Packham North

DWMS/LWMS

Prepared for City of Cockburn

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1 Introduction

1.1 Background

The City of Cockburn (CoC) has commenced planning for the Packham North site within Spearwood. The site is located approximately 6km south of Fremantle and 1km from the coast. The site location and development boundary are presented within **Figure 1** and **Figure 2** respectively. Historical land use within the site has included rural uses, such as market gardens and general farming, as well as the Watsonia meat works.

It is important that stormwater management methods, which avoid flooding and protect the environment, are identified early and clearly at the development planning stage. This provides the framework for actions and measures to achieve the desired outcomes at subdivision stage. This document has been prepared to provide this guidance.

1.2 Town Planning Context

A District Water Management Strategy (DWMS) is generally required to support the rezoning of the land to Urban and provide a broad scale water management strategy for an area. For the Packham North Site, the area is already zoned Urban. As such, a separate DWMS is not required. Although preparing a DWMS can enable more efficient design of the Local Structure Plan (LSP) and optimal location of land uses, a Local Water Management Strategy (LWMS) can be prepared as a combined DMWS and LWMS document. This is the approach taken for the site.

A District Structure Plan (DSP) has been prepared for the Packham North site by the CoC. Through development of the DMWS/LWMS there has been some modification to the DSP in order to make allowances for drainage and Public Open Space (POS) requirements. The strategies for managing the surface water and groundwater which have been presented in this DWMS/LWMS, will guide future subdivision of the site to ensure that it proceeds in a sustainable manner, facilitating the objectives of the Western Australian Planning Commission (WAPC) as described in *Liveable Neighbourhoods* (WAPC, 2007) and in accordance with the objectives of the CoC.

1.3 Policy Framework

There are a number of State Government policies of relevance to the Packham North site. These policies include:

- *State Water Strategy* (Government of WA, 2003).
- *State Planning Policy 2.9* (WAPC, 2006).
- *Planning Bulletin No. 64: Acid Sulphate Soils* (WAPC, 2007).
- *Guidance Statement No. 33: Environmental Guidance for Planning and Development* (EPA, 2008).
- *Statement of Planning Policy No. 3: Urban Growth and Settlement* (WAPC, 2006).
- *Liveable Neighbourhoods Edition 4* (WAPC, 2007).

In addition to the above policies, there are a number of published guidelines and standards available which provide direction regarding the water discharge characteristics that urban developments should aim to achieve. These are key inputs that relate either directly or indirectly to the Packham North site, and include:

- *Better Urban Water Management* (WAPC, 2008).
- *Decision Process for Stormwater Management in Western Australia* (DoW, 2009).

- *Stormwater Management Manual for Western Australia* (DoW, 2007).
- *National Water Quality Management Strategy* (ANZECC, 2000).

The CoC has produced a number of documents for development of land which include detail requirements for rainwater tanks through to strategic planning such as in the *Town Planning Scheme No 3* (2002). This DWMS/LWMS is based on *Amendment 70 of the Town Planning Scheme for DCA 12* (CoC 2009).

All of these documents point to the need for accurate baseline data prior to urban development. Comprehensive baseline data ensures that any future development is able to fulfil the stormwater management requirements of the Department of Water (DoW) and engineering standards specified by the CoC, but will also ensure that realistic water quality criteria are practically achievable are adopted.

Information available for the site, including recent investigations into environmental, hydrological and flora are detailed in **Section 3**.

1.4 Packham North DWMS/LWMS objectives

This DWMS/LWMS has been developed to meet the following major objectives:

- Provide a broad level stormwater management framework to support future urban development.
- Develop a water quality and water quantity management strategy for surface water and groundwater.
- Incorporate appropriate Best Management Practices (BMPs) into the drainage systems that address the environmental and stormwater management issues identified.
- Minimise development construction costs, which will result in reduced land costs for future home owners.
- Minimise ongoing operation and maintenance costs for the land owners and CoC.
- Develop a water conservation strategy.
- Gain support from the DoW and CoC for the proposed method to manage stormwater within the Packham North Site and potential impacts on downstream areas.

2 Proposed Development

Within the Packham North development area there are 79 existing lots with a total area of 70.6ha. The development area is proposed to be developed by two larger developer groups and potentially a number of small groups. However, this DWMS/LWMS outlines a consistent design approach for the whole development area.

The DSP for the site is provided within **Appendix A** and a development layout which this DWMS/LWMS has been based on provided in **Figure 3**. The key elements of the development layout include:

- A total of approximately 1001 mixed density lots.
- The locations of the POS provide a linkage through the site from the Beeliar Region Park (Bush Forever 247) to the Market Garden Swamp (Bush Forever 435).
- Retaining and restoring two wetlands (current highest classification is „Multiple Use Wetland').
- Utilising the wetlands for larger event runoff storage.
- Creation of vegetated treatment basins to improve the quality of surface runoff.
- A town centre.
- Mixed Business Area.

3 Pre-development Environment

3.1 Sources of Information

A number of broad level information sources have been used to provide a regional environmental context for this LWMS. These were reviewed in order to provide suitable background information and to provide an indication of the issues requiring further and more detailed investigation. The background information was sourced from a variety of references including:

- *Acid Sulfate Soils Risk Mapping (WAPC, 2008).*
- *Perth 1:50 000 Geology Map Sheet (Government of WA 1970).*
- *Wetlands of the Swan Coastal Plain (Hill et al, 1996).*
- *Indigenous Heritage Mapping (DIA, 2010).*

In addition to the above information, site specific investigations into various aspects of the site have recently been conducted as part of the development DSP process. These have been aimed at providing more detail to the existing regional information. These additional site specific investigations include:

- *Groundwater Level and Quality (Cardno, 2010).*
- *Acid Sulfate Soils (Cardno, 2009).*
- *Vegetation Survey (Regen4 Environmental Services, 2009).*

The important findings from the previous studies that affect the DSP and this DWMS/LWMS are provided within the following sections.

3.2 Geotechnical Conditions

3.2.1 Topography

The site has a relatively steep average gradient of 5%. Ground levels slope to one of two central low points, where the two depressions / wetlands are located, with the steepest gradients along the south-west and western boundaries. The depressions have an invert elevation of approximately 0 to 1mAHD. The highest point within the development site boundary is 24mAHD along the south western boundary. The topography is presented within **Figure 4**.

3.2.2 Soils

Geological mapping indicates that that the site is within an area of predominately sandy soils with small areas of limestone noted in the south west and north west corners of the site. Geology to the west of the site is noted to be limestone (see **Figure 5**). This classification is confirmed by aerial photography, site investigations and bore soil logs. The location of these monitoring bore is shown in **Figure 8** and bore logs are given in **Appendix B**. The soils near the eastern wetlands have a high content of organic peaty soil (Cardno, 2009).

Due to the coarse sandy soil across the majority of the site, it is anticipated that the infiltration rate of the soils will be very high. However, these types of soils provide the opportunity for at-source retention of surface water runoff within measures such as soakwells and infiltration basins (provided there is adequate clearance to groundwater). These higher infiltration soils tend to have a low Phosphorous Retention Index (PRI). Therefore, for areas proposed to be utilised for drainage or POS it is recommended that imported fill with a PRI of greater than 10 be utilised to maximise retention of nutrients prior to infiltration (DoW, 2007).

3.2.3 Acid Sulfate Soils

The WAPC mapping for Acid Sulfate Soils (ASS) within the site indicates that there is no known risk of ASS being found within 3m of the surface (see **Figure 6**). However, there is a strong possibility of ASS occurring within the site due to the wetland areas having:

- An elevation of below 5mAHD.
- Groundwater levels in close proximity to the surface.
- Soils with evidence of regular water logging.
- Highly organic soils.
- The presence of wetland dependant vegetation (Cardno, 2009).

Therefore detailed ASS investigations across the site are required. These investigations are currently underway but have yet to be complete.

3.3 Hydrology

The preparation of a DWMS/LWMS requires a good understanding of the quantity and quality of the surface and subsurface water across the proposed development. A sound understanding of the constraints and opportunities enables management strategies to be determined which are appropriate for the site.

The groundwater levels across the site are required to determine the optimal post-development land use, e.g. areas of shallow water table are more suitable for POS than for dwellings or infiltration basins. The quality of the groundwater leaving the site will affect the environmental health of the surface water body it drains into, as does the quality of the surface runoff. Understanding the quality of this water is the first step to managing discharges to acceptable water quality standards.

The quantity of the surface runoff is the most visually obvious constraint to management, yet it should be considered equally as important as the surface water quality, groundwater quantity and groundwater quality. The management of surface runoff is important to protect areas from flooding and from potential erosion.

3.3.1 Surface Water Quantity

An understanding of the surface runoff associated with the site is required to produce an effective stormwater management strategy. Surface runoff is estimated using accurate data on topography, infiltration rates, vegetation and existing surface channels. This information is used in a hydraulic and hydrologic model to calculate discharges, volume of runoff and flow paths.

3.3.1.1 Existing Drainage Network and Pre-development Sub-catchments

The LiDAR topography data indicates that the Packham North site has two depression areas with elevation of between 0mAHD to 1mAHD. These areas have been denoted as the „Western Wetland' and the „Eastern Wetland' (see **Figure 7**) for the purpose of this DWMS/LWMS document (further description of the wetlands are provided within **Section 3.4**). Due to the topography of the site, all runoff from the existing site will flow towards one of the two wetlands. Furthermore, these wetlands will receive surface runoff from areas external to the Packham North site boundary. These surface runoff pre-development sub-catchments and flow paths are presented in **Figure 7**.

The site has no open channel drainage networks and all runoff to the wetlands is via overland flow. However, the external existing residential Sub-catchment E2 has a pipe network which discharges to a basin located on Lot 1 Hamilton Road adjacent to the Eastern Wetland. This sub-catchment is also anticipated to discharge runoff events, exceeding the capacity of the pipe network, to both the Eastern and Western Wetlands via overland flow (see **Figure 7**).

The adjacent existing residential Sub-catchment E1 discharges the pipe drainage network to the Western Wetland. This sub-catchment is also anticipated to discharge runoff events, exceeding the capacity of the pipe network, to both the Eastern and Western Wetlands via overland flow (see **Figure 7**).

The existing development immediately east of Mell Road is drained via a pipe network and discharges to the Market Garden Swamps (south of the proposed development site, see **Figure 7**). This sub-catchment is anticipated to discharge runoff events exceeding the capacity of the pipe network also to the Market Garden Swamps (via overland flow down Mell Road). Therefore this catchment does not contribute runoff to the Packham North development site.

The western end of Ocean Road is elevated. The runoff from the section of the road immediately (Sub-catchment F2b) uphill of the site drains into a sump (see **Figure 9**). During large rainfall events (greater than a 5yr ARI), this sump would overtop and the runoff would flow down Ocean Road and into the Western Wetland.

Several of the lots and a small section of the Rockingham Road drains via a pipe network to a sump located behind the Liberty Petrol Station and Cockburn Liquor Store (Sub-catchment E5). During large rainfall events, this sump would overtop and the runoff would flow down Rockingham Road. This Sub-catchment E5 is within the site Sub-catchment 4. Sub-catchment 4 is the only area of the site which does not drain to one of the two wetlands, with all runoff being retained within the catchment or in the sump.

3.3.1.2 Pre-development Modelling Parameters

The total volume of runoff from a site is determined by the amount of rainfall less the losses (due largely to infiltration). The rate of runoff is determined by the slope and roughness (Manning's n) of the surface.

An "initial loss – continuing loss" infiltration model was adopted for the pre-development catchments, with loss values chosen based on Cardno's experience with similar soil types to those found on site. The infiltration rates used in the modelling are described in further detail in **Appendix C**.

3.3.1.3 Pre-development Modelling Results

The XPSWMM pre-development model was run for the 5 year, 10 year and 100 year ARI rainfall events. A multi-storm analysis was conducted to determine the critical duration event that produces the largest peak discharge in the site. This analysis concluded that the critical duration was the 36 hour event for the undeveloped pre-development catchments.

The peak discharge modelling results for the 5 year through to the 100 year ARI 36 hour rainfall events are presented in **Table 1**.

Table 1 Development Site Peak Discharge Results (36hr Rainfall Event)

Sub-catchment	Peak Discharge (m^3/s)			Average Discharge per Unit Area ($m^3/s/ha$)		
	5yr ARI	10yr ARI	100yr ARI	5yr ARI	10yr ARI	100yr ARI
1	0.45	0.58	0.85	0.022	0.028	0.041
2	0.32	0.39	0.57	0.023	0.029	0.042
3	0.30	0.38	0.63	0.017	0.022	0.037
4	0.07	0.13	0.22	0.012	0.023	0.039
5	0.20	0.23	0.31	0.028	0.033	0.045
6	0.39	0.54	0.93	0.010	0.014	0.025

The existing developed residential catchments will discharge surface runoff into the site and thus the site will need to accommodate this runoff. These existing developments were constructed prior to guiding documents such as *Better Urban Water Management* (WAPC, 2008) and therefore, the design criteria for these areas are not consistent with the design criteria for the proposed Packham North development. Nonetheless, the Packham North development is required to manage the inflow from the surrounding catchments in a manner consistent with the revised design criteria presented in **Section** 4. The runoff volumes for the design rainfall duration events of these external sub-catchments are presented in **Table 2** below. The critical duration that produced the most volume of runoff was the 72hr rainfall event.

Table 2 Existing External Development Runoff Volume Results (72hr Rainfall Event)

Sub-catchment	Volume (m^3)			
	1yr-1hr ARI	5yr ARI	10yr ARI	100yr ARI
E1 (Into Western Wetland)*	835	5,525	5,525	5,525
E1 (Into Eastern Wetland)*	0	0	1,090	6,345
E2	270	1,930	2,340	4,245
Ct5 (Undeveloped Area)	10	1,805	2,320	4,955
E3 (Into Market Garden Swamp)*	175	1,090	1,090	1,090
E3 (Into Eastern Wetland)*	0	0	260	1,180
E5	160	970	1,135	1,930
Total	1,450	11,320	13,760	25,270

* The pipe network within sub-catchments E1 and E3 discharge into the Western Wetland and the Market Garden Swamp, respectively. This pipe network carries the 1 year - 1 hour and 5 year ARI rainfall event. Overland flow (i.e. in the 10 and 100 year ARI event) from these sub-catchments then also discharges into the Eastern Wetland.

3.3.2 Surface Water Quality

The site has high infiltration sandy soils and thus there are typically no standing water bodies for surface water quality analysis. However, due to the depression areas associated with the Eastern and Western Wetlands, there are two areas that regularly have standing water. These are likely to be a combination of surface water storage and groundwater.

The water bodies within the Western Wetland and Watsonia Meatworks (Eastern Wetland) site were investigated during a Preliminary Site Investigation (PSI), which is provided in **Appendix D** (RPS

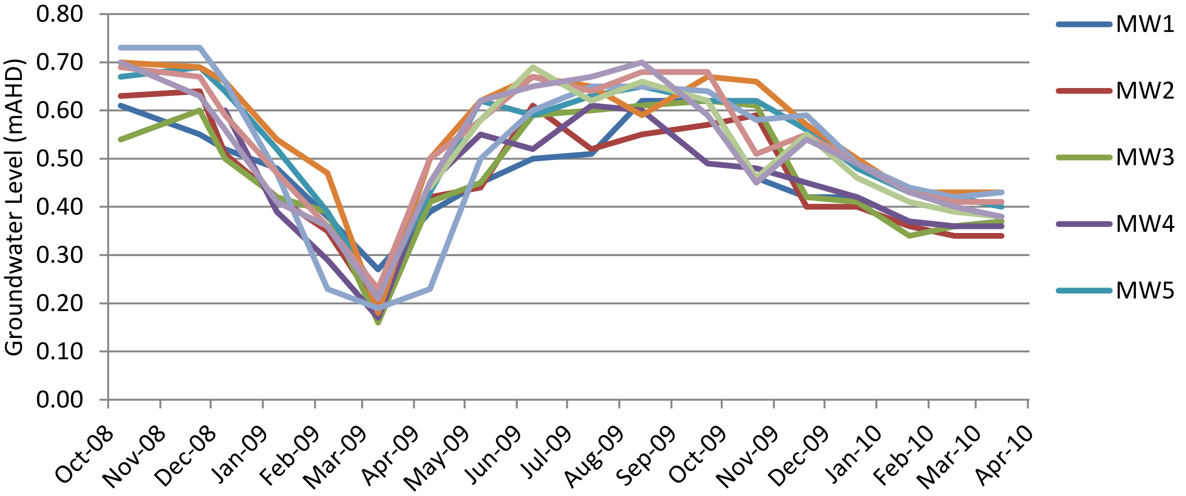
2009). The ponds appeared to be utilised by wildlife and the surrounding vegetation was observed to be healthy.

In order to thoroughly investigate the presence of pesticides, hydrocarbons, heavy metals and nutrients associated with previous land uses a Detailed Site Investigation (DSI) should be completed as part of the UWMP approval process.

3.3.3 Groundwater Levels

The site was installed with 10 groundwater monitoring bores and data was collected from October 2008 to April 2010. This data set captured two winter peaks. A replication of the time series groundwater data from the *Groundwater Monitoring Report* (Cardno, 2010) is presented below.

Graphic 1 Time Series Groundwater Level Data



The data from the groundwater level monitoring was used to determine the Maximum Recorded Groundwater Levels (MGL) contours across the site (see **Figure 8**).

Due to the highly permeable sandy soils and close proximity to the coast, the groundwater levels within the site are largely influenced by the Indian Ocean water level and thus have a peak water level of less than 1mAHD. The MGL were not referenced to any long term DoW bores as the long term bores were more than 1.5km from the site or were too close to the coast and therefore significantly influenced by the Indian Ocean. It is anticipated that due to these reasons the historic peak is unlikely to be significant higher than the MGLs. The earthworks levels will also be predominately determined based on satisfying the 100 year flood water level requirement (**Section 4.4.1**) rather than groundwater requirements (**Section 4.3**); this is further discussed in **Sections** 6 and **Section** 7.

3.3.4 Groundwater Quality

Groundwater quality sampling for physiochemical parameters was conducted on a monthly basis for a period of 18 months (from October 2008 to March 2010) following installation of the monitoring bores. Groundwater quality sampling for nutrient concentrations was conducted on a quarterly basis over the same period (i.e. six occasions) (Cardno, 2010). A replication of the groundwater quality data from the *Groundwater Monitoring Report* (Cardno, 2010) is presented in **Table 3**. Bore locations are shown on **Figure 8**.

Table 3 Summary of Groundwater *in situ* and Laboratory Analysis Results

	Trigger Values	MW1	MW2	MW3	MW4	MW5	MW6	MW7	MW8	MW9	MW10
Field Chemistry Parameters											
Temp (°C)	-	20.9 (1.0)	21.0 (1.1)	21.1 (1.1)	21.4 (1.0)	20.4 (4.6)	21.3 (1.8)	20.6 (1.1)	20.7 (1.0)	20.5 (1.7)	21.8 (1.5)
Salinity (mS/cm)	0.12-0.3	0.6 (0.1)	0.5 (0.1)	1.0 (0.2)	1.0 (0.2)	0.8 (0.2)	1.0 (0.3)	0.6 (0.2)	0.6 (0.2)	1.3 (0.2)	0.7 (0.1)
DO (%)	80-120	69.1 (9.9)	91.7 11.7)	57.3 (9.7)	38.7 (8.5)	43.3 (15.6)	32.7 (12.6)	74.1 (13.7)	26.8 (13.8)	47.0 (19.8)	81.8 (13.7)
pH	6.5-8.0	7.3 (0.6)	7.4 (0.4)	7.4 (0.1)	7.3 (0.1)	7.4 (0.2)	7.4 (7.4)	7.6 (0.5)	7.2 (0.1)	7.3 (0.7)	7.3 (0.2)
Redox	-	138.6 (49.4)	146.6 (48.4)	136.8 (35.4)	130.5 (33.7)	127.7 (30.9)	124.1 (25.4)	130.6 (28.5)	123.1 (21.4)	151.8 (42.3)	135.8 (41.4)
Laboratory Analytes											
TN (µg/L)	1,200	4,083 (504)	2,183 (306)	10,280 (923)	12,300 (1,942)	8,217 (662)	17,983 (6,116)	3,483 (1,165)	4,050 (2,190)	2,793 (4,345)	11,633 (776)
TP (µg/L)	65	137 (159)	88 (115)	186 (139)	52 (40.7)	71 (78.9)	159 (300)	115 (161)	95 (117)	63 (55.0)	186 (133)
Ortho-P (µg/L)	40	5.8 (3.7)	6.3 (3.4)	7.4 (4.0)	9.5 (4.5)	10.7 (4.5)	12.5 (6.5)	9.0 (5.2)	9.3 (5.0)	14.3 (6.1)	11.2 (6.5)
NH_4 (µg/L)	80	12.5 (13.9)	12.0 (11.8)	11.2 (8.6)	16.2 (14.7)	10.8 (9.9)	41.3 (53.1)	20.3 (30.0)	14.2 (13.5)	23.5 (17.4)	15.7 (22.0)
NO_x (µg/L)	150	3,675 (539)	2,060 (333)	9,800 (1,142)	11,733 (1,537)	7,960 (912)	16,050 (6,108)	3,160 (1,129)	3,837 (2,132)	2,442 (4,574)	11,300 (992)
TKN (µg/L)	-	417 (172)	200 (63.2)	480 (295)	733 (665)	350 (176)	2,150 (2,192)	333 (121)	267 (121)	475 (289)	483 (366)

Note: the above statistics are the average and (standard deviation). Trigger values are for Lowland Rivers in South Western Australia, as classified by ANZECC (2000).

The groundwater monitoring data summarised in **Table 3** indicates that Nitrogen concentrations within the groundwater are very high and exceed the trigger values for Lowland Rivers in South Western Australia (ANZECC, 2000). The locations with the highest concentration of Nitrogen are along the southern portions of the site. It is possible that this is the result of current Market Gardening Practices; since the northern half of the site has lower Nitrogen concentration and less Market Garden activity.

Phosphorus concentrations within groundwater were measured to be up to three times the trigger value. The distribution of concentrations of Phosphorous within the groundwater did not present a spatial trend.

Groundwater level monitoring and topographical data indicate that the wetlands intercept groundwater, therefore there is the potential that any surface water bodies within these locations will receive nutrients from the groundwater. This presents the risk that the surface water bodies will have high nutrient concentrations and may have problems with the health of the water body (i.e. algal blooms and midge issues). The water quality of any standing water bodies within the wetlands should be monitored and managed (further detail is provided in **Section** 8).

3.4 Wetlands

There are two wetlands within the Packham North site. Only the Eastern Wetland has been officially recognised and classified as a „Multiple Use Wetland' within the Department of Environment and Conservation's „Geomorphic Wetlands Swan Coastal Plain' dataset. This Eastern Wetland has been accurately classified under this system, as the wetland is in very poor condition and highly modified.

The Western Wetland is not officially recognised and classified. However, this wetland has vegetation that has been classified as „Good' (Regen4, 2009).

3.5 Flora

A flora and vegetation investigation was conducted by Regen4 Environmental Services (2009) for the Western Wetland and the surrounding Lots (Lot 2L, 6L, 7L, 8L, 185, 189, 193, 201 & 301 Hamilton Road, Lot 9 Entrance Road and Lot 40L Ocean Road). This investigation determined that the wetland had vegetation with „Good' condition, however, the vegetation in the adjacent lots was in a „Completely Degraded' condition. The wetland plant community was Paperbark (*Melaleuca raphiophylla*). No Declared Rare or Priority Flora was found during the study.

3.6 Fauna

Due to the site being extensively cleared, it is unlikely to provide habitat for significant fauna populations.

3.7 Current and Historical Land Uses

The DSP and LWMS has been prepared for the Packham North Site. This site has historically been used for farming, market gardens and the Watsonia Meatworks. These historical land uses have the potential to cause contamination. As such, site investigations are currently being undertaken to determine if there are contaminants and how these areas will be remediated.

3.8 Ethnographic Considerations

3.8.1 Indigenous Heritage

A search of the Government of Western Australian Department of Indigenous Affairs, Heritage System found no Register Sites within the Packham North site boundary.

3.8.2 Historical Heritage

A search of the Government of Western Australian, Heritage Council of WA found four registered sites. A summary of the descriptions for the sites is presented below:

<u>Site 1</u>

Place No:*10165 - Name: Cottages opposite Watson's Factory (High level of protection*)

Location: *Lot 5 CSL 133, Plan Diagram P4097, volume folio V1364 F669; Lot 4 CSL 133, Plan Diagram P4097, volume folio V1030 F939.*

Description: *The cottage, situated opposite the Watsonia factory, is next to the ruins of another Watson house (part of an original set of four cottages). The symmetrical facade cottage is built from* *limestone with brick quoins. It has a modern garage attached to the side of the house made from pale brick and a rear fibro extension. The roof is corrugated iron with a broken backed veranda on the facade of the building.*

Site 2

Place No: *Place No: 04242 - Name: House, Spearwood*

Location*: 154 Mell Rd (Currently Demolished)*

Description: T*he building was a small single storey, made of weatherboard timbers residence, tiled roof with a brick chimney. Adjacent to the house was a small stone cottage (possibly the original residence) with a small stone toilet to the rear. There was also a large corrugated iron shed, open to one end. All buildings on site have been demolished.*

Site 3

Place No: *Place No: 17000 - Name: Watsonia Factory*

Location*: 174 Hamilton Road*

Description: *The Watsonia Factory is set close to the railway line in Hamilton Road. Over the road from the factory are three cottages (one occupied, two ruins) originally owned by the factory and included on the Municipal Heritage Inventory owing to their association with Watson's. Some obvious modifications include: many changes have been made over the years no parts of the original factory are obvious; major extensions to the factory were opened in 1983. Foundations of the original 19th century house Woodlands can be seen on the north side of the factory.*

Site 4

Place No: *Place No: 17013   Name: Wetlands*

Location*: Lots 1,2 & 301 Hamilton Road*

Description: *This small wetland is all that remains of what would have been a much larger wetland of natural vegetation. It covers approximately seven hectares of land and is mainly comprised of approx 500 -100 paperbark trees (Melaleuca rhaphiophylla) and their dependent vegetation. The estimated age of the larger paperbarks is between 80 -100 years. It is uncertain as to how old the actual wetland is. The wetland is considered to be in generally good condition however, the understorey has been degraded slightly by human interference alongside the invasion of exotic household plants and Typha rush.*

3.9 Summary of Existing Environment

In summary, the environmental investigations conducted to date indicate that:

- The site has steep topography ranging from 24mAHD in the south west to 0mAHD in the centre of the site. All areas of the site slope towards the central depression areas.
- One wetland is unclassified, while the Eastern Wetland is considered a „Multiple Use Wetland'.
- The site predominately has coarse sandy soils with small areas of limestone in the north-western and south-western corners of the site. The infiltration rate of these soils are anticipated to be high. The areas associated with the depressions have a higher content of organic material.
- The WAPC mapping for ASS within the site indicates that there is no known risk within 3m of the surface. However due to the site characteristic there is potential for ASS to be found within the site, particular near the depression areas. Site investigations are currently underway.
- The development site receives runoff from developed and undeveloped external catchments.
- External runoff into the site will be required to be retained within the site boundary.

- The 72hr duration rainfall event produces the most volume of runoff.
- The MGL were monitored for two years and are all within 0.6 to 0.73mAHD. Due to the close proximity to the coast, there is a small spatial variation in MGL. It is also anticipated that historic MGL would not be significantly higher as the groundwater levels are controlled by water levels in the Indian Ocean.
- There is currently no surface water quality data available. The water quality of the Western Wetland should be monitored to provide a pre-development data for comparison as part of the UWMP.
- No Declared Rare or Priority Flora was found during the Flora Investigation for the Western Wetland.
- The site is unlikely to provide habitat for significant fauna populations.
- No registered Indigenous Heritage Sites were founding within the site.
- Four registered Heritage Sites are presented within the site. One of the sites is listed as having a High Level of Protection.

4 Design Criteria and Objectives

This section outlines the objectives and design criteria that this DWMS/LWMS and future UWMPs must achieve. The objectives and design criteria are both general water management philosophies that reflect state-wide principles and are site specific, taking into account the local environment. The water management strategy covers all aspects of water use, including stormwater management, groundwater management and water consumption.

4.1 Total Water Cycle Management

The water cycle is complex, involving rainfall, evapo-transpiration, overland flow and groundwater flow. Water Sensitive Urban Design (WSUD) grew out of a recognition of the linkages in the water cycle between urban development, stormwater systems and the quality of downstream ecosystems, and is based on a holistic approach to water cycle management and regional natural resource management.

The application of WSUD principles involves incorporating water resource issues early in the landuse planning process. It addresses water resource management at the catchment, suburb, precinct, cluster and lot scale. WSUD makes the entire stormwater treatment network part of the urban fabric via Multiple Use Corridors (MUCs) and BMP treatment trains.

Total water cycle management recognises the finite limit to a region's water resources, and the inter-relationships between the uses of water and its role in the natural environment.

Key principles of total water cycle management include:

- Considering all water sources, including wastewater, stormwater and groundwater.
- Using all water sources sustainably.
- Allocating and using water equitably.
- Integrating water use with natural water processes, including maintaining environmental flows and water quality.

The *State Water Strategy* (Government of WA, 2003) endorses the promotion of total water cycle management and application of WSUD principles to provide improvements in the management of stormwater and to increase the efficient use of existing water supplies.

Total water cycle management therefore addresses not only physical and environmental aspects of water resource use and planning but also integrates other social and economic concerns. Stormwater management design objectives should therefore seek to deliver better outcomes in terms of:

- Potable water consumption.
- Stormwater quality management.
- Shallow groundwater management.
- Flood mitigation.

Therefore, the overall objective for preparing total water cycle management plans for proposed residential developments is to minimise pollution and maintain an appropriate water balance. This objective is central to the Packham North DWMS/LWMS.

4.2 Water Conservation

It is widely thought that the local climate is undergoing a drying trend, and that as Perth's population grows and demands for potable water sources increase, significant attention should be focused on the manner in which the resources currently available are utilised. This consideration is acknowledged and the use of water within the development should be minimised wherever possible. Therefore, the design objectives for water conservation management on a development scale for Packham North are:

- Minimise water requirements for establishment of POS.
- Minimise water requirements for POS maintenance.
- Minimise net use of water by maximising surface aquifer recharge.

Individual households can also contribute to water conservation. The development should achieve The *State Water Strategy* water consumption target of 100kL/person/year.

4.3 Groundwater Management

Any proposed manipulation of groundwater levels during construction should be approached in a manner that adequately considers nearby wetland water dependant ecosystems, elevated nutrient concentrations within superficial aquifers and ASS potential across the site, and should be fully rationalised within future UWMP.

Given that urban developments can have implications for the types and quantity of pollutants released to the local surface water and groundwater, and that the work undertaken to develop the land has the potential to mobilise nutrients introduced by former land uses, it is important that groundwater is adequately managed to minimise the risk to downstream receiving environments.

The design objectives for groundwater management within the Packham North development are to:

- Minimise changes to the underlying groundwater levels as a result of development.
- Minimise the risk of nutrient enrichment of downstream receiving surface water bodies from groundwater sources.
- Implement strategies to reduce the nutrient transport into the groundwater.
- Protect wetlands that are dependent on the underlying groundwater.

The groundwater level is close to the surface in some locations within the development area. To ensure an adequate freeboard to groundwater, all lots must achieve a design criteria clearance of 1.2m to the MGL.

4.4 Surface Water Management

The overall guiding document for development of stormwater management strategies within urban areas is the *Stormwater Management Manual for Western Australia* (DoW, 2007); with the *Decision Process for Stormwater Management in WA* (DoW, 2009) providing guidance as to how urban developments can achieve compliance with the objectives, principles and delivery approach outlined in the *Stormwater Management Manual for WA*.

The *Stormwater Management Manual for WA* also provides guidance on the broad principles of WSUD. The broad level objectives in the Manual are in line with the *National Water Quality Management Strategy* (ANZECC, 2000) and include:

- Maintaining or improving the surface and groundwater quality within the development areas relative to pre-development conditions.

- Maintaining the total water cycle balance within development areas relative to the pre-development conditions.
- Maximising the reuse of stormwater.
- Retaining natural drainage systems and protecting ecosystem health.
- Implementing stormwater management systems which are economically viable in the long term.
- Minimising the public risk, including risk of injury or loss of life, to the community.
- Protecting the built environment from flooding and water-logging.
- Ensuring that social, aesthetic and cultural values are recognised and maintained.
- Ensuring the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

4.4.1 Stormwater Quantity

Through the guiding documents and consultation with the DoW and CoC, the proposed stormwater management design criteria are:

- Retain the 1 year - 1 hour duration ARI rainfall event onsite within vegetated treatment basins to ensure no direct discharge of stormwater runoff into the wetlands.
- A minimum depth of 0.5m of high infiltration sand is to be utilised under basins to encourage infiltration.
- The basin invert must be above the MGL.
- Stormwater is infiltrated within 96 hours after the storm event has ended during November to May.
- Convey the 5 year ARI rainfall event within the pipe network.
- Ensure that the 100 year ARI rainfall event can be conveyed and contained within road reserves.
- Retain the 100 year ARI rainfall event with the site.
- Retain the runoff generated during storms up to the 100 year ARI from each catchment within the catchment boundary.
- The floor levels of all habitable buildings are a minimum of 300mm above the 100 year ARI rainfall event flood level within road reserves.
- The floor levels of all habitable buildings are a minimum of 500mm above the 100 year ARI rainfall event flood levels within storage areas (basin or wetlands).

The above design criteria require that the 100 year ARI rainfall event is retained onsite. This design criterion will maintain the pre-development hydrologic regime of no discharge from the site (due to the existing topography).

The DSP area receives runoff from upstream developed and undeveloped catchments. In the pre-development environment, this runoff discharges to one of the two natural depression areas (Western Wetland or Eastern Wetland). In the post-development, the flow paths and runoff volumes of all externally generated stormwater runoff will be maintained. Therefore, catchments can convey this runoff to the depression areas, but must manage stormwater originating from within the catchment boundary within the catchment.

Catchment boundaries proposed in this DWMS/LWMS are based on the boundaries of the land which are to be developed by each developer group. Due to these boundaries being fixed by land ownership and not solely on topography and structure plan layout, these boundaries may require some modification at detailed design stage. Any boundary changes should be compatible with the strategy proposed in this DWMS/LWMS, meet the requirements of the CoC and be presented in an UWMP. However, if significant modifications or variations to the strategy proposed in this DMWS/LWMS occur due to altered catchment boundaries, then an amended DWMS/LWMS may be required.

4.4.2 Stormwater Quality

Better Urban Water Management (WAPC, 2008) advocates a water quality management approach that establishes pre-development water quality standards and then sets targets for post-development scenarios that reflect the pre-development water quality parameters. The stated principle is that existing surface and groundwater quality should be maintained as a minimum, and preferably improved prior to discharge from the development area.

The groundwater quality presented in **Section 3.3.4** indicates elevated nutrient concentration. This is likely a result of historical market garden practices and input from external catchments. Therefore the design objective is to:

- Maintain and improve (reduce) the nutrient concentrations of the groundwater compared to the concentrations presented in **Section 3.3.4**.

Due to the large variation in nutrient concentrations across the site, post-development groundwater quality data should be compared to the pre-development data for that specific location of the development (see **Section** 8 for proposed monitoring programme).

The principle design criteria to achieve the objective of maintaining and improving groundwater/surface water quality are:

- Use of imported fill and/or amended soils with a minimum PRI of 10 within public open space and drainage areas.
- Retaining the 1 year - 1 hour duration ARI rainfall event onsite as close to source as practical.
- Vegetated bio-retention areas to be sized at 2% of the connected impervious area.

Further specific measures and maintenance practices to achieve to objective should be presented in an UWMP. In addition, adherence to the stormwater quality design criteria relating to imported fill and/or amended soils can be assessed at the UWMP stage.

Further details of the CoC design requirements are provided within the *Guidelines and Standards for the Design, Construction and Handover of Subdivision within the Municipality* (CoC, August 2009).

4.4.3 Basin Design Criteria

Retention basins must achieve the stormwater design requirements and have aesthetic value. Landscape Plans and stormwater design compliance with this DWMS/LWSM must be provided within an UWMP. Basins should be designed to achieve the following design criteria:

- Unfenced basin to have a maximum side slopes of 1:6.
- 1 year - 1 hour vegetated retention basins to have a maximum inundation depth of 0.5m.
- For vegetation basins adjacent to the Western and Eastern Wetlands, the maximum inundation can be 1m.
- Unfenced 5 year and 100 year basins to have a maximum inundation depth of 1m.
- Maximum 100 year ARI inundation depth in Western and Eastern Wetlands of 2m.
- All 100 year retention basins when not fulfilling storage purposes are to be functional, publicly accessible, able to be appropriately maintained and be appropriately integrated with the surrounding urban context.
- Minimal use of vertical walls.
- Unfenced vertical walls to have a maximum height of 1m.

At the detailed design stage, the design criteria of the basins may need to be modified in selective locations to achieve specific design constraints. However, any modification of the design criteria will require approval of the CoC and comment from the DoW.

The basin configurations and design presented in this DWMS/LWMS (**Section** 7) have been utilised to demonstrate that stormwater can be managed within the site. However, some of the presented basin configurations in **Section** 7 do not achieve the above design criteria and will require modification at detailed design stage. The detailed designs for these basins must be approved by CoC and DoW prior to the designs being presented in an UWMP to demonstrate compliance with the design criteria presented in this DWMS/LWMS.

5 Water Source Allocation, Infrastructure and Fit for Purpose

5.1 Water Conservation Strategy

Water is a valuable resource that must be managed sustainably. Conservation of water through fit-for-purpose use and BMPs is encouraged so that water is not wasted. The term fit-for-purpose describes the use of water that is of a quality suitable for the required use of the water. Fit-for-purpose principles have been utilised in the water conservation strategy for the Packham North development

The Packham North development will utilised Rainwater Tanks, Groundwater, Water Efficient Gardens (WEG) and Water Efficient Appliances (WEA) to ensure that the development uses water conservatively. Details of these measures are further discussed in **Section 5.2**.

A water balance study was conducted to determine the effectiveness of the water conservation strategy when compared to a standard development without a water conservation strategy. Thus the strategies presented in the water balance (**Section 5.3**) are:

- Option 1 – Business as Usual (BAU).
- Option 2 – Water Efficient Appliances (WEA), Water Efficient Gardens (WEG) and Groundwater for POS (GW).
- Option 3 – Water Efficient Appliances (WEA), Water Efficient Gardens (WEG), Rainwater Tanks (RWT3000) and Groundwater for POS (GW).

5.2 Water Conservation Measures

5.2.1 Rainwater Tanks

Rainwater collected from roof surfaces can be stored in tanks for later use. This water is of a high quality; however, in urban environments it is advised that this water is considered non-potable. In Perth, 90% of the rainfall occurs in the seven month period from April to October. The remainder of the year has little rainfall but collection is still possible. Thus, collected rainwater is not readily available for irrigation (which is mainly required in summer) but is available to supplement internal building non-potable uses. The Option 2 and 3 water efficiency strategy requires that the rainwater is used in washing machines, toilets and hot water systems.

5.2.2 Water Efficient Appliances

Significant reduction in in-house water uses can be achieved with the use of water efficient appliances. **Table 4** gives an example of the water uses of typical appliance versus water efficient appliances. These water use rates have been used in the water balance investigation.

Table 4 Water Efficient Appliances

Appliance	Water use	
	Standard Device	Water Saving Device
Toilet	12 Litres/Flush	4 Litres/Flush
Washing Machine	130 Litres/Wash	40 Litres/Wash
Shower Head	15-25 Litres/Minute	6-7 Litres/Minute
Taps	15-18 Litres/Minute	5-6 Litres/Minute

(Australian Government, 2009 & Melbourne Water, 2003)

The water conservation strategy proposes that all dwellings use water efficient appliances. This can be encouraged by state and local government rebates, as well as education and additional incentives from the developers.

5.2.3 Water Efficient Gardens

Studies by the Water Corporation (2003) have found that for a typical dwelling, 56% of the water consumed by the lot is used on the gardens. Therefore, reductions in water irrigation by employing water efficiency measures can significantly reduce the total water usage of a lot. The following water efficiency measures should be used on lot gardens:

- Where required, soil shall be improved with soil conditioner certified to Australian Standard AS4454 to a minimum depth of 150mm where turf is to be planted and a minimum depth of 300mm for garden beds (for entry statement only).
- The irrigation system shall be designed and installed according to best water efficient practices. The controller must be able to irrigate different zones with different irrigation rates. Emitters must disperse coarse droplets or be subterranean.
- Installing adequate irrigation control systems to ensure that water can be applied selectively.
- Utilise sub-surface irrigation where appropriate.
- Limiting the amount of turfed areas.
- The turf species used should be a genotype endorsed by the UWA Turf Industries Research Steering Committee (e.g. Couch grass – *Cynodon dactylon*).
- Garden beds to be mulched to 75mm with a product certified to Australian Standard AS4454.

Water conservation can also be reduced on a development scale within POS areas. As well as using the lot scale garden measures on POS gardens, the following additions measures should be utilised:

- Encouraging at-source surface aquifer recharge where possible. This can be achieved via soakwells, vegetated retention basins and swales.
- Retention of remnant native trees within POS areas where possible. This will reduce demands for water during establishment of POS areas.
- Minimise the proportion turfed areas within the POS.
- Provision of some smaller lot sizes that will require less landscaping.
- Turf species will be low water and nutrient requiring.
- Entry statements should include a 1:1 mix of hardstand areas to turfed areas and garden beds.
- The adoption of Xeriscaped POS gardens, where garden beds within POS and community areas are landscaped using „waterwise plants', which are local native species from regions with similar climates that require less water inputs than exotic species.
- Managing irrigation practises within POS areas to minimise losses to evaporation (e.g. amount applied is not excessive, timing irrigation to avoid wastage, etc.).

5.2.4 Groundwater

Non-potable groundwater can be used for irrigation of POS areas. Turfed areas require 7,500kL/ha. It has been approximated that 80% of the POS area will be turfed and therefore the total water required for irrigation would be 55.1ML/yr. This provides a conservative estimate of the water required for the POS area, a more precise calculation of the water required can be produced at UWMP stage once the POS landscape design is complete.

There are 18 lots within the development area that currently have groundwater extractions licences. These licences can be transferred to the development to provide non-potable water for the irrigation of the POS. The total extraction licences currently for the development area is 116ML/year; therefore there are sufficient licences available to meet the water requirements for the POS.

5.2.5 Wastewater Reuse

Wastewater can be recycled and used as potable or non-potable water (depending on the quality of the treatment). However, the costs involved can be significant and are not justified for developments such as Packham North that are within the metropolitan area and are thus close to existing sewerage infrastructure. Therefore, wastewater reuse is not recommended for this development.

5.2.6 Grey Water Reuse

Grey water can be described as all the wastewater use in the home besides the water from toilets (and potentially kitchens). This water has moderate concentrations of solids and nutrients. Grey water can be used for subsoil irrigation and in some other non-potable water uses. However, there is the potential of nutrient leaching if the water is used for irrigation. If there are nearby surface water bodies, these could potentially be contaminated with the nutrients from the grey water. Within the vicinity of the site, there are numerous wetlands systems. For this reason, it is not recommended that grey water be used on a development scale to conserve water.

5.3 Water Balance

The water balance analysis has been based on the rates and calculation methodology presented in the *Water Corporation Spreadsheet AltWaterSupply_Water_Use_Model.xls*. This spreadsheet has been adapted to model the effects of using water efficient appliances and gardens. The water balance analysis has assumed that there would be on average 2.5 people per dwelling. This value has been calculated from data provided by Australian Bureau of Statistics for new housing developments in Perth (ABS, 2007) and the anticipated target market of potential buyers within the development.

The water balance has also been calculated assuming the new lots will be 520m^2, on average 520m^2 based on the provided DSP. These contemporary lots typically have smaller garden areas when compared to traditional lots (due to the large size of the houses) and therefore the lot water consumption rates (due to garden watering) are lower than those reported for traditional lots (WC, 2003).

The lot scale water consumption for the three water conservation strategies is presented in **Table 5.**

Table 5 Lot Water Consumption

Scheme Water	Option 1 (BAU)	Option 2 (WEA,WEG,GW)	Option 3 (WEA,WEG,TWT3000 GW)
Total Scheme Water Required (ML/year)	354.0	232.6	194.7
Scheme Water Required per Capita (kL/year/person)	141.5	92.9	77.8

The results of the water balance indicate that on average in the development, a dwelling not using any water conservation strategies will exceed the 100kL/year/person water consumption target.

The comparison of the consumption rates of water efficient appliances and standard appliances in **Table 4** indicates that use of water efficient appliances has the potential to significantly reduce the total water used in the household. This has been proven through the water balance analysis presented in **Table 5**; Option 2 has significantly reduced the water usage to 92.9kLyear/person. This option achieves the water consumption target of less than 100kL/year/person of scheme water. Therefore this option is an acceptable water conservation strategy.

The water consumption of the dwellings can be further reduced by using rainwater tanks. The water balance analysis calculates that by utilising the Option 3 water consumption strategy, the consumption rate will be 77.8kL/year/person (it is assumed that all lots have a 3000 litre rainwater tank). This strategy therefore also achieves the water consumption target.

The development has approximately 8.676ha of POS area. It has conservatively assumed that this would be 80% turfed and 20% native vegetation. Therefore this area would require approximately 55.1ML/year of water for irrigation. In Option 2 and 3 this water has been supplied with non-potable groundwater, which significantly reduces the total Scheme water required for the development (see **Table 6**).

There is approximately 0.65ha of commercial area within the development. This will require approximately 7.3ML of scheme water. There is the potential for commercial lots to reduce the water consumption requirements through water efficient practices and fit-for-purpose use.

The total scheme water required and wastewater produced in the development is presented in **Table 6**.

Table 6 Development Scheme Water Required and Waste Water Produced

	Option 1 (BAU)	Option 2 (WEA,WEG,GW)	Option 3 (WEA,WEG,TWT3000 GW)
Total Development Scheme Water Required (ML/year)	416.4	239.8	202.0
Total Development Waste Water Produced (ML/year)	146.1	68.0	68.0

6 Groundwater Management Strategy

6.1 Groundwater Level Management

The objectives for groundwater management outlined in **Section 4.3** are to maintain the groundwater level and quality in the post-development environment.

MGLs across the development site vary between 0mAHD, where groundwater is likely to intersect the Eastern and Western Wetlands, 0.6mAHD in the west and 0.73mAHD in the east. The majority of the site already has a clearance of greater than 1.2m, through from the natural topography to the MGL of greater than 1.2m. For lots proposed to be adjacent to the wetlands, sand fill will be required to achieve the 1.2m separation clearance required i.e. a minimum earthworks level of 1.9mAHD.

The lots adjacent to the wetland will also require sand fill to achieve a 0.5m vertical clearance to the 100 year ARI water level in the wetland/basin. Therefore the minimum earthworks levels will be dictated by the 100 year ARI water level and not the clearance to the MGL (see **Section 7.2** for 100 year water levels within the development basins). Due to this significant clearance to the groundwater and sandy soil, soakwells will be suitable on all lots.

Subsoil drainage is not recommended nor required within this development due to the significant clearance to groundwater.

6.2 Groundwater Quality Management

The groundwater monitoring investigation (Cardno, 2010) determined that the groundwater within the structure plan has elevated concentrations of nutrients. This is likely due to the historic and existing market garden practices, and due to elevated nutrient concentrations within the groundwater entering the site from upstream catchments.

The post-development will have reduced area available for vegetation than in the pre-development environment. There is therefore potential that if the vegetated areas are managed appropriately, less nutrients will be introduced into the groundwater and the quality will improve. The reduction of nutrient load to the groundwater should be achieved in the development by:

- Increasing the proportion of garden areas containing native vegetation compared to exotic plant species which require fertilisers.
- Minimising the use of fertilisers to establish and maintain vegetation within POS areas and road verges.
- Selection of drought tolerant turf species that require minimal water and nutrients.
- Use of roll-on turf within the POS areas and road verges, to prevent the high nutrient input requirement during establishment of the turf.
- Utilisation of amended soils with high PRI.
- Direct stormwater to vegetated (with native wetland species) treatment areas which will improve the quality of the water prior to it infiltrating into the underlying groundwater.
- Garden beds should not be located immediately adjacent to the infiltration or vegetated retention areas to reduce nutrient transportation into these areas.

Further detail on the measures and maintenance plan to be utilised within the development to reduce nutrient transport to the groundwater should be presented within the UWMP.

7 Stormwater Management Strategy

Surface water runoff will be managed both on a development scale and at a lot scale. The principles behind the stormwater management strategy are to maintain the existing hydrology by retaining or detaining surface flows and to infiltrate the stormwater runoff as close to source as possible. The development drainage system has been designed to achieve the objectives and criteria stated in **Section 4.4**.

The Packham North development area is, in respect to hydrology, a highly constrained site. In the existing environment, all surface runoff from the development area and upstream catchments discharge to one of the two wetlands. Since there is no discharge out of the DSP area, the size of the area required to store large rainfall events is considerably larger than would be required for a site that can discharge offsite.

To maximise the developable area, a detail water management strategy and proof of the strategy through a surface water model is required. The strategy that is presented in this document has been determined through consultation with the CoC and the representatives of the land owners. The modelling has confirmed that the strategy is compatible with the proposed DSP and the results presented in the tables in **Section 7.2** can be used to calculate the POS credits of the DSP.

The proposed strategy and modelled outputs are highly specific; this level of detail is required in order for the DSP, POS and drainage requirements to be achieved. Further detailed design of the development must follow the specific requirements detailed in this strategy. Future UWMP must demonstrate that the detailed design of the development achieves and follows the guidance provided in this document. Whilst it is anticipated that minor modification to the strategy will be required due to specific detail design constraints, the UWMP must demonstrate that any modifications to the strategy will not adversely impact on the overall local water management strategy.

Detail of the specific requirements of the strategy at a lot and development/catchment scale is provided in the following sections.

7.1 Lot Drainage Strategy

Rain that falls on the garden areas of the lots will infiltrate at source or, in large events, may overflow into the road drainage network. The strategy has assumed runoff from the roof will be directed to a rainwater tank and overflow to a soakwell. Lots with a soakwell (of $2.65m^3$ capacity) and a rainwater tank that is 50%[1] full at the time of the storm event would provide approximately 1,500L of retention storage. As well as reducing the scheme water requirements of the household, the rainwater tanks provide additional retention storage of roof runoff during intense short duration rainfall events. Any rainfall event which exceeds the capacity of the soakwells and/or rainwater tanks will overflow to the lot garden and potentially into the road drainage network. For the long duration (72hr) design storm events modelled, the soakwells alone have sufficient capacity to infiltrate all the roof runoff.

7.2 Development Drainage Strategy

The development scale drainage strategy has been developed through extensive consultation with CoC and the main land developers for the lots within the structure plan. The strategy requires that all runoff originating from within the proposed catchments is retained within the catchment boundary.

[1] Due to the continual use of the rainwater within the Laundry, Toilet and for hot water, the rainwater tank will unlikely be full prior to the significant rainfall event.

Runoff from the 1 year - 1 hour rainfall event may be retained and treated within bottomless drainage pits and vegetated basins prior to infiltrating into the underlying groundwater. The use of bottomless drainage pits is subject to CoC approval at the UWMP stage. The vegetated retention storage areas will be separated from the 5 and 100 year ARI retention basins to maximise useable POS and concentrate the treatment of the runoff. This will also reduce the area of maintenance associated with the removal of debris from runoff of frequent rainfall events.

The 100 year ARI event runoff can be retained within the catchments due to the high infiltration potential of the sandy soils and significant clearance to groundwater. For the catchments adjacent to the existing wetlands, the wetlands will be used to retain the 100 year ARI events as occurs under the existing environment.

The DSP area is located within a drainage catchment that is partially developed. Runoff from these developed areas currently discharge through the DSP area and into the Western and Eastern Wetlands. The design criteria and strategies for these external developed areas are different to that proposed for the DSP area and this DWMS/LWMS must work with these existing constraints. Therefore the DWMS/LWMS has proposed that these external flows from developed or undeveloped catchments can be conveyed through the DSP catchments until the runoff drains to the lowest point in the landscape. Maintaining these existing flow paths will help to maintain the existing environment of the wetlands.

7.2.1 Catchment Boundaries

The post-development catchment boundaries (**Figure 9**) for the structure plan area follows the existing landowner/developer lot boundaries. This strategy allows for each landowner/developer to develop the lots individually, potentially without affecting or being affected by the development on neighbouring developer lots.

It should be noted that at detailed subdivision design stage, it may be determined that the post-development hydrologic catchment boundaries cannot physically follow the landowner lot boundaries. In such circumstances, the developers will need to justify to the CoC how the catchment boundaries need to be modified.

7.2.2 Catchment 1

Catchment 1 is proposed to be a residential development with a Water Corporation oxygenation facility located within the south western POS. Due to the existing topography, the catchment is split into two drainage sub-catchments (1a and 1b). The large catchment consists of highly permeable sandy soils and has a minimum separation to MGL of approximately 4m.

For the existing environment, runoff produced during large rainfall events would discharge from Catchment 1, through Catchment 4 and into the Western Wetland. In the post-development environment, all runoff up to the 100 year ARI rainfall event will be retained within the two retention basin areas of Sub-catchment 1a and 1b. The treatment basin and first infiltration basin are assumed to infiltrate at a rate of 2.5×10^{-5}m/s, as is detailed in **Appendix C**.

The proposed basin configuration for Sub-catchments 1a and 1b proposed by the developer, currently do not achieve the basin configuration design criteria. However, the basin configuration will be modified at the detailed design stage to achieve the requirements of the design criteria (**Section 4.4.3**) and CoC.

The configuration of the basins are presented in **Figure 10** with the results of the surface water modelling presented in **Table 7** and **Table 8**.

Table 7 Surface Runoff from Catchment 1

Sub-catchment	1 year – 1 hour ARI (m^3)	5 Year ARI (m^3)	100 Year ARI (m^3)
1a	315	1,960	4,655
1b	180	1,290	2,985

Table 8 Basin Inundation Modelling Results for Catchment 1

Basin	Basin Base Area (m^2)	Basin Top Area (m^2)	Weir Height (m)	Max Basin Depth (m)	Flood Depth (m)			Inundated Area (m^2)		
					1y-1h	5y	100y	1y-1h	5y	100y
1a-1y1h	685	685	0.70	1.60	0.33	0.71	0.95	685	685	685
1a-5y	1,020	1,020	1.20	1.60	0	0.10	0.95	0	1,020	1,020
1a-100y	2,390	2,390	1.20	1.60	0	0	0	0	0	0
1b-1y1h	240	240	0.85	1.66	0.57*	0.86	1.34	240	240	240
1b-5y	380	380	0.85	1.66	0	0.77	1.34	0	380	380
1b-100y	885	885	0.81	0.81	0	0.02	0.44	0	255	885

Note: The above table presents the modelled results for each sub-catchment and basin during the modelled ARI rainfall events. For Sub-catchment 1a, the first vegetation retention basin is "1a-1y1h", the second infiltration basin is the "1a-5y" and the final infiltration basin is the "1a-100y".

*The UWMP will need to demonstrate reduction in flood depth to <0.5m through additional storage below ground.

The provided basin configuration for Catchment 1 demonstrates that runoff from the catchment can be managed and retained within the catchment. However, future detailed design of the basins must achieve the basin design criteria presented in **Section 4.4.3** and be presented within an UWMP.

7.2.3 Catchments 2 and 3 - Western Wetland

The area immediate south of Ocean Road currently has some market garden properties which are proposed to be developed into an urban catchment. This area receives runoff from upstream Catchment F2. This upstream catchment will not be developed.

The proposed structure plan for Catchment 2 and 3 includes pockets of POS which will have a dual use by providing stormwater retention. By utilising several locations for stormwater retention, the overall size of each basin can be reduced and this provides treatment/infiltration close to source. The basins within Catchment 2 and 3 are assumed to infiltrate at a rate of 2.5×10^{-5} m/s, as detailed in **Appendix C**.

7.2.3.1 Sub-catchment 2c

The most upstream basins are located within Sub-catchment 2c. This basin receives runoff from the urban Sub-catchment 2c and the undeveloped Sub-catchment F2a-1. The results of the modelling and the proposed basin sizes are presented in **Table 9** and *** The** [1] year - 1 hour rainfall that falls on this catchment is fully infiltrated.

Table 10.

Table 9 Surface Runoff from Sub-catchment 2c

Sub-catchment	1 year – 1 hour ARI (m^3)	5 Year ARI (m^3)	100 Year ARI (m^3)
Ct2c	40	250	565
CtF2a-1	0*	270	870
Total	40	520	1,435

* The 1 year - 1 hour rainfall that falls on this catchment is fully infiltrated.

Table 10 Basin Inundation Modelling Results for Sub-catchment 2c

Basin	Basin Base Area (m^2)	Basin Top Area (m^2)	Basin Depth (m)	Flood Depth (m)			Inundated Area (m^2)		
				1y-1h	5y	100y	1y-1h	5y	100y
2c-1y1h	30	130	0.50	0.39	0.52	0.54	100	130	130
2c-5y	35	245	0.80	0	0.78	0.83	0	235	245
2c-100y	10	205	1.00	0	0	1.02	0	0	205

The basin have been sized to retain all of the runoff from Sub-catchment 2c and a proportion of the runoff from the undeveloped Sub-catchment F2a-1. The design criteria in **Section 4.4**, states that runoff from the undeveloped upstream catchments can be allowed to flow through the development to the lowest point in the landscape (i.e. the Western Wetland). However, the drainage strategy for Sub-catchment 2c has retained some of the runoff from the upstream catchment instead of allowing this runoff to flow through the development. This strategy enables additional retention within Sub-catchment 2c, which has ample space for drainage infrastructure, so that less storage is required in the lower proportions of the catchment (i.e. Sub-catchment 2a) which has less available space for drainage infrastructure.

7.2.3.2 Sub-catchment 2b

The total volume of discharge (185m^3) from the Sub-catchment 2c basins to the downstream Sub-catchment 2b is provided within **Table 11**. This table also provides the total runoff from the contributing catchments within Sub-catchment 2b. The size of the basins proposed for Sub-catchment 2b is provided within **Table 12**.

Table 11 Surface Runoff from Sub-catchment 2b

Sub-catchment	1 year – 1 hour ARI (m^3)	5 Year ARI (m^3)	100 Year ARI (m^3)
Overflow from upstream Ct2c	0	0	185
Ct2b	90	650	1,540
CtF2a-2	0	30	95
CtF2a-4	0	50	150
Total	90	730	1,970

Table 12 Basin Inundation Modelling Results for Sub-catchment 2b

Basin	Basin Base Area (m^2)	Basin Top Area (m^2)	Basin Depth (m)	Flood Depth (m)			Inundated Area (m^2)		
				1y-1h	5y	100y	1y-1h	5y	100y
2b-1y1h	95	245	0.50	0.41	0.52	0.54	210	245	245
2b-5y/100y	20	270	1.00	0	0.68	1.03	0	160	270

7.2.3.3 Sub-catchment 2a

The POS area provided within Sub-catchment 2b is smaller than Sub-catchment 2c and thus it is proposed to discharge a higher volume (580m^3) from these basins to the downstream Sub-catchment 2a.

The final set of basins within the POS area adjacent to the Western Wetland, will receive runoff from all of the catchments including from Sub-catchment 3a and 3b. The results of this model and the proposed basin sizes are presented within **Table 13** and **Table 14**.

Table 13 Surface Runoff from Sub-catchment 2a

Sub-catchment	1 year – 1 hour ARI (m^3)	5 Year ARI (m^3)	100 Year ARI (m^3)
Overflow from upstream Ct2b	0	0	580
Ct2a	140	1,045	2,425
Ct3a	135	1,035	2,470
Ct2b	85	590	1,360
CtF2a-3	0	100	340
Total	360	2,770	7,175

Table 14 Basin Inundation Modelling Results for Sub-catchment 2a

Basin	Basin Base Area (m^2)	Basin Top Area (m^2)	Basin Depth (m)	Flood Depth (m)			Inundated Area (m^2)		
				1y-1h	5y	100y	1y-1h	5y	100y
2a-1y1h	515	820	0.50	0.40	0.55	0.60	755	820	820
2a-5y	195	675	1.00	0	1.00	1.06	0	675	675
2a-100y	515	1,205	1.00	0	0	1.04	0	0	1,205

For the proposed basin configuration, there will be 670m^3 discharged into the Western Wetland during the 100 year ARI event and no discharge during the 5 year or 1 year - 1 hour ARI events. A total of 1,455m^3 of runoff enters the development area from the upstream undeveloped Sub-catchment F2a. Therefore, the basins will discharge less volume of runoff into the Western Wetland than is allowed under the design criteria of **Section 4.4**.

The surface water strategy and the proposed basin configuration achieves the design criteria. Future UWMPs must demonstrate that the refined basin design achieves the proposed water management strategy and design criteria.

7.2.4 Catchment 4

The structure plan for Catchment 4 has not currently been designed. It is currently proposed in the DSP that there will be a central linear POS connecting the Western Wetland to the undeveloped Catchment F1.

The surface water modelling and strategy has assumed development layout that is similar to the other catchments i.e. assumed similar proportion of road, verge, lot size etc. Runoff from Catchment F1 has been assumed to be completely routed into the Western Wetland. However, the modelling for Catchment 4 will have to be revised at UWMP stage and will likely need to include runoff from Catchment F1, similar to strategy proposed for Catchment 2 and 3 (**Section 7.2.3**). The results of the model conducted for Catchment 4 is presented in **Table 15** and **Table 16** below.

Table 15 Surface Runoff from Catchment 4

Sub-catchment	1 year – 1 hour ARI (m^3)	5 Year ARI (m^3)	100 Year ARI (m^3)
Ct4	425	3,240	7,525

Table 16 Basin Inundation Modelling Results for Catchment 4

Basin	Basin Base Area (m^2)	Basin Top Area (m^2)	Basin Depth (m)	Flood Depth (m)			Inundated Area (m^2)		
				1y-1h	5y	100y	1y-1h	5y	100y
4-1y1h	525	835	0.50	0.44	0.55	0.59	790	835	835
4-5y	360	955	1.00	0	0.86	1.07	0	855	955
4-100y	1,020	1,930	1.00	0	0	0.66	0	0	1,590

The proposed basin configurations for the catchment will enable the water management strategy for this area to be achieved. Infiltration within these basins was assumed to occur at a rate of $2.5x10^{-5}$m/s, as is detailed in **Appendix C**. Future UWMPs must demonstrated that the refined basin design and structure plan achieves the proposed water management strategy and design criteria.

7.2.5 Catchments 5, 6, F1, F2 and F3 - Western Wetland

The catchment and water management strategy for the Western Wetland is similar to the strategy for the Eastern Wetland (**Section 7.2.6**). This wetland is located within Catchment 5. Catchment 5 has been used for rural purposes and still contains a historic building (**Section 3.8.2**). Runoff from this catchment will discharge to the Western Wetland, which is proposed to be surrounded by POS. The 1 year - 1 hour runoff will be retained within a vegetation area surrounding the wetland and larger flows will discharge to the centre of the wetland area (see **Figure 10** for the basin configuration).

The Western Wetland currently receives runoff from Catchment 6 and will continue to receive runoff in the post-development environment. The pipe network from Sub-catchment E1 conveys minor event runoff along Hamilton Road and into the Western Wetland.

During the 100 year ARI rainfall event, the pipe network of Catchment 6 will be at capacity and there will likely be considerable runoff flowing along the road surface. All surface runoff from Sub-catchment E1 and Sub-catchment E2 not conveyed by the pipe network (i.e. conveyed by the road surface) will pass through the intersection of Hamilton Road and Mell Road and continue northwards down Hamilton Road.

Hamilton Road has a dual cross-fall and thus it is anticipated that this surface runoff will be conveyed approximately evenly by both sides of the road. The runoff on the western side of Hamilton Road will flow down to the intersection within Ocean Road and ultimately into the Western Wetland. The runoff along the eastern side of Hamilton road will flow into the development surrounding the Eastern Wetland via one of several roads leading off Hamilton Road. These flow paths should be further refined at UWMP stage. Both the Eastern and Western Wetland areas must retain runoff from Catchment 6 as a requirement of this DWMS/LWMS. The volume of runoff that must be retained is presented in **Table 17**.

Runoff from the undeveloped Catchments F1 and F2 currently follows the natural topography into the Western Wetland. In the post-development environment, this runoff would first flow through Catchment 2 and 3 (for F2) and Catchment 4 (for F1). It is assumed that Catchments 4 and 5 will allow upstream flows to flow through to the Western Wetland (see **Section 4.4** of design criteria). However, as was discussed in **Section 7.2.3.3**, Catchment 2 and 3 will discharge less than the volume allowed in the design criteria.

Runoff from Catchment F3 flows into the developed Sub-catchment E2. During minor events this pipe network and the runoff from F3 is discharged into the Eastern Wetland. However, during the 100 year ARI event, a proportion of the runoff from F3 would be conveyed via overland flow down Hamilton Road and into the Western Wetland, as detailed above.

The total runoff volumes from the catchments of the Western Wetland are presented in **Table 17**. These volumes must be provided for above the maximum groundwater levels (**Figure 8**) within the wetland. The basin configuration proposed by the developer is presented in **Figure 10** and the results of the surface water modelling for these basins is presented **Table 18**.

Table 17 Surface Runoff from Catchments 5, 6, F1, F2 and F3

Sub-catchment	1 year – 1 hour ARI (m^3)	5 Year ARI (m^3)	100 Year ARI (m^3)
F1	0	1,915	6,200
F2b	50	160	595
Overflow from upstream 2a	0	0	670
E1	600	4,655	
E2	0	0	5,485
F3	0	0	
5	400	3,000	7,050
Total	1,050	9,730	20,000

Table 18 Basin Inundation Modelling Results for Catchments 5, 6, F1, F2 and F3

Basin	Basin Base Area (m^2)	Basin Top Area (m^2)	Weir Height (m)	Max Basin Depth (m)	Flood Depth (m)			Inundated Area (m^2)		
					1y-1h	5y	100y	1y-1h	5y	100y
5-1y1h	5,970	6,585	0.30	1.30	0.07	0.36	0.56	5,970	6,585	6,585
5-5y	330	6,700	1.00	2.00	0	0.82	1.26	0	6,700	6,700
5-100y	6,175	6,175	0.40	1.30	0	0	0.56	0	0	6,175

The configuration of the basins provided by the developer have invert levels of 1.2mAHD, 0.5mAHD and 1.2mAHD for the 5-1y1h, 5-5y and 5-100y basins, respectively. These invert levels have been used to calculate the depth of water in each basin under the design rainfall events.

The results in **Table 18** show that the 1 year - 1 hour basins are flooding during all storm events, the 5yr basin is inundated during the 5yr and 100yr ARI rainfall event and the 100yr basin is inundated during the 100yr ARI rainfall event (see **Figure 10**). The inundation mapping for this wetland is presented in **Figure 11** to **Figure 13**.

The peak water level during the 100yr ARI rainfall event is 1.76mAHD. This is 1.35m below the level of the lowest house adjacent to the wetland and therefore there is sufficient freeboard to achieve the 0.5m vertical clearance design criteria in **Section 4.4**.

The proposed basin configurations for the combined drainage catchments will enable the water management strategy for this catchment to be achieved. Future UWMPs must demonstrate that the refined basin design achieves the proposed water management strategy and design criteria.

7.2.6 Catchments 6, 9a, 11, 12a, 12b, 13 and F3 - Eastern Wetland

Catchments 11, 12a, 12b and 13 consist of rural residential market garden lots. Due to the topography, the site likely has sandy peaty soils with low permeability and does not have significant depth to groundwater. It is anticipated that these areas will be remediated and sand fill will be required for portions of the area and this will enable the use of lot scale infiltration through soakwells.

The surface runoff from the lots in the existing environment discharge to the depression area, which is denoted as being part of the Eastern Wetland, and is proposed to be the central POS area. This area has an elevation of below 2mAHD. Near to the Eastern Wetland depression area, the soils are likely to be a mixture of low permeability sandy and peaty soils. There is not a significant depth to groundwater in this region. Lots near to this area will require sand fill of high PRI to enable lot scale infiltration via soakwells.

In the existing environment, this section of the Eastern Wetland receives surface runoff from external upstream catchments. Catchment 6 is an existing residential area and is not within this structure plan area; however, it does discharge surface runoff into the Eastern Wetland.

The road network of Sub-catchment E2 discharges to a sump located within Lot 1 Hamilton Road. This discharge location will need to be relocated but it will still ultimately be required that the runoff from Sub-catchment E2 discharges to the Eastern Wetland area. During large rainfall events, the road pavement of E1 and E2 will convey runoff via overland flow to both the Western and Eastern Wetlands as described in **Section 7.2.5**. The volume of runoff that must be retained within the Eastern Wetland is presented in **Table 19**.

Catchment F3 is zoned under the MRS as Parks and Recreation, and consequentially has no proposed development. However, this area still produces surface runoff during large rainfall events. Surface runoff from this catchment is directed by the natural topography into Sub-catchment E2 and largely discharges into the Eastern Wetland (via the pipe network). The runoff from this catchment which must be retained within the Eastern Wetland is also presented in **Table 19**.

Table 19 Surface Runoff from Catchments 6, 9a, 11, 12a, 12b, 13 and F3

Sub-catchment	1 year – 1 hour ARI (m^3)	5 Year ARI (m^3)	100 Year ARI (m^3)
E1	0	0	8,545
E2	265	2,065	
F3	0	995	
9a	0	5	160
11	275	1,850	4,270
12a	100	720	1,675
12b	190	1,400	3,155
13	175	1,285	2,950
Eastern Wetland	35	385	1,085
Total	1,040	8,705	21,840

Table 19 shows that during the 5 year ARI rainfall event, approximately 3,060m^3 of runoff from Sub-catchment E2 and the undeveloped Catchment F3 combined will be discharged via the pipe network to the Eastern Wetland. During the 100 year ARI rainfall event, an additional 5,485m^3 of surface runoff from Sub-catchment E1, Sub-catchment E2 and Catchment F3 will discharge into the Eastern Wetland via road surface[2] with 3,060m^3 still discharging via the pipe network, making a combined volume of 8,545m^3.

In order to achieve the proposed water management strategy for the runoff volumes presented in **Table 19**, it is proposed that the area will require two vegetated basins for the 1 year - 1 hour ARI rainfall event, three basins for the 5 year ARI event and two basins for the 100 year ARI rainfall event. Two vegetated basins will likely be required at either end of the POS area to ensure adequate grade for the pipe drainage network. These treatment basins are assumed to infiltrate at a rate of 2.5×10^{-5}m/s, as is detailed in **Appendix C**. The proposed configuration of these basins is provided within **Figure 10** and the results of the surface water modelling for these basins is presented in **Table 20**.

[2] See **Section 7.2.5** for the proportion of runoff from these same catchments which discharge to the Western Wetland.

Table 20 Basin Inundation Modelling Results for Catchments 6, 9a, 11, 12, 13 and F3

Basin	Basin Base Area (m^2)	Basin Top Area (m^2)	Culvert Invert (m)	Weir Height (m)	Flood Depth (m)			Inundated Area (m^2)		
					1y-1h	5y	100y	1y-1h	5y	100y
E-1y1h-a	1,245	1,425	0.20	0.40	0.36	0.46	0.55	1,425	1,425	1,425
E-5y-a	410	1,655	1.70	1.90	0.41	1.91	2.03	635	1,655	1,655
E-100y-a	5,630	8,880	1.40	1.60	0	0.36	1.50	0	6,295	8,880
E-5y-b	90	885	1.70	1.90	0	0	1.77	0	0	885
E-1y1h-b	200	275	0.20	0.40	0.24	0.30	0.35	275	275	275
E-5y-c	160	735	1.20	1.40	0.04	0.83	1.29	175	515	735
E-100y-b	1,715	3,675	1.40	1.60	0	0	0.27	0	0	1,995

Basins E-1y1h-a, E-5y-a, E-100y-a and E-5y-b are proposed to be connected by culverts (modelled generically as 450mm diameter culverts) and weirs. Similarly, basins E-1y1h-b, E-5y-c and E100y-b are proposed to be connected by culverts and weirs. Due to the presence of these weirs, runoff from the 1 year - 1 hour ARI event flows into the adjoining 5 year basin. Future UWMPs must demonstrated that the refined basin designs achieve the proposed water management strategy and design criteria.

7.2.7 Catchment 7 and 8

The structure plan proposes that Catchment 8 will comprise commercial land, which is consistent with the current land use of this catchment. Runoff from the lots and a section of Rockingham Road within Catchment 7 discharge to an existing sump located on Catchment 8. This sump also receives runoff from the commercial impervious areas located on Lot 6 (see **Figure 7**).

A surface water model was used to calculate the total runoff from Catchment 7 and 8. The results of this modelling are presented in **Table 21**.

Table 21 Surface Runoff from Catchment 7 and 8

Catchment	1 Year - 1 Hour ARI (m^3)	5 Year ARI (m^3)	100 Year ARI (m^3)
Catchment 7	80	565	1300
Catchment 8	570	3830	7440
Total	650	4395	8740

Catchment 8 is located in an area with highly permeable sandy soils and clearance to maximum groundwater levels of approximately 12m. These characteristics permit management of surface runoff via onsite infiltration. It is therefore proposed to modify the existing sump to increase its capacity and utilise in the post-development environment. In addition, it is proposed to utilise soakwells to retain and infiltrate any runoff greater than the capacity of the sump.

The hydraulic model of the catchments has calculated that the runoff can be retained via the use of 55 soakwells (with a capacity of 2.65m^3 each) and the full area of Lot 50 (where the sump is currently). This sump requires side slopes of 1:3, total depth of 3m and will need to be fenced.

The sump will receive surface runoff from a commercial area and may therefore have a higher proportion of gross pollutants than from a residential area. It is proposed that the runoff from this catchment should first be treated by a Gross Pollutant trap prior to discharging to the sump.

Alternatives to the current sump configuration will be investigated as part of the future development and/or subdivision of the adjacent lot (Lot 14). Any modifications and demonstration of compliance with the design criteria should be presented within an UWMP.

7.2.8 Catchment 9b

This catchment is located immediately south of Catchment 8 and has similar soil and groundwater characteristics (see **Figure 9**). It is proposed that this catchment will be a high density residential area, consisting of various levels of nursing care. The residential area will be positioned around a centrally located POS area.

The existing undeveloped Catchment 9b has highly permeable soils, clearance to maximum groundwater levels of approximately 9m and due to the relatively flat topography, a large proportion of the rainfall is retained within the pre-development environment catchment.

The water management strategy for Catchment 9b proposes that all runoff from the development discharges to a vegetated retention basin. Larger runoff events will also discharge to this basin and then overflow into an adjacent infiltration basin. The proposed configuration of these two basins is presented in **Figure 10**. The results of the surface water modelling for these basins is presented in **Table 22** and **Table 23**, and inundation mapping presented in **Figure 11** to **Figure 13**.

Table 22 Surface Runoff from Catchment 9b

Catchment	1 year – 1 hour ARI (m^3)	5 Year ARI (m^3)	100 Year ARI (m^3)
9b	215	1,625	3,660

Table 23 Basin Inundation Modelling Results for Catchment 9b

Basin	Basin Base Area (m^2)	Basin Top Area (m^2)	Weir Height (m)	Basin Depth (m)	Flood Depth (m)			Inundated Area (m^2)		
					1y-1h	5y	100y	1y-1h	5y	100y
9b-1y1h	185	660	0.5	1.00	0.45	0.51	0.92	365	390	610
9b-5y	135	560	1.0	1.00	0	0.51	0.92	0	315	515

Note: The above table presents the modelled results for each basin during the modelled ARI rainfall events. The first vegetation retention basin is the "9-1y1h" and the second infiltration basin is the "9-5y".

The above vegetated retention basin has been proposed to have a maximum depth of 1.0m; however during the 1 year - 1 hour rainfall event it will have an inundation depth of less than the required 0.5m.

The vegetation basin is connected via a weir to an infiltration basin. During larger rainfall events, once the vegetation basin reaches capacity, it will discharge via a weir into the adjacent infiltration basin. These basins can fill together to a total depth of 1m (see **Figure 10** for potential basin configuration).

The provided basin configuration for Catchment 9b will enable the water management strategy for this catchment to be achieved. Future UWMP must demonstrated that the refined basin design achieves the proposed water management strategy for this catchment and achieves the POS requirements.

7.2.9 Catchment 10 - Eastern Wetland

The lots within Catchment 10 have previously been used for commercial activities. The landuse of the area is proposed to be modified to contain a mixture of residential and commercial areas. The catchment is proposed to have one POS area near the commercial area and one large central POS area. The central POS area is to be located where there are currently settling ponds for the activities associated with the previous land use (Watsonia Meat Works). The catchment is split into two sub-catchments; Sub-catchment 10a includes Lot 132 and Sub-catchment 10b includes Lots 3 and 4.

Near to the Eastern Wetland, as described in **Section 7.2.6**, the soils are likely to be a mixture of low permeability sandy and peaty soils. There is not a significant depth to groundwater in this region. Lots near to this area will require sand fill of high PRI to enable lot scale infiltration via soakwells.

For the remaining area of the catchment, there are sandy soils of high permeability and significant depth to groundwater. These characteristics enable lot scale infiltration through soakwells. Runoff from the catchment would ultimately be directed to and retained within the Eastern Wetland area and slowly infiltrate into the shallow groundwater.

The maximum depth of water that can be retained within the vegetated basin and wetland area has been increased to 2m for this catchment because the proposed area is a natural depression and would be inundated to large depths in the existing environment. This will also minimise the drainage area that would otherwise be required if the depth was designed to have a maximum depth of 1m for large event retention.

The proposed basin configuration for Sub-catchment 10a and 10b proposed by the developer, currently does not meet the basin configuration design criteria. However, the basin configuration will be modified at detail design stage to achieve the requirements of the design criteria (**Section 4.4.3**) and CoC.

The 1 year – 1 hour ARI rainfall event is proposed by the developer to be retained within two basins (it will be required at the detailed design stage that these are vegetated treatment basins). During larger ARI rainfall events, the 1 year – 1 hour basins discharge into three larger 5 year ARI basins, which can then discharge to a single 100 year ARI basin. It has conservatively been assumed in the surface water modelling that there is negligible infiltration within any of the basins of this catchment due to the soil and minimal depth to groundwater (see **Appendix C**). The proposed configuration of these basins is provided within **Figure 10** with the results of the surface water modelling for these basins presented in **Table 24** and **Table 25**.

Table 24 Surface Runoff from Catchment 10

Sub-catchment	1 year – 1 hour ARI (m^3)	5 Year ARI (m^3)	100 Year ARI (m^3)
10a	545	3,790	3,790
10b	90	610	0
Wetland Area	30	300	0
Total	665	4,700	3,790

The presented runoff for Sub-catchment 10a and 10b in **Table 24** is the runoff from the proposed developed area of the catchment. The runoff volume presented from the “Wetland Area” is the runoff that is a result of the rainfall that falls within the central POS area. This runoff volume has been separated from the sub-catchment runoff values since it will not need to be directly managed by the development stormwater drainage network however will contribute to the total volume of water that will be required to be stored.

Table 25 Basin Inundation Modelling Results for Catchment 10

Basin	Basin Base Area (m^2)	Basin Top Area (m^2)	Weir Height (m)	Basin Depth (m)	Flood Depth (m)			Inundated Area (m^2)		
					1y-1h	5y	100y	1y-1h	5y	100y
10-1y1h-a	970	970	0.90	2.00	0.57*	0.93	1.16	970	970	970
10-1y1h-b	295	295	0.90	2.00	0.50	0.93	1.16	295	295	295
10-5y-a	310	310	0.40	1.10	0	0.13	0.33	0	310	310
10-5y-b	2,115	2,420	1.50	2.20	0	0.13	1.32	0	2,115	2,420
10-5y-b	2,280	2,975	1.10	2.20	0	1.20	1.32	0	2,975	2,975
10-100y	1,600	1,600	1.30	2.00	0	0	0.83	0	0	1,600

Note: The above table presents the modelled results for each sub-catchment and basin during the modelled ARI rainfall events. The vegetation basins are "10-1y1h-a" and "10-1y1h-b". The set of basins to retain the 5yr ARI event are the "10-5y-a", "10-5y-b" and "10-5y-c". The final basin to retain the 100yr ARI event is the "10-100y".

* The UWMP will need to demonstrate reduction in flood depth to <0.5m through additional drainage storage below ground.

For the proposed basin configuration, the top water level during the 100 year ARI event is 2.3mAHD. Lots adjacent to this wetland will require a minimum floor elevation of 2.8mAHD to satisfy the design criteria presented in **Section 4.4**.

The provided basin configuration for Catchment 10 will enable the surface water runoff to be retained within Catchment 10. The basin configuration will need to be modified at detail design stage to achieve all design requirements of **Section 4.4** and CoC, and be presented in an UWMP.

7.3 Quality Strategy

The purpose of this section is to describe the management methods that are proposed to manage the surface water quality. The principle methodology is to retain minor events as close to source as practical and treat the runoff prior to infiltrating into the groundwater.

7.3.1 Development Strategy

The runoff from the 1 year - 1 hour rainfall event will be retained within vegetated treatment basins. The vegetation and soil profile will remove a proportion of the nutrients prior to the surface water infiltrating into the underlying groundwater. This will aide in improving the quality of the groundwater underlying the development site.

The vegetation species to be used within the basin should typically be endemic, have the ability to uptake large quantities of nutrients and withstand periods of inundation and dry conditions. A list of potential species is presented within the *overarching landscape concept plan*.

The vegetated basins are proposed to be located within POS areas and associated with the infiltration basins for larger rainfall events. The vegetated area should aim to achieve the design criteria of 2% of the connected impervious area being vegetated.

These vegetated basins will receive nutrients, sediments and gross pollutants within the surface runoff. Therefore these areas will require continual maintenance. A management and maintenance strategy for the development in regard to POS and drainage infrastructure should be presented in the UWMP.

7.3.2 Lot Strategy

For frequent minor rainfall events, rainfall will infiltrate within the lot. This will reduce the amount of runoff conveyed through the development which potentially may have high nutrient concentrations or contain sediment and gross pollutants. Rainfall will be encourage to infiltrate within the site via soakwells connected to the roof and levelled lots reducing the ability for water to flow off the lot. Due to the existing sandy soils, it is anticipated that the lots will have the ability to infiltrate a large proportion of rainfall.

During large ARI and intense rainfall events, a proportion of the rainfall will flow off the lot. This surface runoff will be conveyed via the pipe network to the vegetated basins for treatment.

The use of fertilizers within the lots can increase the load of nutrients that are transported to the underlying groundwater. Whilst the practices used by individual lot owners cannot be controlled, developers can provide guidance to lot owners (at point of sale) on landscaping packages and fertilizer practices that when utilised will reduce the risk of nutrients being transported to the underlying groundwater.

8 Monitoring

Post-development groundwater monitoring should begin at the completion of the construction of POS areas. Groundwater bores should be located as close as possible to pre-development monitoring locations, which are shown in **Figure 8**. This allows for comparison with pre-development monitoring results as well as an upstream / downstream analysis for the whole Packham North area. Post-development monitoring should continue until handover to the CoC and should not be less than three years after construction is complete. Groundwater levels should be monitored monthly, whereas groundwater quality should be monitored on a quarterly basis.

Surface water monitoring should only be conducted for areas where there will be standing water for a large proportion of the year (e.g. the Western and Eastern Wetlands). Post-development monitoring should continue on a quarterly basis until handover to the CoC and should not be less than three years after construction of POS areas is complete. Pre-development monitoring of surface water quality should be conducted so that there is baseline data to compare the post-development surface water quality to. As was stated in **Section 3.3.2**, a DSI will be required as part of the UWMP approvals process and will include an assessment of the pre-development surface water quality within the Eastern Wetland.

Future UWMP should outline in more detail the exact location, timing and method for conducting the post-development monitoring.

The groundwater and surface water monitoring programme should measure the same in situ parameters and nutrient species as was completed in the pre-development monitoring and as presented below:

In situ field chemical parameters:

- pH.
- Temperature.
- Salinity.
- Dissolved Oxygen (DO).
- Electrical Conductivity (EC).
- Oxidation-Reduction Potential (Redox).

Laboratory analytes

- Total Nitrogen (TN).
- Total Phosphorous (TP).
- Ortho-Phosphorous (ORP).
- Oxides of Nitrogen (NO_x).
- Total Kjeldahl Nitrogen (TKN).
- Ammonium (NH_4).

Results from the post-development monitoring programme should be compared to baseline data or trigger values to provide an assessment of the development. Post-development groundwater level and quality results may be compared to pre-development baseline data (**Appendix E**). It is likely that post-development surface water quality results will be compared to pre-development results given within future DSI. However, in the absence of baseline data, post-development surface water quality should be compared to the guidance provided in *National Water Quality Management Strategy* (2000), which maybe more stringent than if baseline data was provided. A summary of the trigger values for lowland rivers in South Western Australia are provided in **Table 26**.

Table 26 Surface Water Quality Trigger Values

Analyte	Temp (°C)	Salinity (mS/cm)	DO (%)	pH	Redox	TN (µg/L)	TP (µg/L)	Ortho-P (µg/L)	NH_4 (µg/L)	NO_X (µg/L)	TKN (µg/L)
Trigger Value	-	0.12-0.3	80-120	6.5-8.0	-	1,200	65	40	80	150	-

In the event that post-development groundwater or surface water quality results consistently exceed baseline values (or trigger values, if no baseline data is available), contingency actions may be employed. These are likely to include:

- Resample quality to confirm results.
- If results still exceeding values, identify source if possible.
- If source can be identified, remove source if possible (e.g. fertiliser input, existing contamination etc).
- If source cannot be identified, consult with CoC as to appropriate actions.

It is anticipated that the appropriate actions will be determined and undertaken in conjunction with the CoC. For example, in relation to high nutrient levels, action may be implemented to remove sediments within basins or undertake additional street sweeping.

9 Future Management and Maintenance

The design and construction of drainage features and POS areas will be undertaken in a manner that promotes the long-term health of the water bodies and groundwater underlying the region. Additionally, these areas will require ongoing management, particularly in the first years after construction, to ensure that the areas continue to provide the intended functions and maintain high standards of amenity. **Table 27** provides a general outline of the future roles to construct, manage and maintain drainage and POS areas.

Table 27 Future Construction, Management and Maintenance Responsibilities

Action	Proposed Timing	Responsibility
Design and construction of drainage structures	As per developer construction schedule	Developer
Design, construction and landscaping of POS areas	As per developer construction schedule	Developer
Post-development groundwater and surface water (if present) monitoring	Until handover of POS area to CoC	Developer
	After handover of POS area to CoC	CoC
POS condition monitoring	Until handover of POS area to CoC	Developer
	After handover of POS area to CoC	CoC
Maintenance of drainage structures and POS areas for nutrients, water quality, gross pollutants, sediments and vegetation	Until handover of POS area to CoC	Developer
	After handover of POS area to CoC	CoC

10 Next Stage – Urban Water Management Plan

The requirement to undertake preparation of more detailed water management plans to support subdivision is generally imposed as a condition of subdivision. The development of the UWMP should follow the guidance provided in *Urban Water Management Plans: Guidelines for Preparing Plans and for Complying with Subdivision Conditions* (DoW, 2008). While strategies have been provided within this DWMS/LWMS that address planning for water management within the study area, it is a logical progression that future subdivision designs and supportive UWMP will clarify details not provided within the DWMS/LWMS. The main areas that will require further clarification in future UWMPs include:

- Completion of Geotechnical Investigation.
- Modelling of local road drainage networks and roadside swales to demonstrate compliance with water quantity management criteria and calculations supporting sizing of the water quality improvement infrastructure.
- Completion of contaminated site investigations.
- Flood storage requirements, basin configurations and ultimate discharge structure characteristics.
- Details of, and proposed implementation of, water conservation strategies.
- Non-structural water quality improvement measures to be implemented.
- Proposed management measures for drainage infrastructure that discharge to vegetated infiltration PFSA.
- Ongoing monitoring requirements.
- Construction period management strategy.
- Confirmation of groundwater extraction licences.

10.1 Geotechnical Investigation

The geotechnical investigation should be completed prior to finalisation of the UWMP. The geotechnical investigation will confirm the infiltration rates assumed within infiltration basins. Other investigations such as ASS and contamination investigations should also be completed. However, these are unlikely to directly affect the stormwater management strategy.

10.2 Modelling of Local Road Drainage Network

The surface water modelling documented in this DWMS/LWMS has been extensive and adequate for this level in the planning and design process. The detail designs produced at subdivision stage will need to follow the strategy produced in this document. It should be acknowledged that some degree of refinement will be required. Future UWMP documents will need to outline these refinements and demonstrate that the revised and detailed strategy achieves the requirements detailed in this DWMS/LWMS.

10.3 Completion of Contaminated Site Investigations

Several of the lots with the DSP area have had historical uses such as market gardens, farming and industrial purposes. Therefore these areas will require PSIs and/or DSIs. These reports will determine the most appropriate remediation. Depending on the remediation, this could have impacts on the landscaping or detailed design of POS and basins. Therefore, future UWMP should state if or how the potential remediation affects the water management strategy for the subdivision.

10.4 Basin Storage Configurations and Outlet Structures

While the drainage catchments have been defined based on the existing topography and the proposed structure plans, it is possible that these could undergo some change to accommodate stakeholder feedback prior to final subdivision design.

In order to review the final catchment and basin configurations, the hydrological model that has been developed to support this DWMS/LWMS may need to be refined in light of stakeholder feedback. It is expected that the basins will be designed to a level that provides detailed cross-sections, sizes of storage areas, pipe sizes, inverts, etc. The ultimate aim of revising the hydrological model will be to confirm that the post-development drainage infrastructure achieves the performance requirements detailed within this DWMS/LWMS.

10.5 Implementation of Water Conservation Strategies

A number of potential measures to conserve water have been presented within this DWMS/LWMS. These water conservation management strategies should be incorporated into the design and the ongoing maintenance of all POS areas. Landscape design measures that will be incorporated into the water conservation strategy should be further detailed within the future UWMPs produced for the development.

The manner in which the developer intends to promote water conservation measures discussed in this DWMS/LWMS to future lot owners should be discussed within future UWMP.

10.6 Non-structural Water Quality Improvement Measures

Guidance for the development and implementation of non-structural water quality improvement measures is provided within the *Stormwater Management Manual for Western Australia* (DoW 2007). Some measures will be more appropriately implemented at a local government level, such as street sweeping, however many can be implemented relatively easily within the design and maintenance of subdivisions and the POS areas. It is expected that the future UWMP will provide reference to measures such as public education (through measures such as signage that may be implemented to raise awareness).

10.7 Management and Maintenance Requirements

Section 9 details the future management and maintenance requirements for drainage and POS areas within the development at a high level. The future UWMP will provide detailed management and maintenance plans that will set out maintenance actions (e.g. gross pollutant removal), timing (i.e. how often it will occur), locations (i.e. exactly where it will occur) and responsibilities (i.e. who will be responsible for carrying out the actions). Consultation with the CoC should be undertaken and referral to guiding policies and documents should be made.

10.8 Monitoring

The proposed post-development monitoring is presented in **Section 8**. Further detail on the monitoring programme and contingency measures should be provided within the UWMP.

10.9 Construction Period Management Strategy

It is anticipated that the construction stage may require some management of various aspects (e.g. dust, surface runoff, noise, traffic etc.). In particular, dust generation has the potential to cause significant public disturbance during construction works. Given the sandy nature of the soils underlying the study area, it is anticipated that minimal dust suppression will be required during the subdivision stage. Should the generation of dust occur, then appropriate management measures will be implemented, such as:

- Not undertaking earthworks during dry, windy conditions where practical.
- Watering down cleared areas will occur as necessary during dry dusty periods.
- Covering materials during construction to reduce dust emissions where practical.
- Undertaking revegetation as soon as practically possible to ensure that soils are protected from wind erosion.

10.10 Groundwater Licences

As previously discussed in **Section 5.2.4** the extraction allocation for the development should be secured and reported on in the UWMP.

11 Implementation

The development of this DWMS/LWMS has been undertaken with the intention of providing a structure within which subsequent development can occur. It is also intended to provide overall guidance to the general stormwater management principles for the area and to guide the development of future UWMP.

11.1 Roles and Responsibilities

This DWMS/LWMS provides a framework that the proponent can utilise to assist in establishing stormwater management methods that have been based on a number of site specific investigations, are consistent with relevant State and Local Government policies and have been endorsed by CoC. It is noted that a number of developments within the Packham North DWMS/LWMS have not been subject to detailed investigations given that the areas are not anticipated to be developed within the short to medium term. The responsibility for working within the framework established within the DWMS/LWMS rests with the subdivision developers, although it is anticipated that future UWMP documents will be developed in consultation with CoC and DoW and in consideration of other relevant policies and documents.

11.2 Technical Review

The stormwater management strategies presented in this DWMS/LWMS have been recommended based on experience with similar developments and research into BMPs. The water management strategies presented in this DWMS/LWMS and future UWMP, will be reviewed by the DoW and CoC. This will ensure that the proposed strategies consistent with design guidelines approved by each authority.

11.3 Funding and Ongoing Maintenance Responsibilities

The development land owners will be responsible for all costs for the creation of the development including monitoring, surveys, investigations and construction of the water management infrastructure. The maintenance of the infrastructure will initially be the responsibility of the developer, until which time the CoC is satisfied that the infrastructure is performing suitably and the responsibility will be transferred to CoC. The timing for the transfer must be negotiated between the CoC and the developer.

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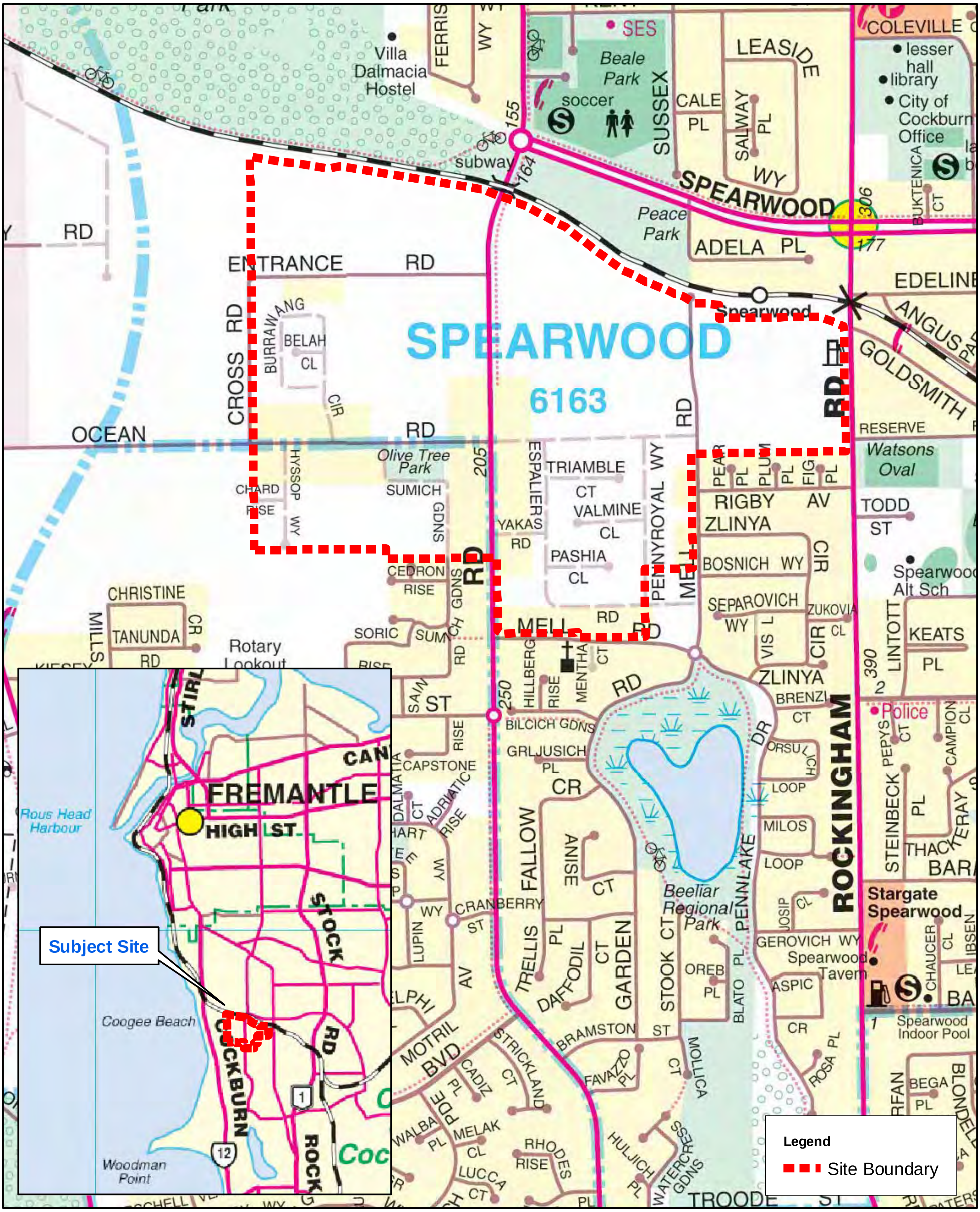
Figures



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PROJECT: Packham North DWMS/LWMS

DRAWING TITLE: FIGURE 1 : Locality Plan

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Drawing Number: SK01
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Local Authority: City of Cockburn
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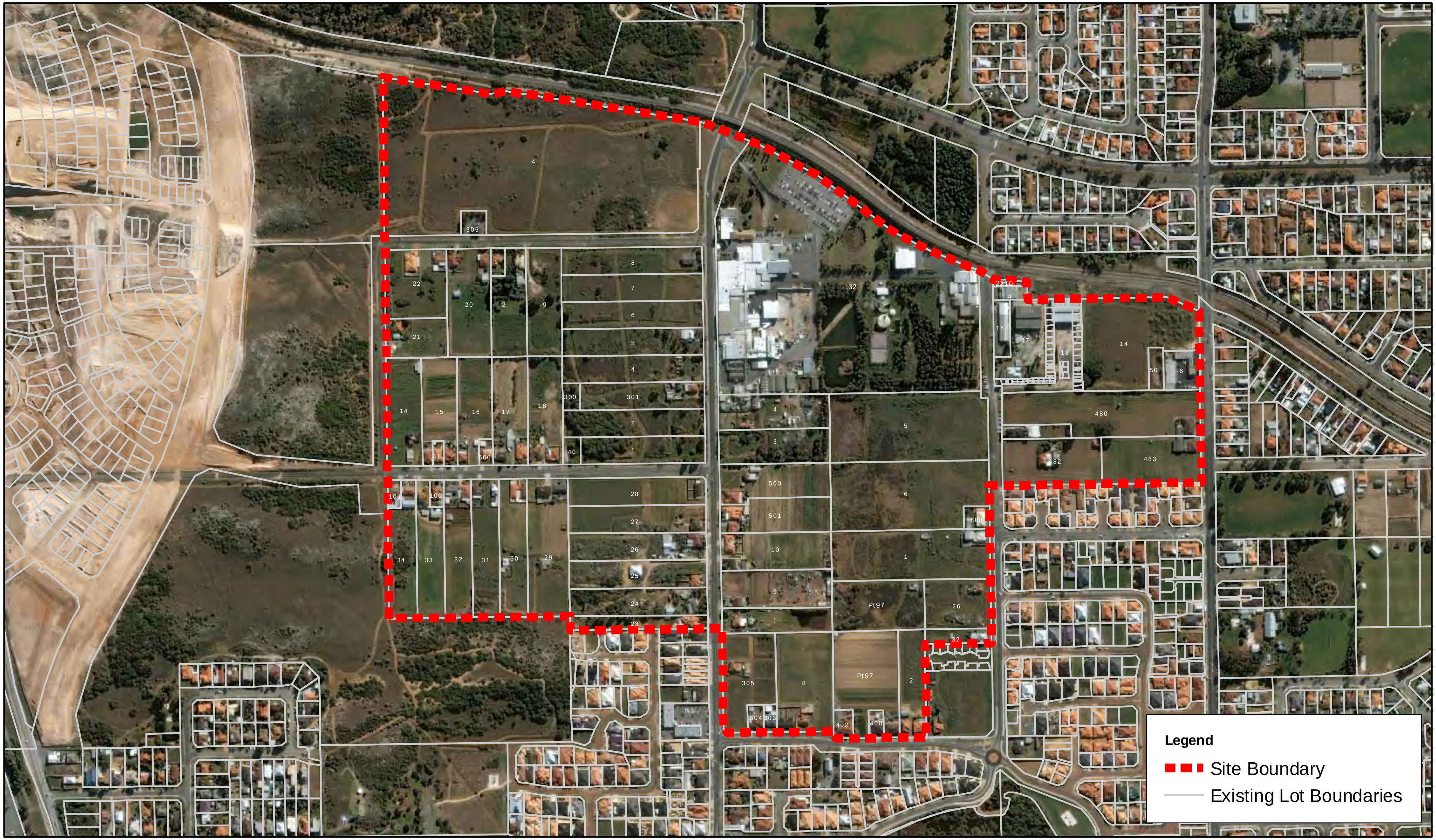
Date 28/02/11



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DRAWING TITLE **FIGURE 2 : Development Boundary**

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0 100 200 400 600 800 Metres

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PROJECT **Packham North DWMS/LWMS**

DRAWING TITLE **FIGURE 3 : Structure Plan**

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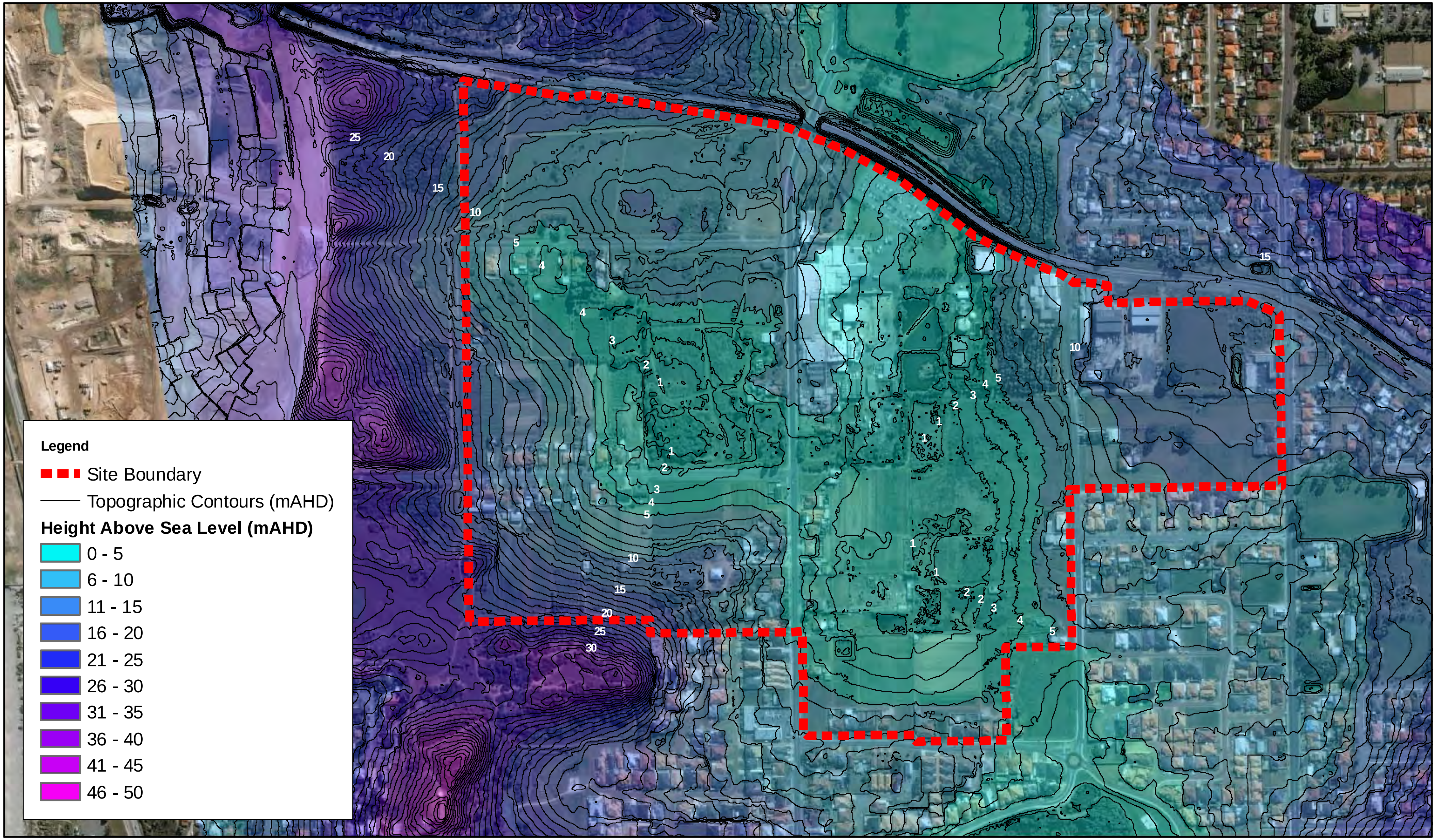

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DRAWING TITLE **FIGURE 4 : Topography**

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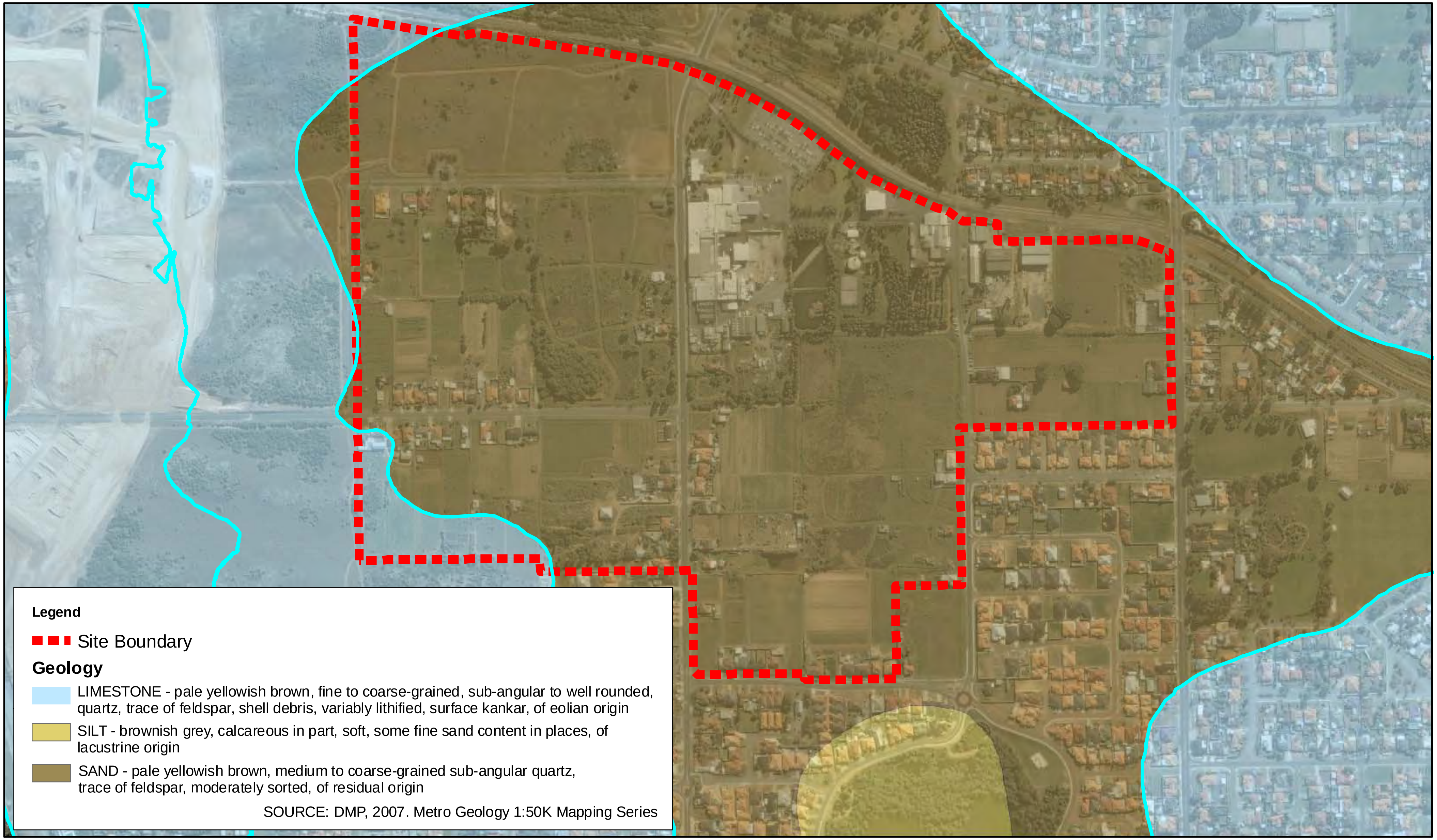

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DRAWING TITLE **FIGURE 5 : Soil Types**

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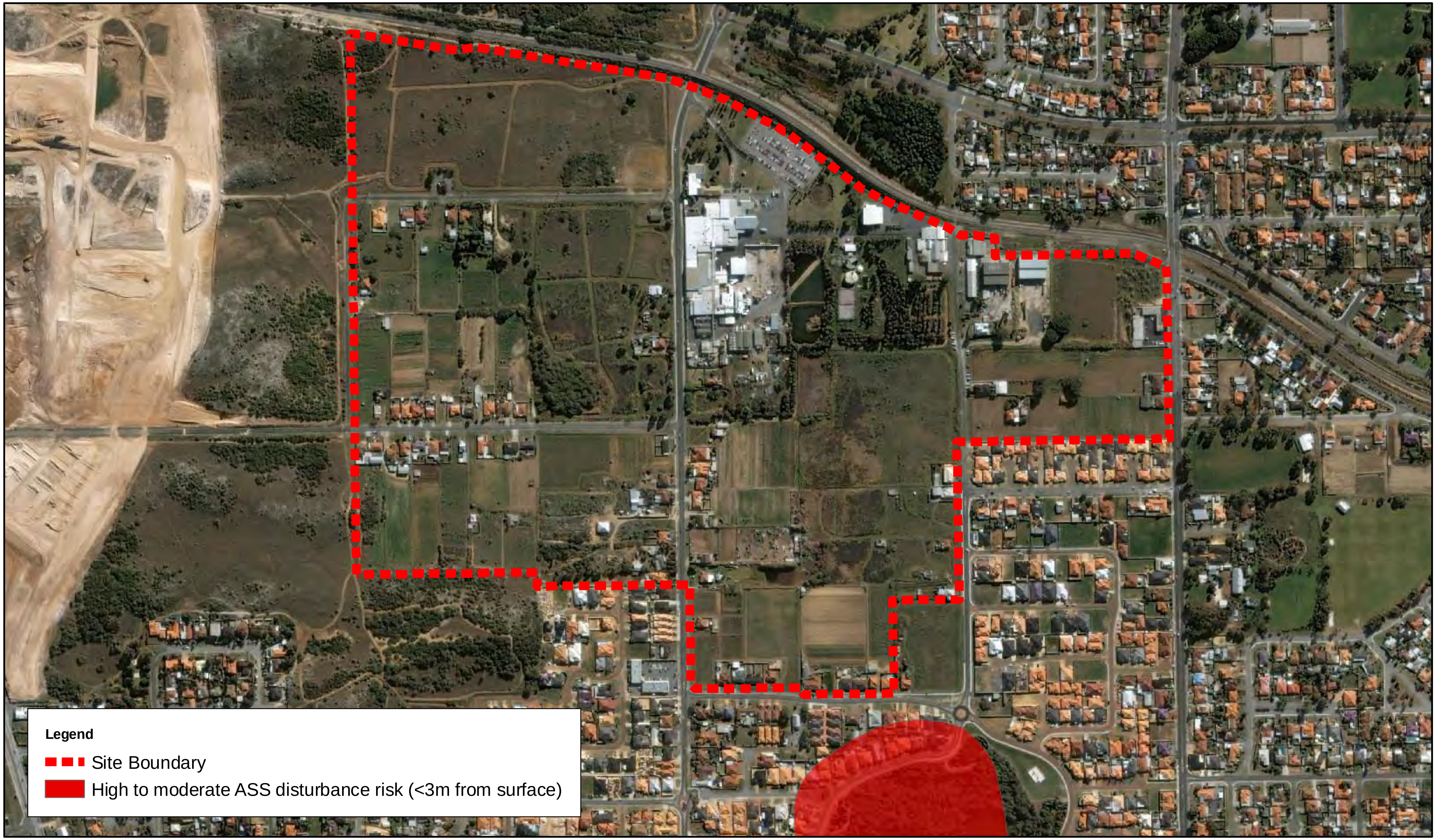

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DRAWING TITLE **FIGURE 6 : Acid Sulfate Soild**

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DRAWING TITLE FIGURE 7 : Pre-development Subcatchments

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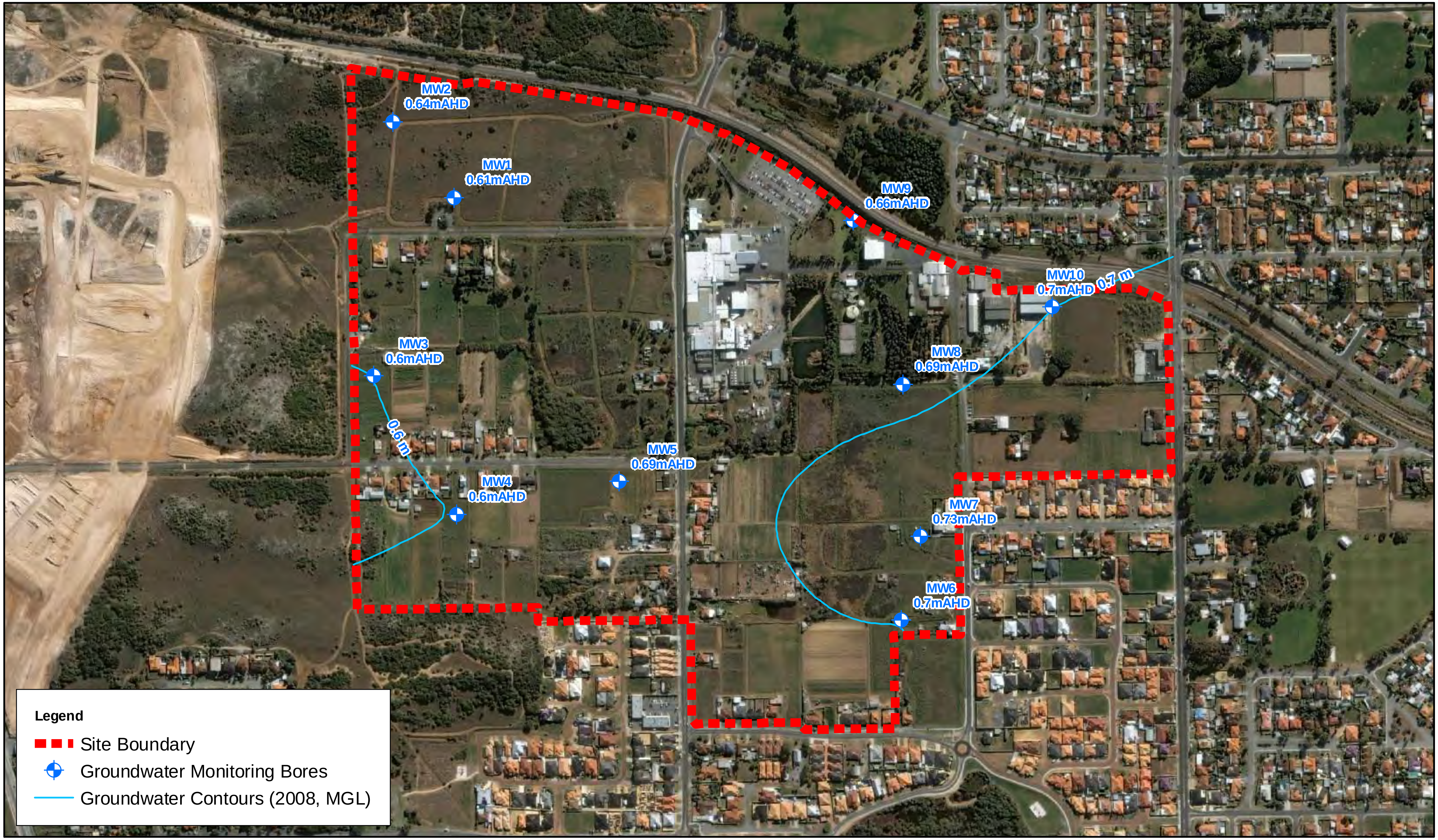

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DRAWING TITLE **FIGURE 8 : Maximum Recorded Groundwater Levels**

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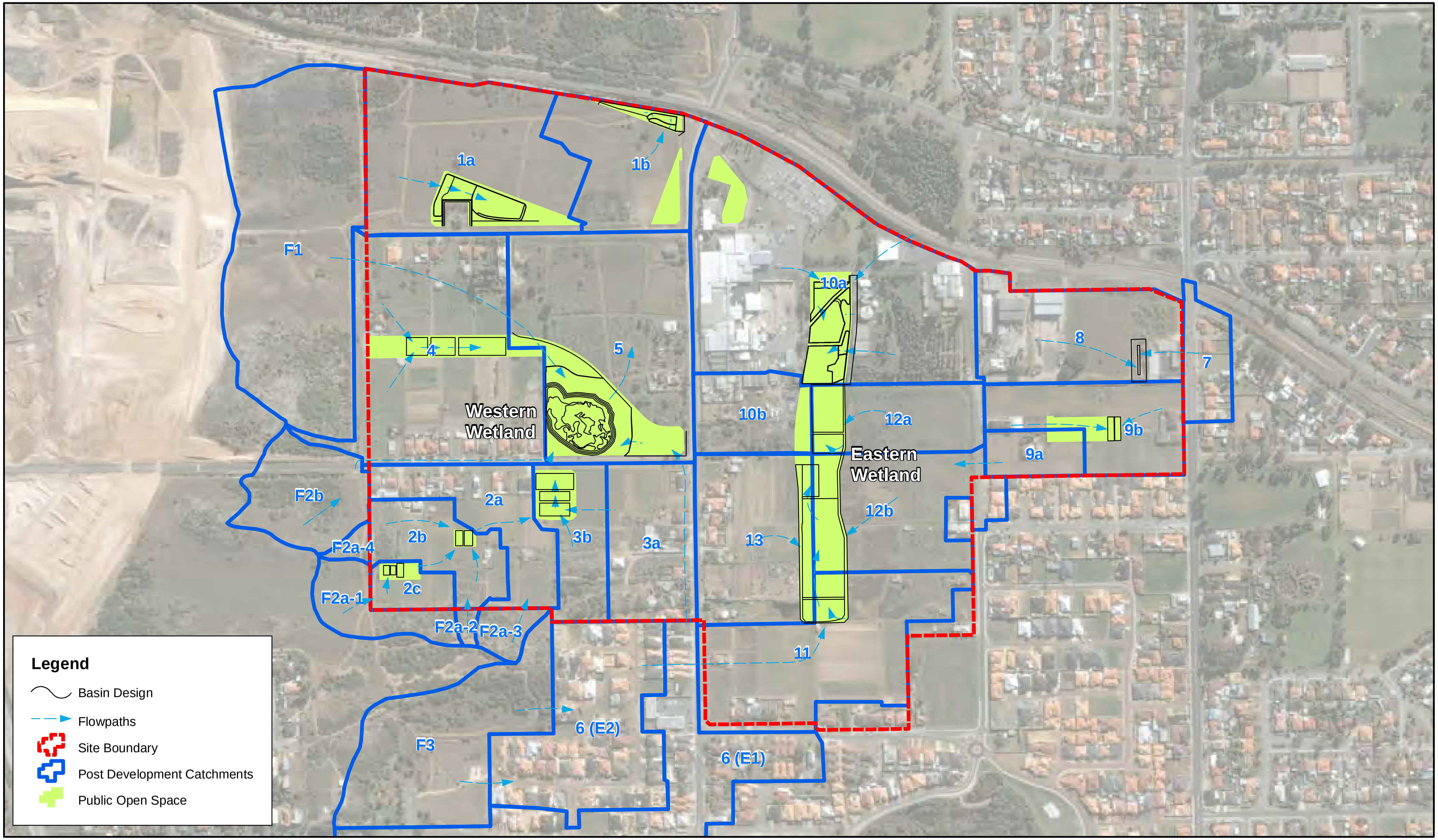

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PROJECT **Packham North DWMS/LWMS**

DRAWING TITLE **FIGURE 9 : Post-development Catchments and Flow Paths**

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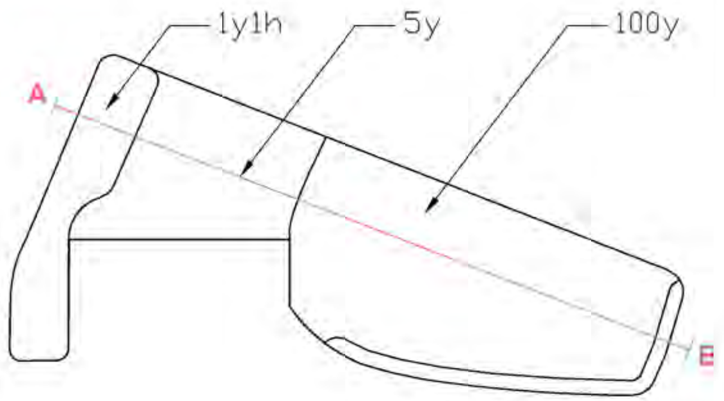
Subcatchment 1a – Plan View



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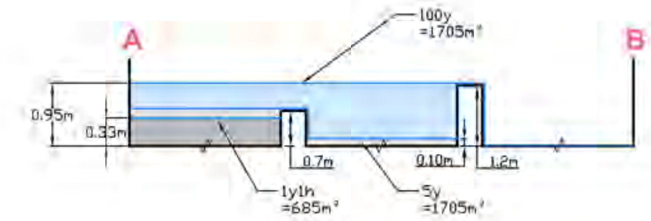
Subcatchment 1a – Section View



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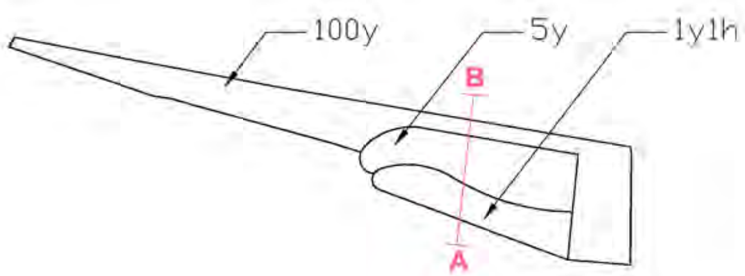

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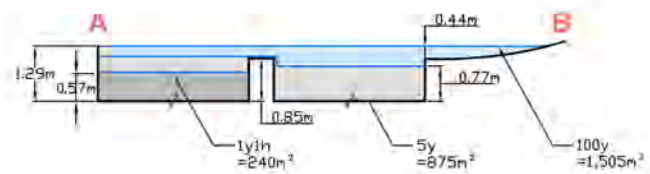

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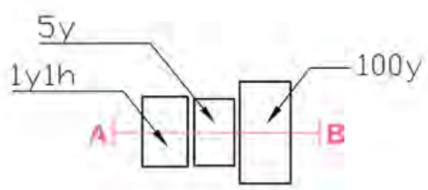
Subcatchment 2a – Plan View



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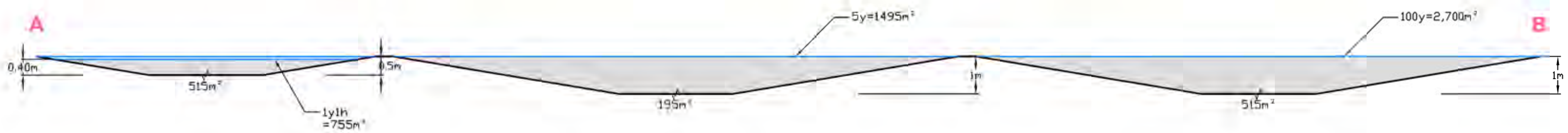

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DRAWING TITLE FIGURE 10a – Basin Configuration (1 of 5)

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Project – Phase – Plan Number V9100-001-SK15A			Revision

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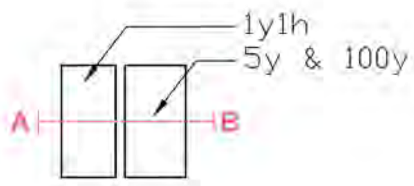
Subcatchment 2b – Plan View



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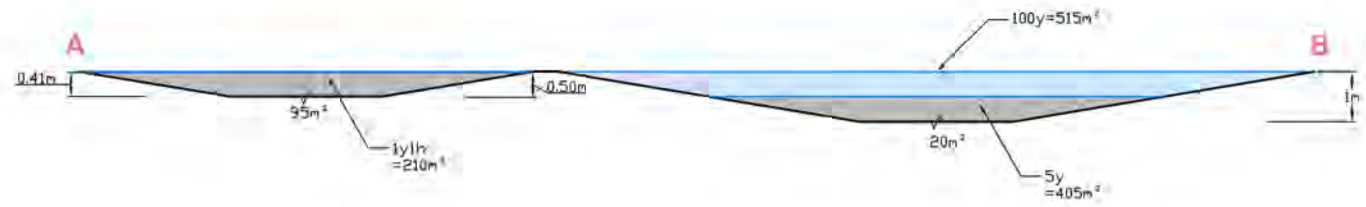

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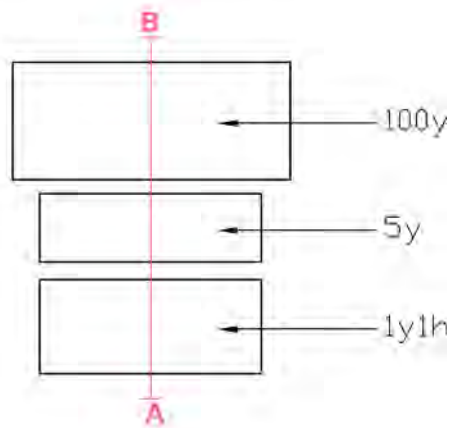
Subcatchment 2c – Plan View



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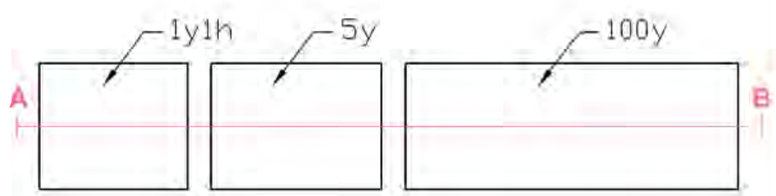
Subcatchment 2c – Section View

Scale 1:150

Subcatchment 4 – Plan View



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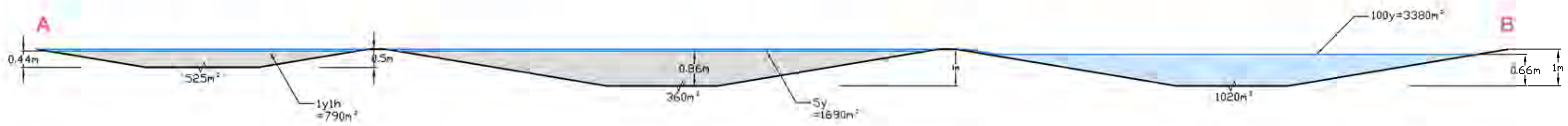
Subcatchment 4 – Section View



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DATE	No.	ACTIVITY – REVISION DESCRIPTION	DES	DRN	CHK'D	APP'D

PROJECT Packham North DWMS/LWMS

DRAWING TITLE FIGURE 10b – Basin Configuration (2 of 5)

PRINCIPAL City of Cockburn

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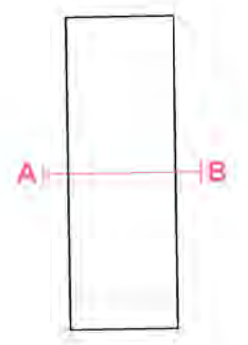
Project – Phase – Plan Number V9100–001–SK15B			Revision A

ORIGINAL A3

Subcatchment 7 & 8 – Plan View



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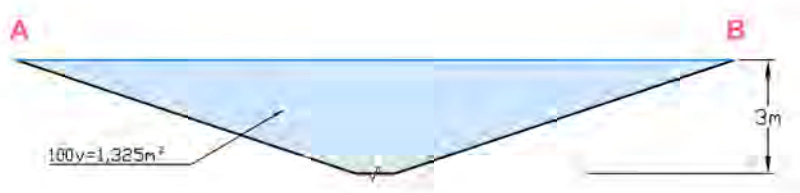
Subcatchment 7 & 8 – Section View



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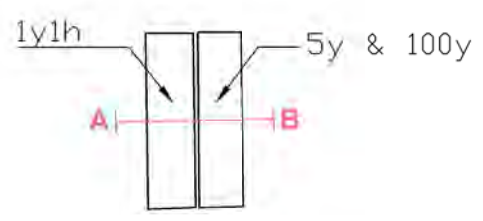
Subcatchment 9b – Plan View



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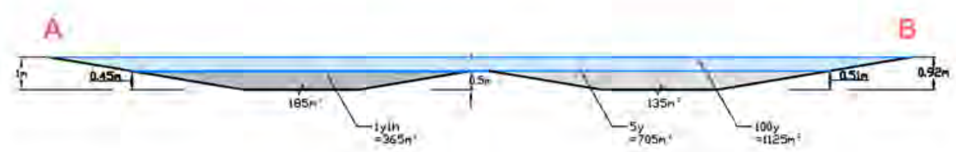
Subcatchment 9b – Section View



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DATE	No.	ACTIVITY – REVISION DESCRIPTION	DES	DRN	CHK'D	APP'D

PROJECT Packham North DWMS/LWMS

DRAWING TITLE FIGURE 10c – Basin Configuration (3 of 5)

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Local Authority City of Cockburn	Sheet 1 Of 1
Project – Phase – Plan Number V9100 – 001 – SK15c	Revision A
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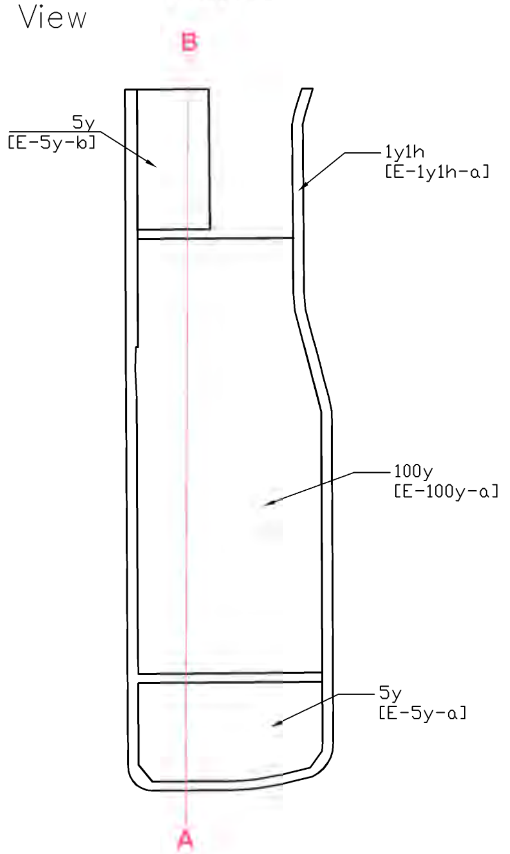
Easern Wetland
(Catchment 6,9a,11,12b,13,F3)
Plan View



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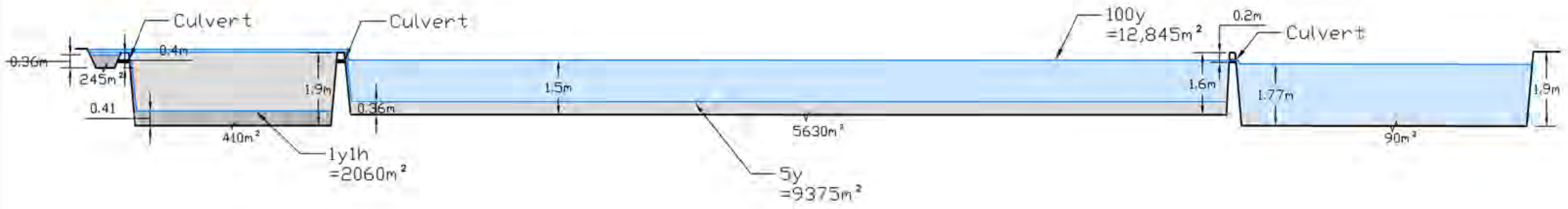
Eastern Wetland (Catchment 6,9a,11,12b,13,F3) – Section View



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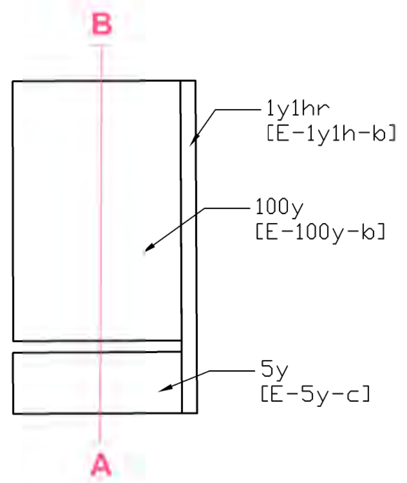
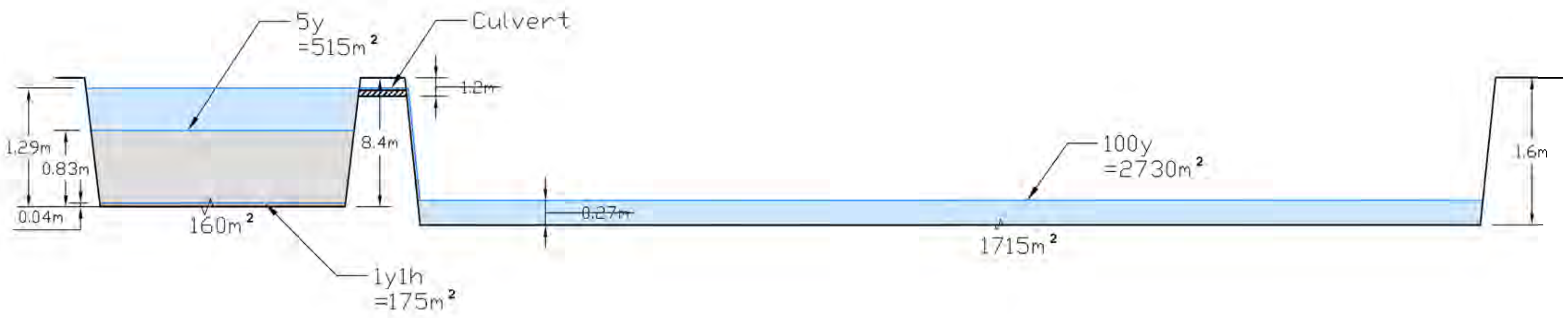
Eastern Wetland
(Catchment 12a) – Plan View



Scale 1:2000

Eastern Wetland (Catchment 12a) – Section View



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DATE	No.	ACTIVITY – REVISION DESCRIPTION	DES	DRN	CHK'D	APP'D

PROJECT Packham North DWMS/LWMS

DRAWING TITLE FIGURE 10d – Basin Configuration (4 of 5)

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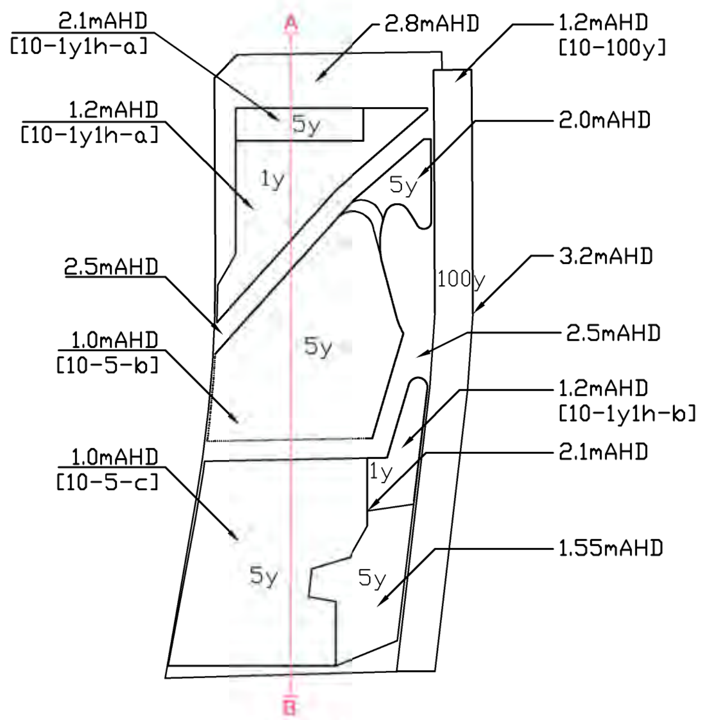
		ORIGINAL	A3

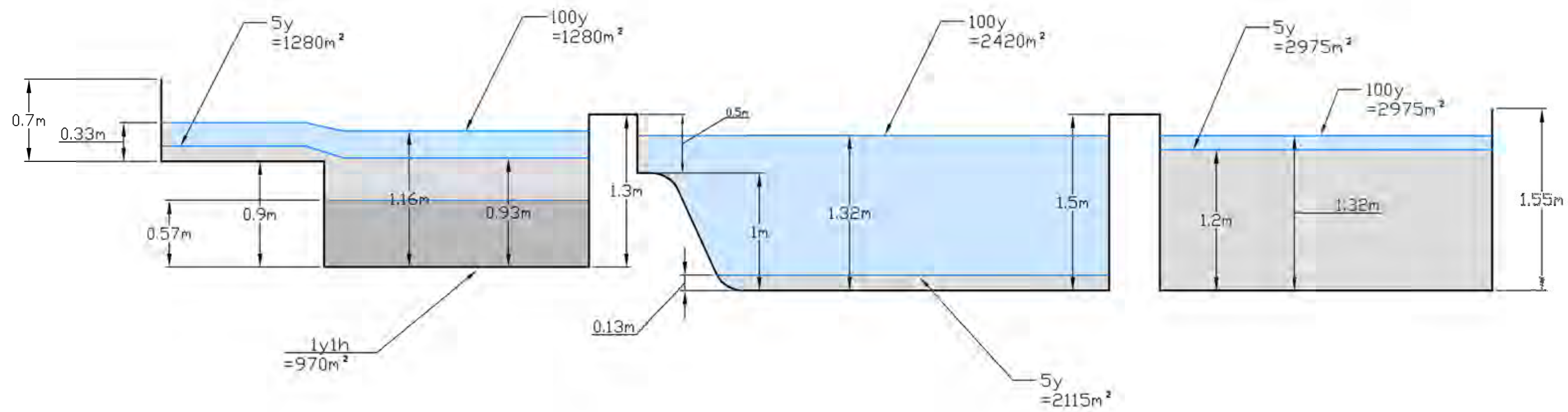
Eastern Wetland (Catchment 10) – Plan View



See Figure 11-13 for Inundation Sequence

Scale 1:200

Eastern Wetland (Catchment 10) – Section View



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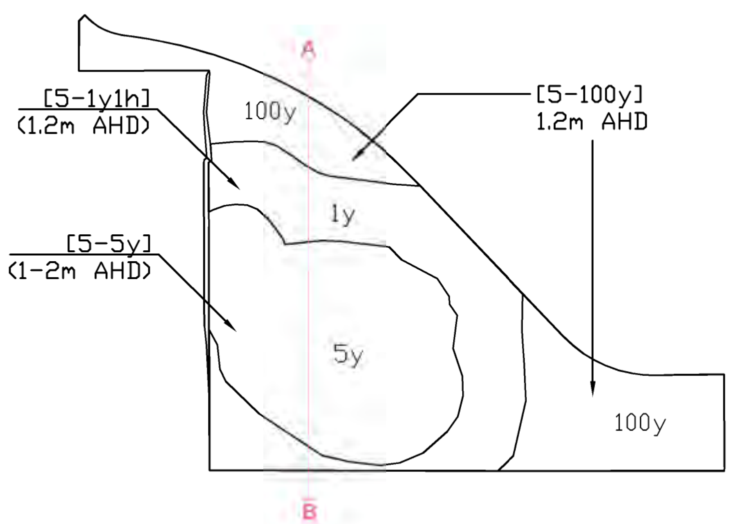
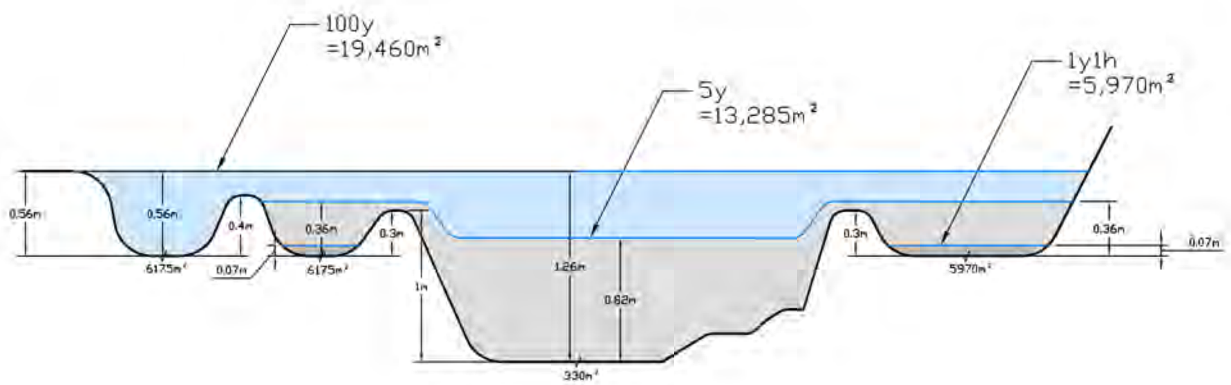
Western Wetland (Catchment 5,6,F1,F3) – Plan View



See Figure 11-13 for Inundation Sequence

Scale 1:300

Western Wetland (Catchment 5,6,F1,F3) – Section View



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DATE	No.	ACTIVITY – REVISION DESCRIPTION	DES	DRN	CHK'D	APP'D

PROJECT: Packham North DWMS/LWMS

DRAWING TITLE: FIGURE 10e – Basin Configuration (5 of 5)

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V9100 – 001 – SK15E			A
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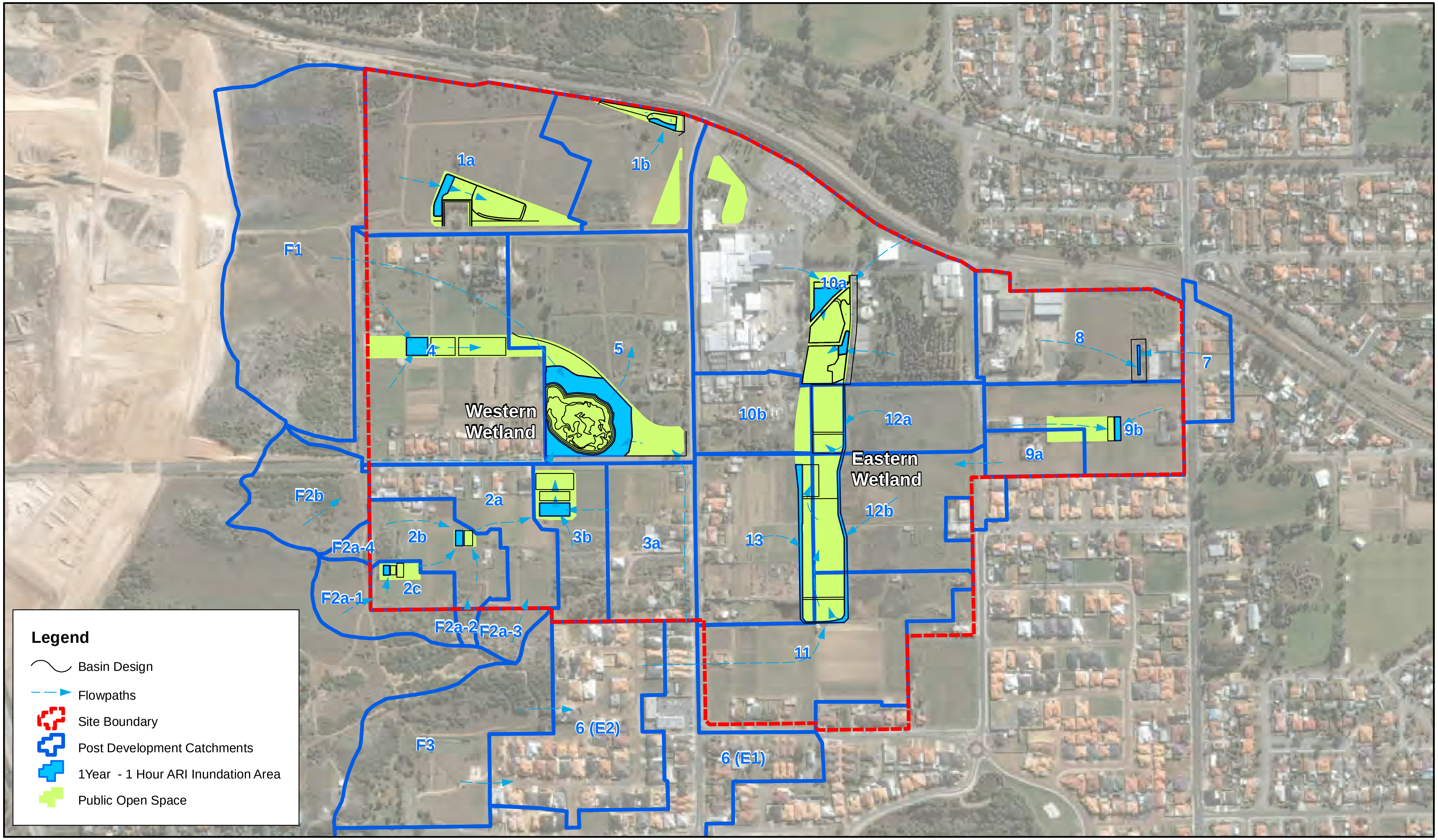

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PROJECT **Packham North DWMS/LWMS**

DRAWING TITLE **FIGURE 11 : 1 Year - 1 Hour ARI Inundation Area**

PRINCIPAL **City of Cockburn**

Scale: **1:7,500** 0 100 200 400 600 800 Metres

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V9100	SK11	01	A4

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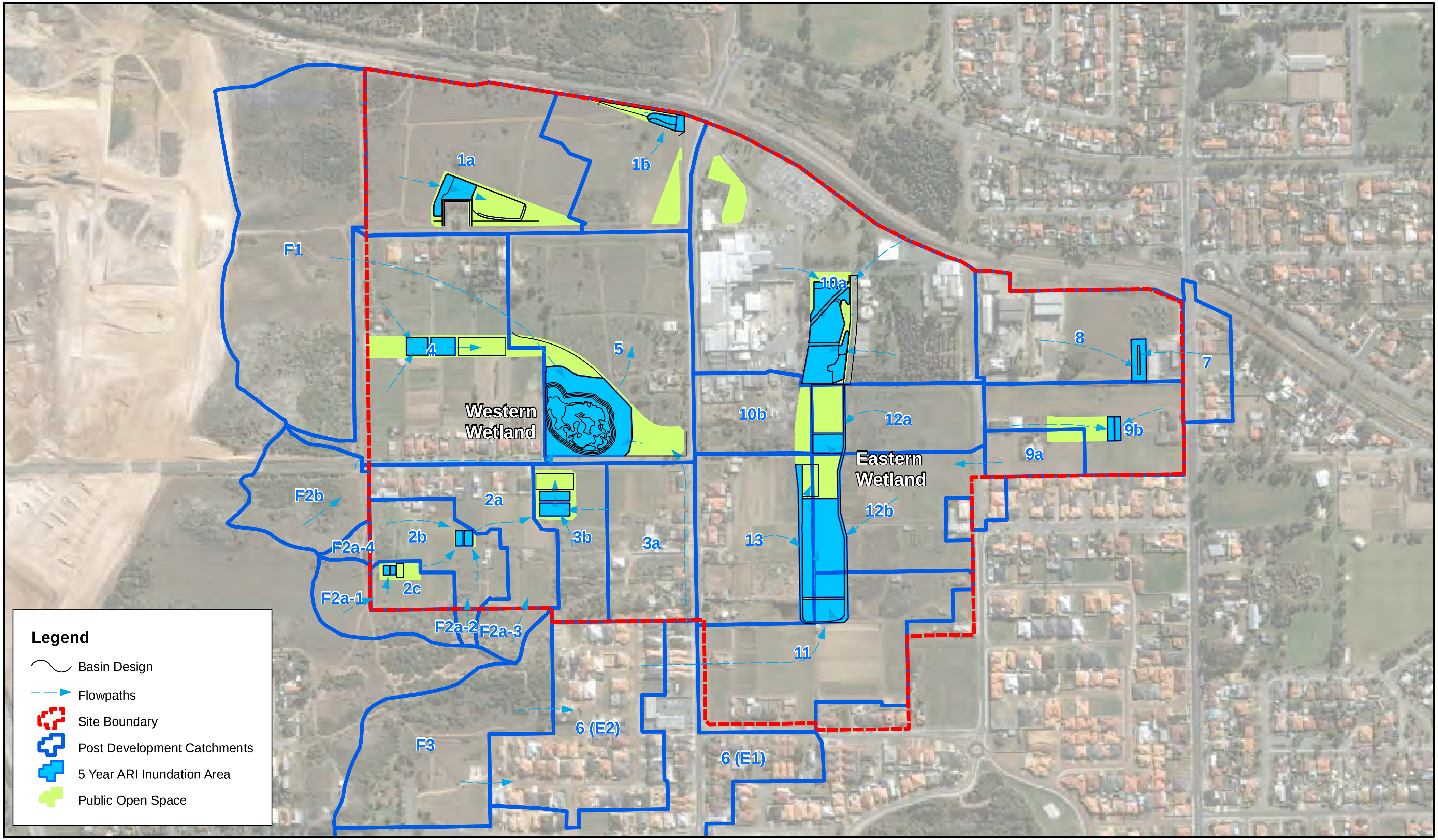
Date 20/12/11
Local Authority City of Cockburn
Sheet 1 of 1



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PROJECT **Packham North DWMS/LWMS**

DRAWING TITLE **FIGURE 12 : 5 Year ARI Inundation Area**

PRINCIPAL **City of Cockburn**

Scale: **1:7,500** 0 100 200 400 600 800 Metres

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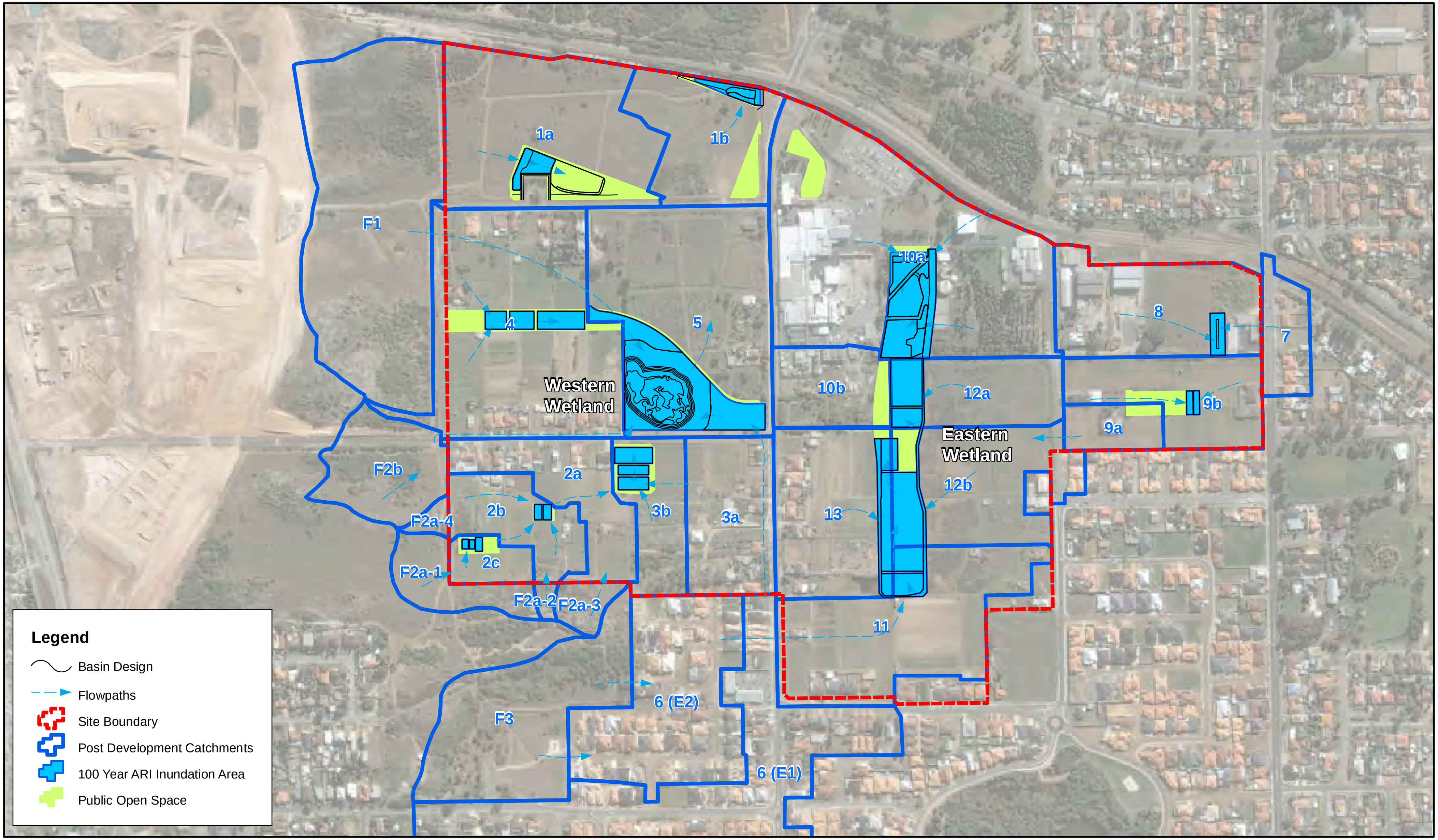
Local Authority City of Cockburn			Sheet 1 of 1



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PROJECT **Packham North DWMS/LWMS**

DRAWING TITLE **FIGURE 13 : 100 Year ARI Inundation Area**

PRINCIPAL **City of Cockburn**

Scale: 1:7,500 — 0, 100, 200, 400, 600, 800 Metres

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Project Number	Drawing Number	Revision	Original
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Designed ASC		Checked	Date 20/12/11
Drawn MGW		Approved	
Local Authority City of Cockburn			Sheet 1 of 1

Appendix A

District Structure Plan

NOTES:

PUBLIC OPEN SPACE AND DRAINAGE

Public Open Space and Drainage areas are indicative only and subject to detailed design and modeling at the Local Structure Plan stage.

TOWN CENTRE

Uses within the Town Centre are as per the City of Cockburn's Town Planning Scheme No.3 use class table with an emphasis on encouraging a main street style local centre.

RESIDENTIAL

Uses within the Residential areas are as per the City of Cockburn's Town Planning Scheme No.3 use class table. Residential densities are indicative only and shall be confirmed at the local structure plan stage aiming to achieve a minimum density of R25 across the structure plan area with higher densities concentrated around high frequency public transport routes, public open spaces, commercial centres and schools.

LOCAL STRUCTURE PLANS

Subdivision and development of the subject area is to be in accordance with an endorsed applicable local structure plan.

DEVELOPER CONTRIBUTIONS

Development in this area is also subject to developer contributions. Schedule 12 of Town Planning Scheme No.3 details Developer Contribution Area provisions. Persons or companies proposing to undertake subdivision in this area should review Schedule 12 and also contact the City's Strategic Planning team to ascertain there are no pending amendments to this schedule.

Structure Plan Boundary	Public Purposes
Residential	Additional Uses / Restricted Uses
Public Open Space	Key Road Structure (Existing and Proposed)
Town Centre	Indicative Road Connections
Local Centre	Roundabout
Mixed Business (Restricted Use: Non-Residential)	
Drainage	

City of Cockburn
wetlands to waves

N
GNA 7/11

0 100m
SCALE

DISTRICT STRUCTURE PLAN PACKHAM NORTH

SPEARWOOD / COOGEE

Figure 8

Appendix B

Groundwater Monitoring Report

Ground Water Monitoring Report available to download here:

http://www.cockburn.wa.gov.au/documents/CouncilServices/CityDevlpmt/Packham_North/Appendix_2_-_Ground_Water_Monitoring_Report.pdf

Appendix C

Modelling Parameters, Assumptions and Results

Surface Runoff Modelling

Surface water runoff from rainfall events can be estimated using the relationship between the surface slope, area, roughness, infiltration and rainfall. The interaction of runoff from areas with different characteristics and the routing of this runoff through a catchment can be very complex. It is for these reasons that computational models are used to ensure the accuracy and speed of the calculations.

For the calculation of the surface water runoff, the XPSWMM hydrologic and hydraulic modelling software was used. The hydrologic component of the software uses the Laurenson non-linear runoff-routing method to simulate runoff from design storm events. The Laurenson runoff-routing method assumes that runoff is proportional to slope, area, catchment roughness, infiltration and percentage of imperviousness of a catchment. The runoff from each catchment is routed through the catchment using the hydraulic component of XPSWMM.

Pre-Development and Post-development Modelling Parameters

The total volume of runoff from a catchment is determined by the amount of rainfall less the losses (usually from infiltration) and the rate of runoff is determined by the slope and roughness (Manning's n) of the surface. An "initial loss - continuing loss" infiltration model was adopted and the method utilised to determine these infiltration rates is described below.

The desktop soil study presented in **Section 3.2.2** found that the majority of the site consists of sandy soils. The higher elevated areas (mainly external undeveloped Catchments of F1, F2 and F3) have areas of limestone outcrops. The low elevated areas associated with the wetlands are likely to have increased proportion of organic material and lower infiltration rates. The infiltration rates are also further reduced due to the close proximity to the underlying groundwater. For these reasons, and incorporating the soil log data presented in **Section 3**, the loss rates in **Table 1** were determined.

Table 1 Initial and Continuing Loss Parameters for Pre-development Hydrological Modelling

Infiltration Land Types	Initial Loss (mm)	Continuing Loss (mm/hr)
Sandy Sparse Vegetation	20	3
Sandy Medium Vegetation	25	3
Limestone Outcrop Sparse Vegetation	17.5	2.5
Limestone Outcrop Medium Vegetation	22.5	2.5
Wetland	5	0.5

The loss rates used in the post-development scenario were influenced by the existing loss rates used in the pre-development environment and by Cardno experience on other residential development sites. The post-development loss rates are presented in **Table 2**.

Table 2 Initial and Continuing Loss Parameters for Post-development Hydrological Modelling

Infiltration Land Types	Initial Loss (mm)	Continuing Loss (mm/hr)
Residential Impervious Areas (Roof, Driveway)	1	0.1
Garden	20	2.5
Road	1	0.1
Verge	9	2
POS	12.5	2.5

The infiltration rates used were predominantly based on the following assumptions:

- There will be no infiltration on roofs and driveways. There will however be some minor adsorption storage loss and this is reflected in an initial loss of 1mm and continuing loss of 0.1mm/h.
- Garden areas will have high infiltration rates as it is likely that sand or mulch will be used. Residential lots will have little slope (flat) and pockets of storage are likely. This will effectively increase the initial loss (storage) and overall infiltration rate (continuing loss).
- POS areas will likely contain dense vegetation or turf over a sand base. This turfed area will become compacted over time and reduce initial infiltration rates. For these reasons, it is anticipated that the Initial Loss and Continuing Loss will be lower than the pre-development sandy soil areas.
- The verge area is similar to POS areas except that it will also have an impervious footpath portion. For this reason, it is anticipated that the averaged Initial Loss and Continuing Loss will be lower than the POS rates.
- Due to the sandy soils, it is assumed that the infiltration rates in the lot soakwells will be high. The rate used in the model for Lot Soakwells is $5x10^{-5}$m/s. It is assumed all soakwells will have a size of 2.65m^3. The rainwater tanks will provide some addition lot storage; however, this will not affect the amount of runoff from the lots during the 72hr rainfall event.
- The vegetated treatment basins will have a high initial loss and will also have a continuing infiltration loss. However, the infiltration in vegetated treatment basins has been modelled by a different method. This is because these basins will be full of water and thus the infiltration rate has been modelled assuming it will behave like a sump (infiltration rate assumed to have a clogging rate of 50% and thus a rate of $2.5x10^{-5}$m/s was utilised in the modelling). For the Western and Eastern Wetlands, a conservative modelling approach was used that assumed no infiltration due to the close proximity to the groundwater. However, it is anticipated that in reality there will be some infiltration which will occur over a larger time duration than the rainfall event.

Table 3 provides the infiltration rate that has been modelled within each basin and the total volume that is infiltrated within each basin during the 1 year - 1 hour, 5 year and 100 year ARI event.

Table 3 Infiltration Parameters for Post-development Hydrological Monitoring

Basin	Infiltration Rate (m/s)	Infiltrated Volume (m^3)		
		1 year - 1 hour ARI	5 Year ARI	100 Year ARI
1a-1y1h	2.5x10-5	315	1,515	2,470
1a-5y	2.5x10-5	0	450	2,185
1a-100y	No infiltration			
1b-1y1h	2.5x10-5	180	780	1,300
1b-5y	2.5x10-5	0	510	1,685
1b-100y	No infiltration			

2a-1y1h	2.5x10-5	380	1,960	3,220
2a-5y	2.5x10-5	0	825	1,505
2a-100y	2.5x10-5	0	10	1,820
2b-1y1h	2.5x10-5	90	505	865
2b-5y/100y	2.5x10-5	0	165	485
2c-1y1h	2.5x10-5	50	240	420
2c-5y	2.5x10-5	0	235	270
2c-100y	2.5x10-5	0	0	270
4-1y1h	2.5x10-5	445	2,115	3,415
4-5y	2.5x10-5	0	1,065	2,140
4-100y	2.5x10-5	0	0	1,855
5-1y1h	No infiltration			
5-5y	No infiltration			
5-100y	No infiltration			
8	2.5x10-5	255	1,780	4,525
9b-1y1h	2.5x10-5	215	1,085	2,195
9b-5y/100y	2.5x10-5	0	390	1,415
10-1y-a	No infiltration			
10-1y-b	No infiltration			
10-5y-a	No infiltration			
10-5y-b	No infiltration			
10-5y-c	No infiltration			
10-100y	No infiltration			
E-1y1h-a	2.5x10-5	705	3,880	7,230
E-5y-a	No infiltration			
E-100y-a	No infiltration			
E-5y-b	No infiltration			
E-1y1h-b	2.5x10-5	105	535	955
E-5y-c	No infiltration			
E-100y-b	No infiltration			

From analysis of aerial imagery of residential areas, the proportion of land uses were determined for typically areas such as residential lots. Through this analysis, it was assumed that the Packham North development lots on average would be consistent with other Perth new developments and have 50% of the lots roof, 34% of the non-roof area as paved and 66% of the non-roof area as pervious garden. The road reserve is assumed to contain approximately 50% of the width as bitumen and 50% as verge.

Appendix D

Contaminated Sites Information

Please contact the City of Cockburn for copies of contaminated sites reports.