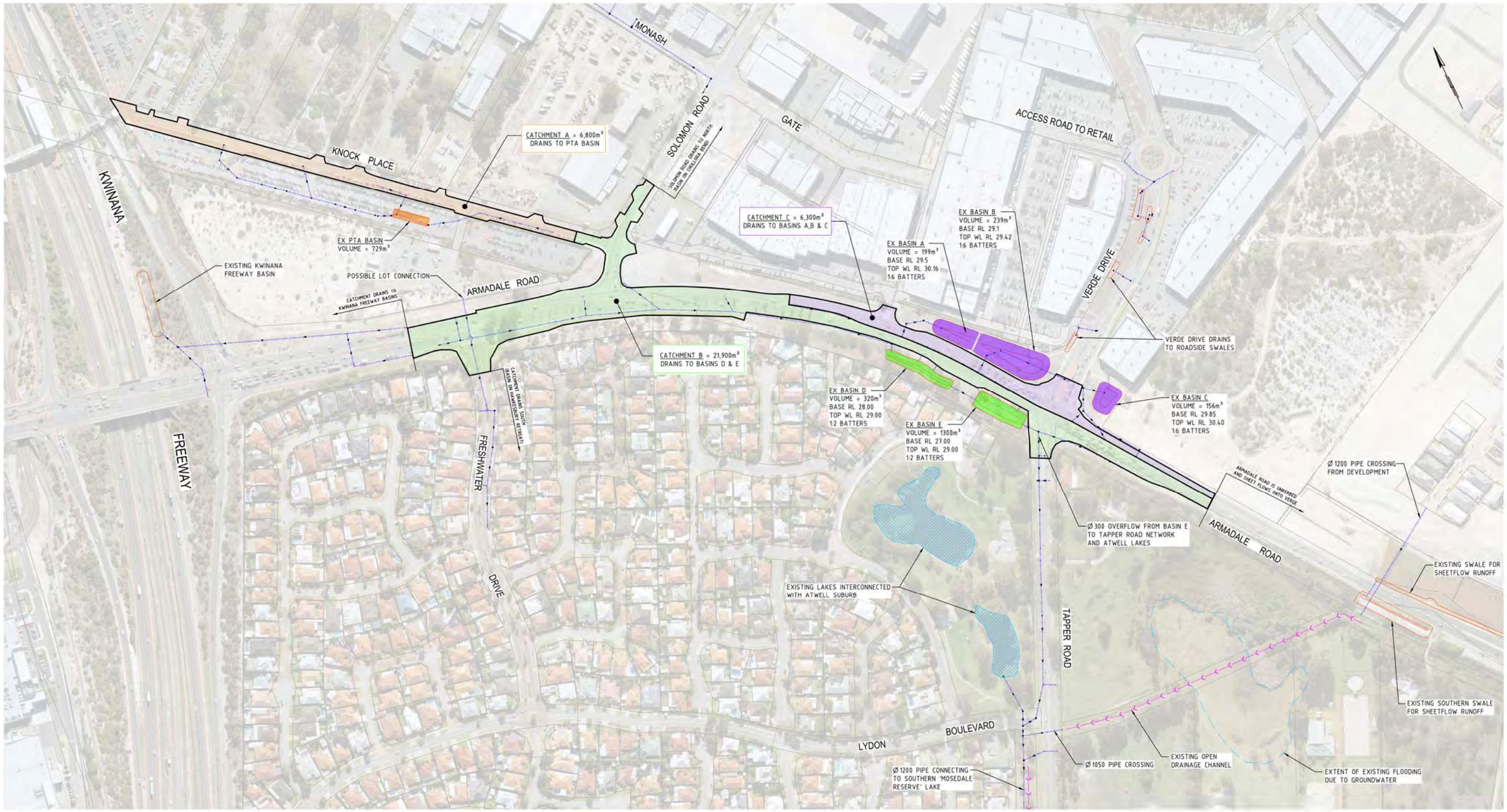
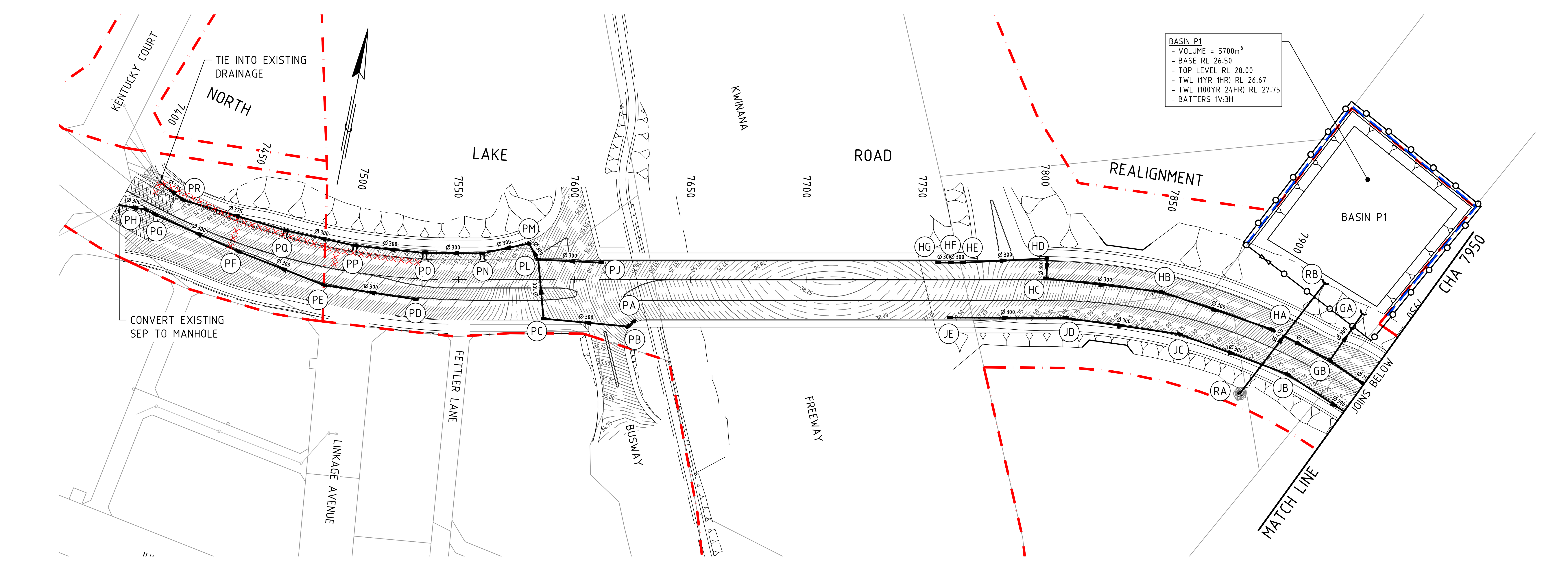
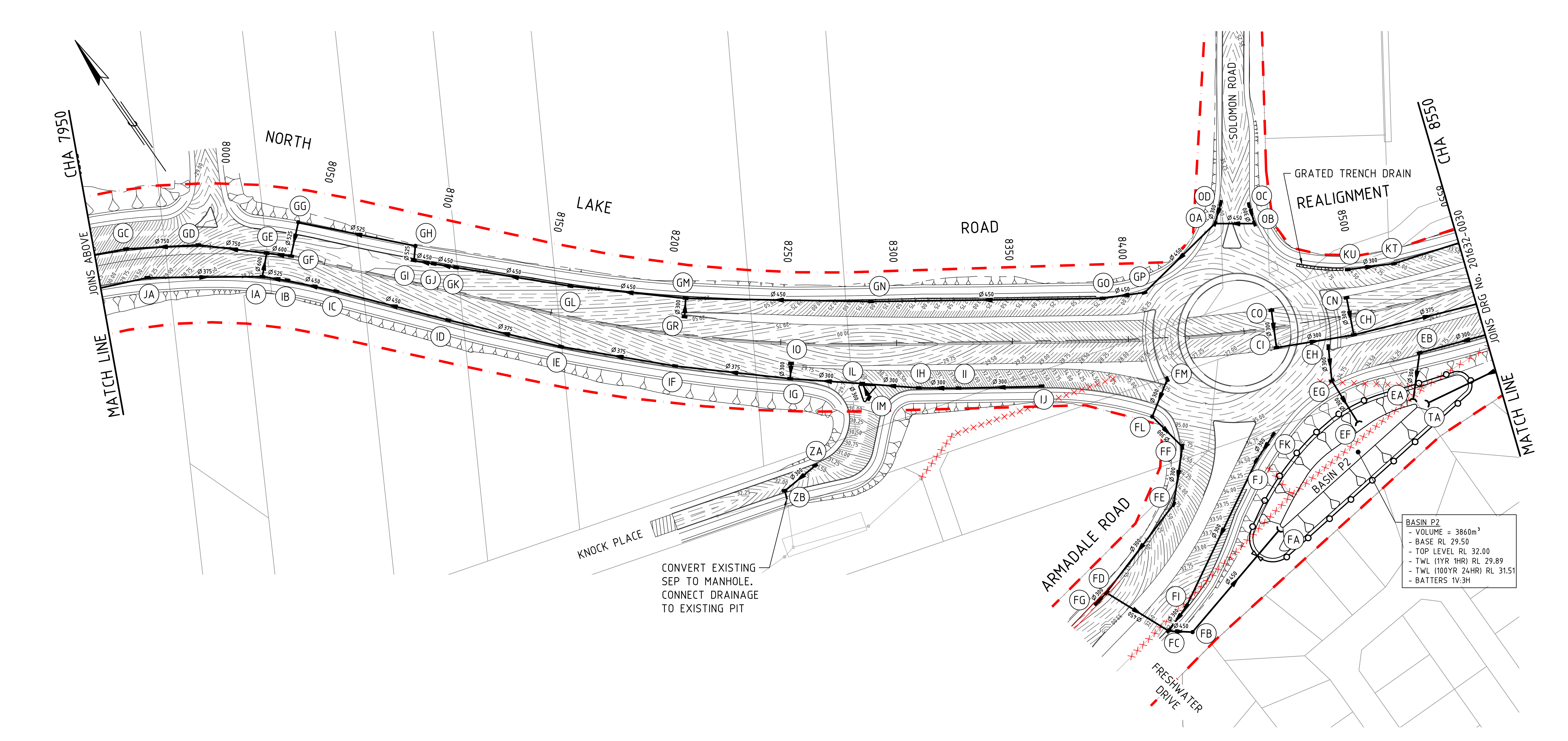


E15084-043-SK-C-0010 (Rev A)

Existing Drainage Catchments and Drainage Network
North Lake Road Realignment - Kwinana Freeway to Fraser Road

Scale 1:2000 at A1





AMENDMENTS

No.	DESCRIPTION	APPROVED & DATE
A	ISSUED FOR 15%	CR 21-11-16
B	ISSUED FOR 15% REPORT	AW 18-01-17

NOTES

1. ALL DIMENSIONS SHOWN ARE IN METRES UNLESS NOTED OTHERWISE.
2. ALL LEVELS IN mAHD UNLESS NOTED OTHERWISE.
3. PIPE SIZES NOT SHOWN, TO BE ADDED AT NEXT SUBMISSION.

LEGEND

- MRS BOUNDARY
- CADASTRAL BOUNDARY
- STORMWATER PIPE
- GULLY PIT
- MANHOLE
- HEADWALL
- PUMP STATION (5m DIAMETER)
- OVERFLOW PIT
- DRAINAGE STRUCTURE NUMBER
- KERB OPENING
- 1.8m HIGH FENCE
- RETAINING WALL
- EXISTING PIPE TO BE REMOVED
- MAJOR CONTOURS
- MINOR CONTOURS
- FUTURE WORKS BY OTHERS

METADATA

GROUND SURVEY STANDARD: 67-08-43
DATE OF CAPTURE:
MAPPING SURVEY STANDARD:
DATE OF CAPTURE:
MAIN ROADS PROJECT ZONE: PCG94
HEIGHT DATUM: AHD

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mainroads WESTERN AUSTRALIA
PLANNING AND TECHNICAL SERVICES DIRECTORATE
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Waterloo Crescent East Perth 6004
Telephone (08) 9323 4111 Fax (08) 9323 4430

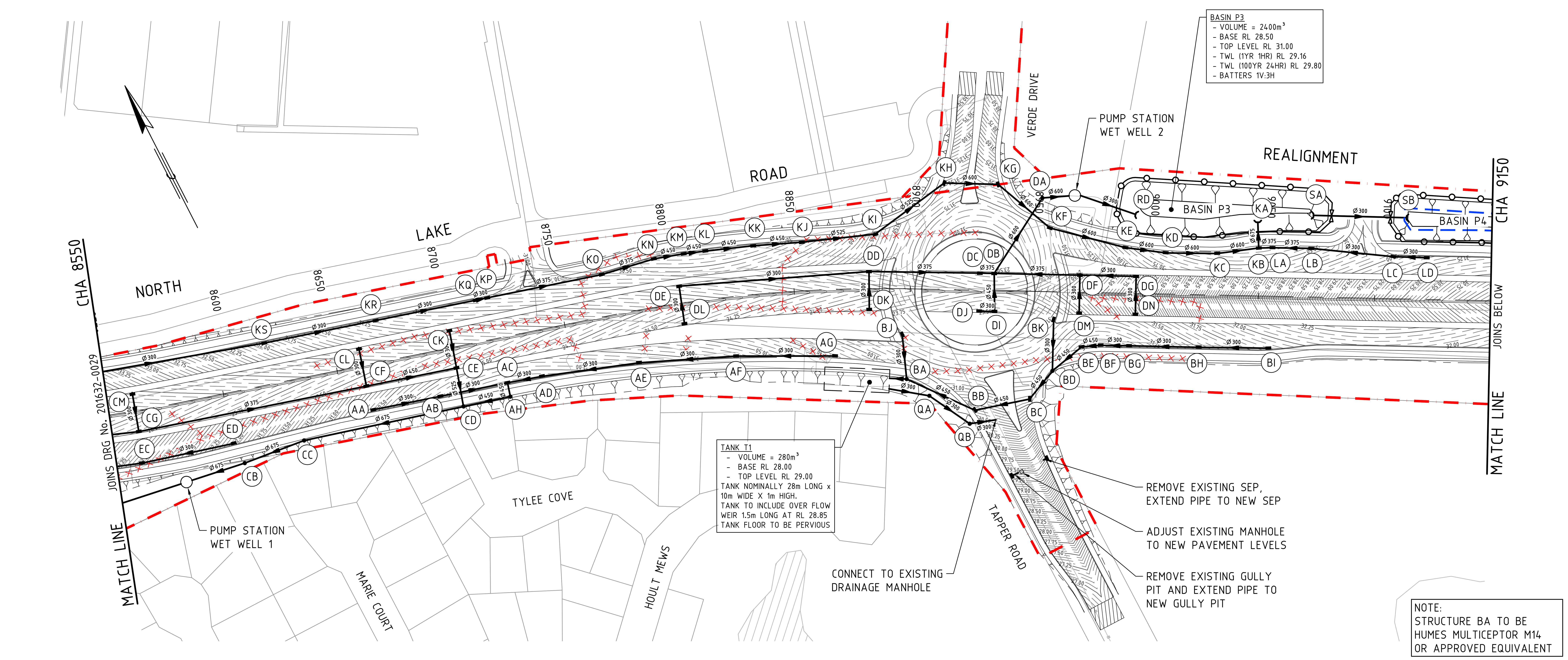
SCALES 1:1000 A1

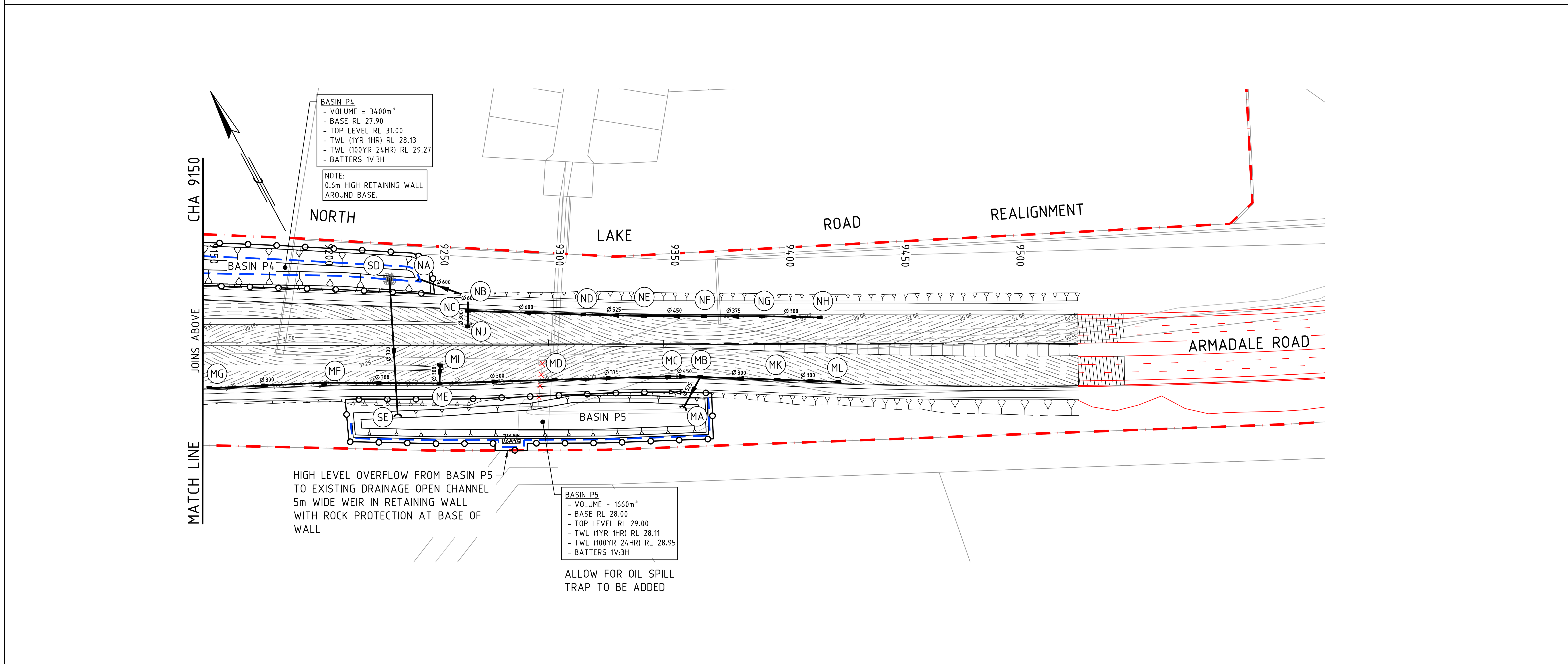
MRWA FILE NUMBER
APPROVED (MRWA)

NORTH LAKE ROAD REALIGNMENT
MIDGEGOOROO AVE TO INTERSECTION OF ARMADALE RD

DRAINAGE PLAN
SHEET 1

LOCAL AUTHORITY (103) CITY OF COCKBURN
MRWA DRAWING NUMBER
201632-0029 B





AMENDMENTS

No.	DESCRIPTION	APPROVED & DATE
A	ISSUED FOR 15%	CR 21-11-16
B	ISSUED FOR 15% REPORT	AW 18-01-17

NOTES

1. ALL DIMENSIONS SHOWN ARE IN METRES UNLESS NOTED OTHERWISE.
2. ALL LEVELS IN mAHD UNLESS NOTED OTHERWISE.
3. PIPE SIZES NOT SHOWN, TO BE ADDED AT NEXT SUBMISSION.

LEGEND

- MRS BOUNDARY
- CADASTRAL BOUNDARY
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- GULLY PIT
- MANHOLE
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- OVERFLOW PIT
- DRAINAGE STRUCTURE NUMBER
- KERB OPENING
- 1.8m HIGH FENCE
- RETAINING WALL
- EXISTING PIPE TO BE REMOVED
- MAJOR CONTOURS
- MINOR CONTOURS
- FUTURE WORKS BY OTHERS

METADATA

GROUND SURVEY STANDARD: 67-08-43
DATE OF CAPTURE:
MAPPING SURVEY STANDARD:
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MAIN ROADS PROJECT ZONE: PCG94
HEIGHT DATUM: AHD

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VERIFIED CR
DIRECTOR

SCALES 1:1000 A1

THE GOVERNMENT OF WESTERN AUSTRALIA
mainroads WESTERN AUSTRALIA
PLANNING AND TECHNICAL SERVICES DIRECTORATE
ROAD AND TRAFFIC ENGINEERING BRANCH
Waterloo Crescent East Perth 6004
Telephone (08) 9323 4111 Fax (08) 9323 4430

MRWA FILE NUMBER
APPROVED (MRWA)

NORTH LAKE ROAD REALIGNMENT
MIDGEGOOROO AVE TO INTERSECTION OF ARMADALE RD

DRAINAGE PLAN
SHEET 2

LOCAL AUTHORITY (103) CITY OF COCKBURN
MRWA DRAWING NUMBER
201632-0030 B

Document Set ID: 8164350
Version: 1, Version Date: 22/02/2019

Local Water Management Strategy

APPENDIX C

INFILTRATION TESTING RESULTS

Permeability Calculation - Inverse Auger Hole Method

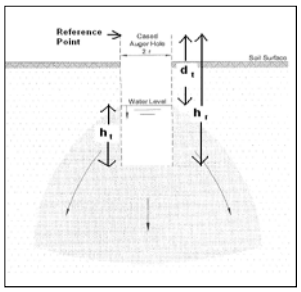
Cardno Geotech

Job No:	CW988000
Client:	City of Cockburn
Site:	Cockburn Central East
Location:	Cockburn Central East
Calc by:	Milan Bozic
BH Name:	BH1
Test Depth:	0.85 m

Spreadsheet author: CBD 1-Jun-15

$$K = 1.15r\frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

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	Comment field
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	Fixed field

Parameter	Description	Value	Units
K	Permeability		m/s
r	radius of test hole	0.05	m
t	time since start of measurement		s
h_r	reference point height above base	0.87	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

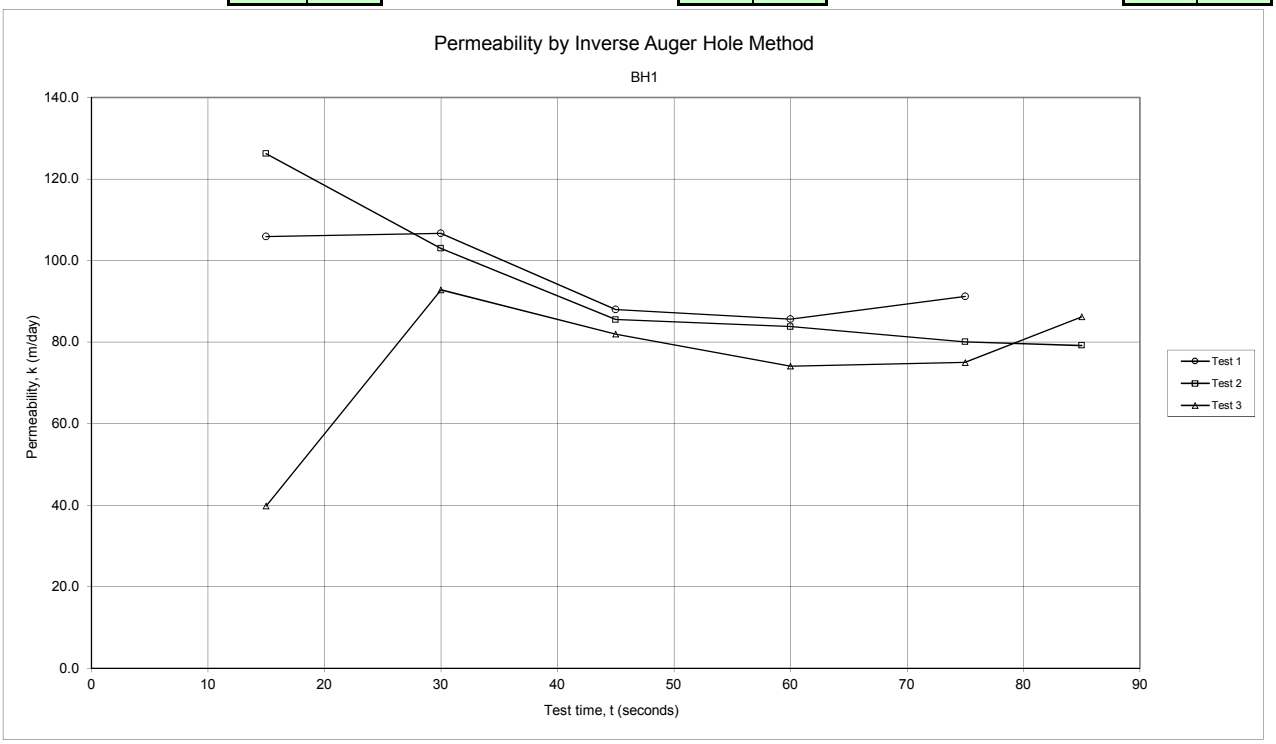
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.3	0.57		
15	0.61	0.26	1.2E-03	105.9
30	0.76	0.11	1.2E-03	106.7
45	0.8	0.07	1.0E-03	88.0
60	0.84	0.03	9.9E-04	85.6
75	0.87	0	1.1E-03	91.2
		AVERAGE	1.1E-03	95.5

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.33	0.54		
15	0.66	0.21	1.5E-03	126.2
30	0.76	0.11	1.2E-03	103.0
45	0.8	0.07	9.9E-04	85.5
60	0.84	0.03	9.7E-04	83.8
75	0.86	0.01	9.3E-04	80.0
85	0.87	0	9.2E-04	79.1
		AVERAGE	1.1E-03	92.9

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.15	0.72		
15	0.33	0.54	4.6E-04	39.8
30	0.69	0.18	1.1E-03	92.8
45	0.76	0.11	9.5E-04	81.9
60	0.8	0.07	8.6E-04	74.1
75	0.84	0.03	8.7E-04	75.0
85	0.87	0	1.0E-03	86.2
		AVERAGE	8.7E-04	74.9



Permeability Calculation - Inverse Auger Hole Method

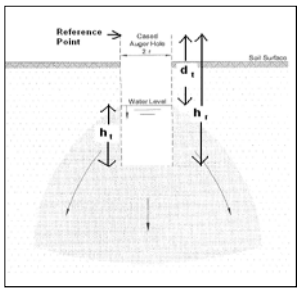
Cardno Geotech

Job No:	CW988000
Client:	City of Cockburn
Site:	Cockburn Central East
Location:	Cockburn Central East
Calc by:	Milan Bozic
BH Name:	BH2
Test Depth:	0.65 m

Spreadsheet author: CBD 1-Jun-15

$$K = 1.15r\frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

	Required input
	Calculated field
	Comment field
	Field not used
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Parameter	Description	Value	Units
K	Permeability		m/s
r	radius of test hole	0.04	m
t	time since start of measurement		s
h_r	reference point height above base	0.96	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

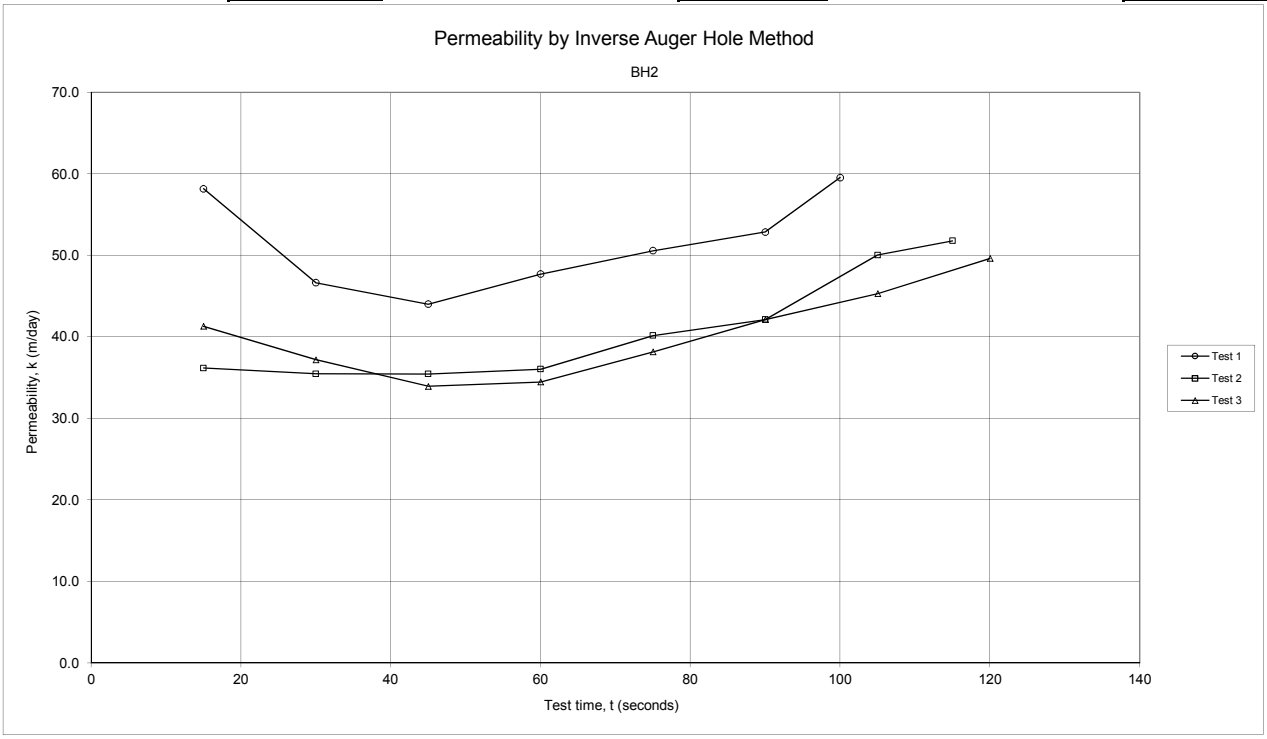
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.35	0.61		
15	0.6	0.36	6.7E-04	58.2
30	0.7	0.26	5.4E-04	46.7
45	0.78	0.18	5.1E-04	44.0
60	0.86	0.1	5.5E-04	47.7
75	0.91	0.05	5.9E-04	50.6
90	0.94	0.02	6.1E-04	52.9
100	0.96	0	6.9E-04	59.5
		AVERAGE	5.9E-04	51.4

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.35	0.61		
15	0.52	0.44	4.2E-04	36.2
30	0.64	0.32	4.1E-04	35.5
45	0.73	0.23	4.1E-04	35.5
60	0.8	0.16	4.2E-04	36.0
75	0.87	0.09	4.6E-04	40.2
90	0.91	0.05	4.9E-04	42.1
105	0.95	0.01	5.8E-04	50.0
115	0.96	0	6.0E-04	51.8
		AVERAGE	4.7E-04	40.9

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.35	0.61		
15	0.54	0.42	4.8E-04	41.3
30	0.65	0.31	4.3E-04	37.2
45	0.72	0.24	3.9E-04	33.9
60	0.79	0.17	4.0E-04	34.5
75	0.86	0.1	4.4E-04	38.2
90	0.91	0.05	4.9E-04	42.1
105	0.94	0.02	5.2E-04	45.3
120	0.96	0	5.7E-04	49.6
		AVERAGE	4.7E-04	40.3



Permeability Calculation - Inverse Auger Hole Method

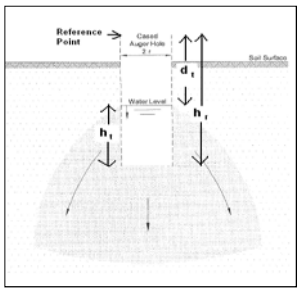
Cardno Geotech

Job No:	CW988000
Client:	City of Cockburn
Site:	Cockburn Central East
Location:	Cockburn Central East
Calc by:	Milan Bozic
BH Name:	BH3
Test Depth:	0.67 m

Spreadsheet author:	CBD	1-Jun-15

$$K = 1.15r\frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}(h_t + \frac{1}{2}r)}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

	Required input
	Calculated field
	Comment field
	Field not used
	Fixed field

Parameter	Description	Value	Units
K	Permeability		m/s
r	radius of test hole	0.04	m
t	time since start of measurement		s
h_r	reference point height above base	0.9	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

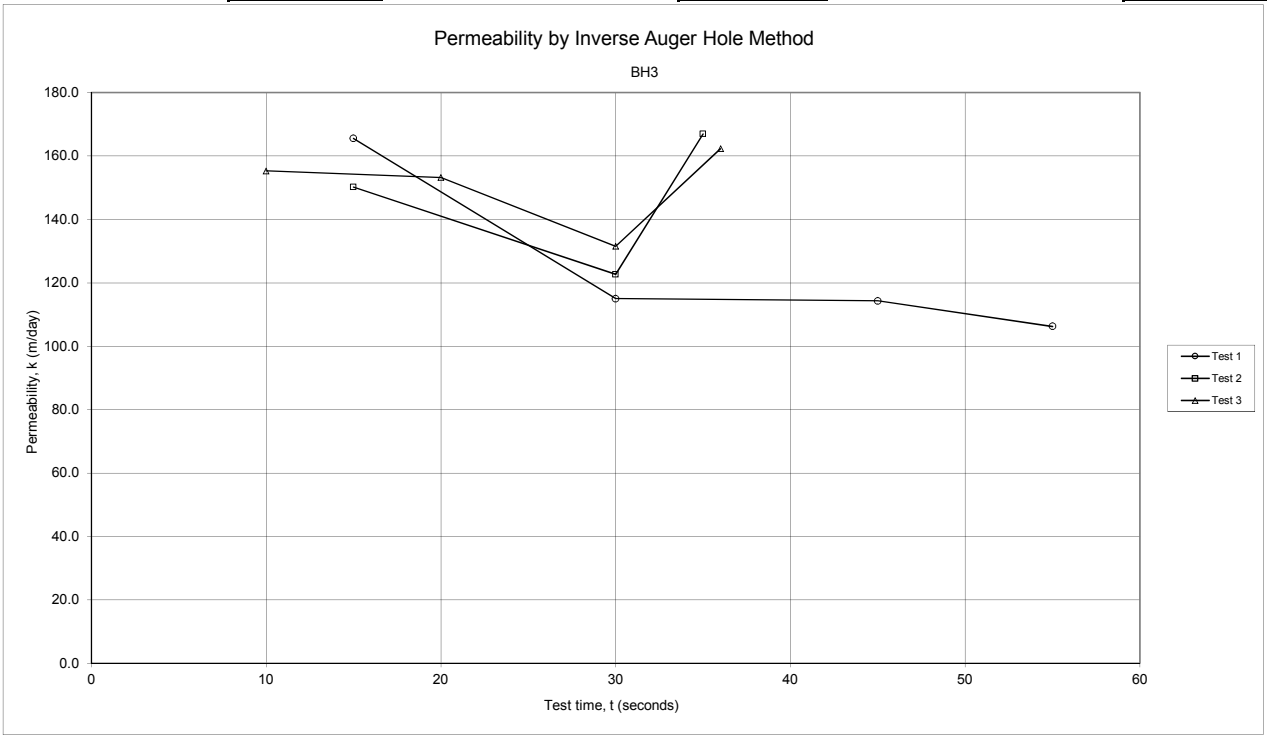
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.33	0.57		
15	0.78	0.12	1.9E-03	165.5
30	0.84	0.06	1.3E-03	115.0
45	0.89	0.01	1.3E-03	114.3
55	0.9	0	1.2E-03	106.2
		AVERAGE	1.4E-03	125.2

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.33	0.57		
15	0.76	0.14	1.7E-03	150.2
30	0.85	0.05	1.4E-03	122.6
35	0.9	0	1.9E-03	166.9
		AVERAGE	1.7E-03	146.6

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.33	0.57		
10	0.68	0.22	1.8E-03	155.3
20	0.82	0.08	1.8E-03	153.2
30	0.86	0.04	1.5E-03	131.5
36	0.9	0	1.9E-03	162.3
		AVERAGE	1.7E-03	150.6



Local Water Management Strategy

APPENDIX D

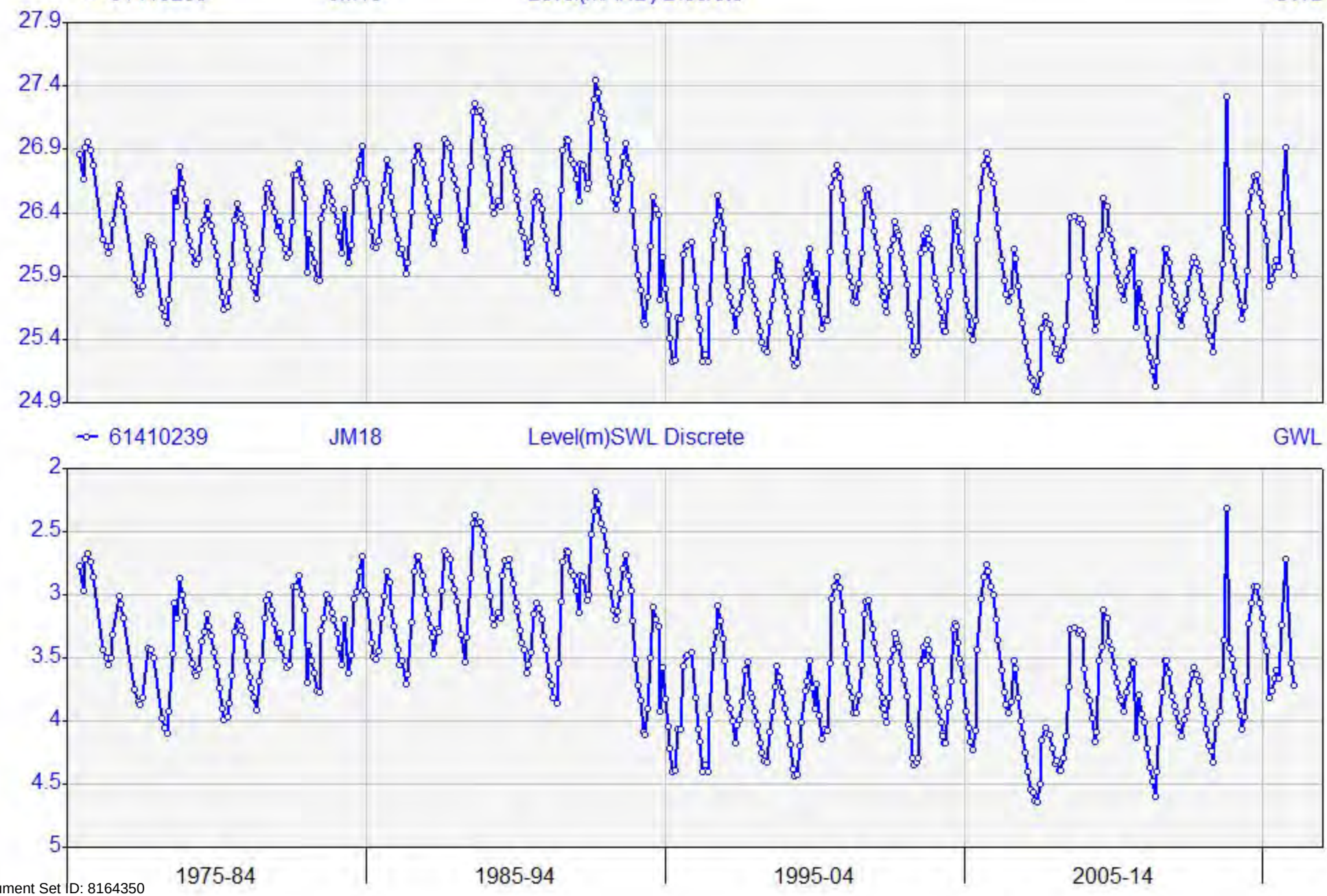
DOW BORE HYDROGRAPHS

Cardno
Shaping the Future

Department of Water

HYPLOT V133 Output 26/01/2017

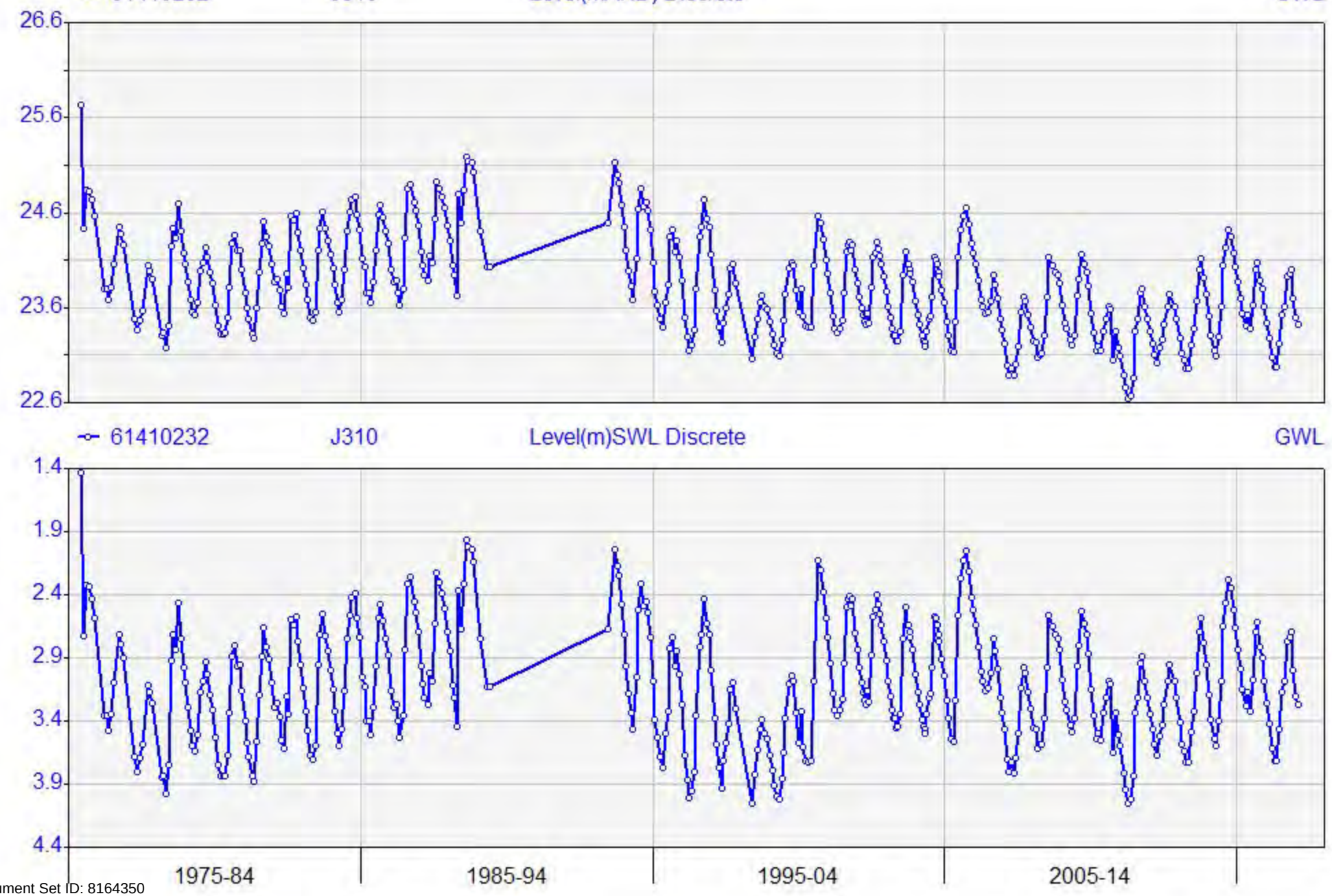
Period 42 Year 01/01/1975 to 01/01/2017 1975-2016



Department of Water

HYPLOT V133 Output 21/02/2017

Period 43 Year 01/01/1975 to 01/01/2018 1975-2017

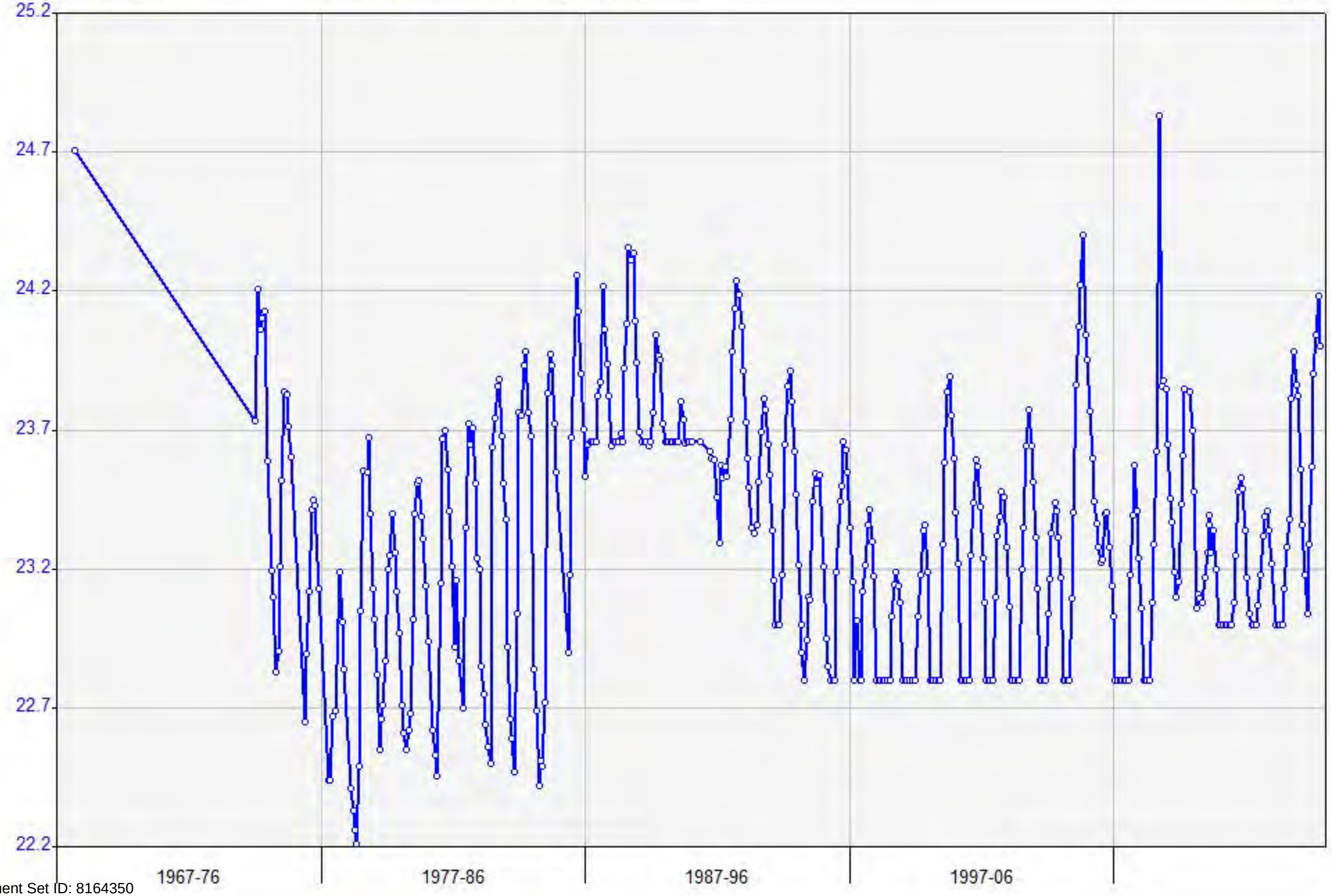


Department of Water

HYPLOT V133 Output 03/12/2016

Period 48 Year 01/01/1967 to 01/01/2015 1967-2014

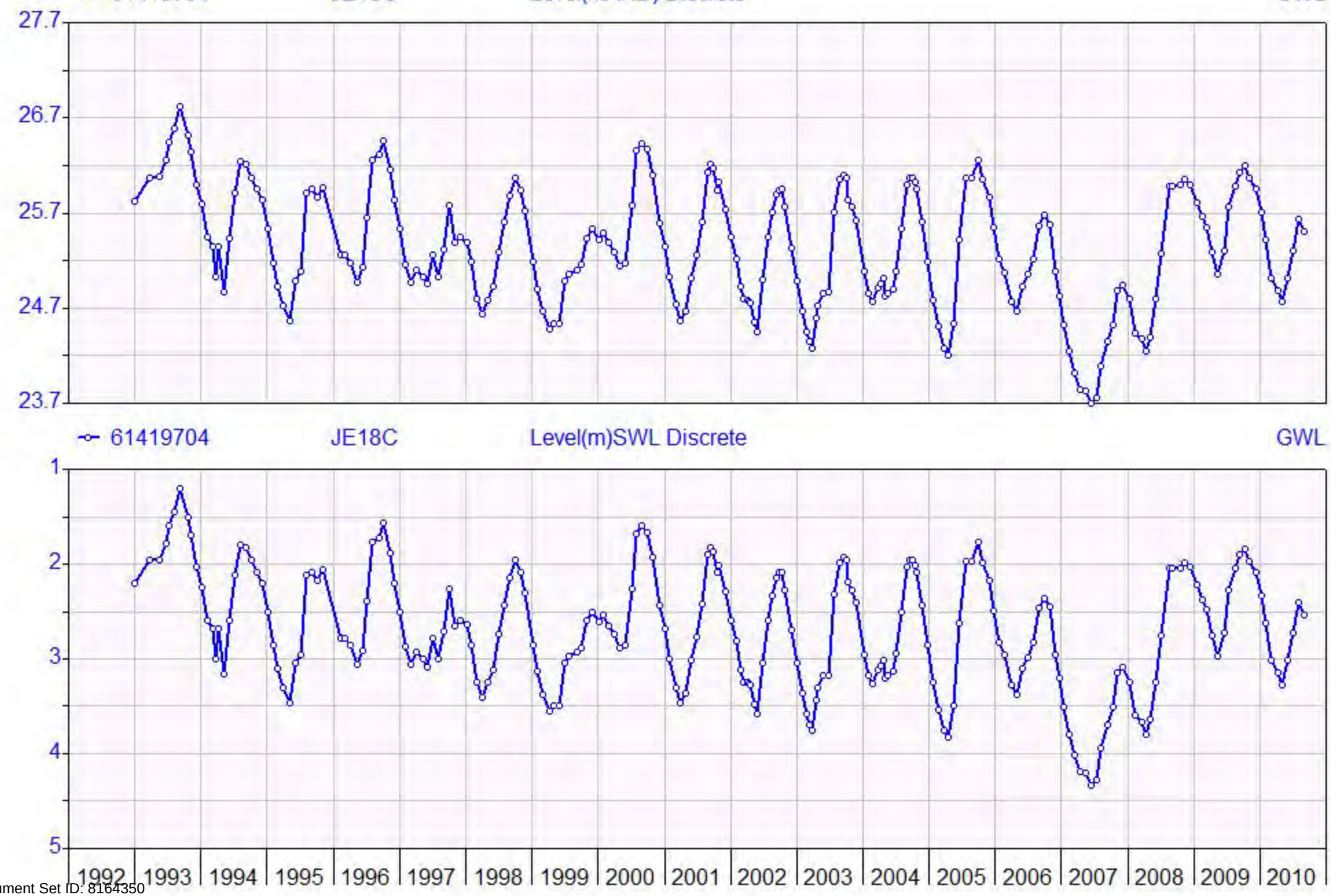
6142525 PRINCEP SWAMP 7731Level(mAHD) Discrete GWL



Department of Water

HYPLOT V133 Output 23/04/2016

Period 19 Year 01/01/1992 to 01/01/2011 1992-2011



Local Water Management Strategy

APPENDIX E

DOW UNDO TOOL

Cardno
Shaping the Future

Government of Western Australia
Department of Water

Project: CCW LWMA

Date: 13/04/2017

Version: Version 1.1.0.16333

Subregion name: wetland

Landuse	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Input load Phosphorus (kg)
Residential	0	0.00	0.00	0.00
Industrial, commercial & schools	0	0.00	0.00	0.00
Rural living	0	0.00	0.00	0.00
Public open space	100	4.69	18.75	0.00
Road reserve	0	0.00	0.00	0.00

Total area	Total percent (%)
4.69	13

Nitrogen input	Phosphorus input
43.26	0.70

Nitrogen export	Phosphorus
0.54	0.00

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	0	0.00
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	100	4.69
Sport	0	0.00
Recreation	0	0.00
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area	Total percent (%)
4.69	100

Nitrogen input (kg)	Phosphorus input (kg)
18.75	0.00

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**No**
Soil type	**Bassendean**	**Does subregion contain onsite sewage diposal system?**	**No**
Depth to groundwater (m)	**1.5**		
Groundwater slope (%)	**0.01**		
Soil PRI	**5.0**		

Note: Please attach the results of soil tests to this report when submitting.

Subregion name: Roads and carpark

Landuse	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Input load Phosphorus (kg)
Residential	0	0.00	0.00	0.00
Industrial, commercial & schools	0	0.00	0.00	0.00
Rural living	0	0.00	0.00	0.00
Public open space	0	0.00	0.00	0.00
Road reserve	100	16.58	191.53	59.70

Total area	Total percent (%)
16.58	46
Nitrogen input	**Phosphorus input**
278.26	62.19
Nitrogen export	**Phosphorus**
2.08	0.42

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	70	11.61
Road reserve - impervious	15	2.49
Road reserve - native garden	0	0.00
Road reserve - non-native garden	15	2.49
Road reserve - turf	0	0.00
Road reserve - not fertilised	0	0.00

Total area	Total percent (%)
16.583	100
Nitrogen input (kg)	**Phosphorus input (kg)**
191.53	191.53

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**No**
Soil type	**Bassendean**	**Does subregion contain onsite sewage diposal system?**	**No**
Depth to groundwater (m)	**2**		
Groundwater slope (%)	**0.01**		
Soil PRI	**5.0**		

Note: Please attach the results of soil tests to this report when submitting.

Subregion name: Mixed business

Landuse	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Input load Phosphorus (kg)
Residential	0	0.00	0.00	0.00
Industrial, commercial & schools	100	14.78	390.21	94.60
Rural living	0	0.00	0.00	0.00
Public open space	0	0.00	0.00	0.00
Road reserve	0	0.00	0.00	0.00

Total area	Total percent (%)
14.78	41
Nitrogen input	**Phosphorus input**
467.51	96.81
Nitrogen export	**Phosphorus**
3.54	0.65

Commercial, Industry and Schools

Landuse	Percent (%)	Area (ha)
Light industrial	0	0.00
Heavy industrial	0	0.00
Commercial / Offices	100	14.78
Schools	0	0.00
Public buildings	0	0.00

Total area	Total percent (%)
14.78	100
Nitrogen input (kg)	**Phosphorus input (kg)**
390.21	94.60

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**No**
Soil type	**Bassendean**	**Does subregion contain onsite sewage diposal system?**	**No**
Depth to groundwater (m)	**2**		
Groundwater slope (%)	**0.01**		
Soil PRI	**5.0**		

Note: Please attach the results of soil tests to this report when submitting.

Summary: Nutrient stripping devices

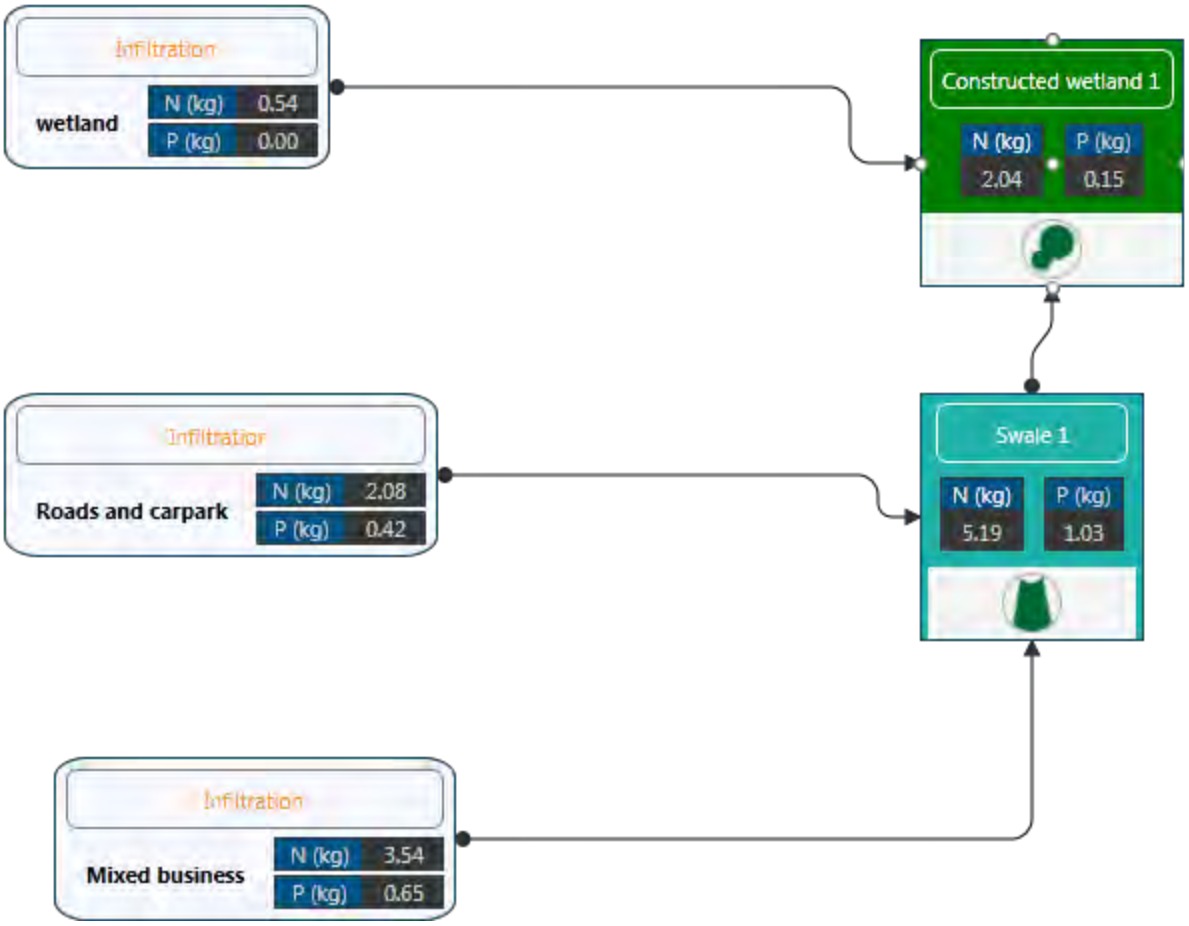
Treatment	Name	Size (m²)	Treated area (ha)	Treating	N removed (kg/yr)	P removed (kg/yr)
Swale	Swale 1	2675.00	31.36	Sandy soils – Runoff only (infiltration on lots)	0.42	0.04
Constructed wetland	Constructed wetland 1	47000.00	36.05	Sandy soils – runoff, subsoils and groundwater	3.69	0.88
Load removed					**4.11**	**0.92**
Net export					**2.04**	**0.15**

Summary: Nutrient load exports

Region	Area (ha)	P export (kg/yr)	N export (kg/yr)
wetland	4.69	0.00	0.54
Roads and carpark	16.58	0.42	2.08
Mixed business	14.78	0.65	3.54

PRE-TREATMENT LOAD (kg/yr)		LOAD REMOVED (kg/yr)		NET LOAD EXPORT (kg/yr)	
NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS
6.15	**1.07**	**4.11**	**0.92**	**2.04**	**0.15**

Treatment diagram



About Cardno

Cardno is an ASX200 professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

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