East Wanneroo District Structure Plan

District Water Management Strategy

Prepared for Department of Planning, Lands and Heritage

By Urbaqua

March 2021

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1 INTRODUCTION

In accordance with *Better Urban Water Management* (WAPC 2008), this District Water Management Strategy (DWMS) has been prepared on behalf of the Department of Planning, Lands and Heritage (DPLH) to support the East Wanneroo District Structure Plan (DSP) (WAPC, 2020) to meet the requirements of *State Planning Policy 2.9: Water Resources*.

The East Wanneroo DMWS provides high level water management strategies to guide planning and development. Consistent with the objectives *of Better Urban Water Management* (WAPC, 2008), the DWMS provides a summary of existing water resources and environmental conditions within the structure plan area to demonstrate that the land is capable of development. Further detailed investigations including the preparation of local water management strategies and urban water management plans will occur at later planning stages.

1.1 Strategy area

The East Wanneroo DSP and DWMS area covers 8,300 hectares of land. It extends from north of Neaves Road to Gnangara Road in the south, to Centre Way to the east and as far west as Pinjar Road and includes a small portion of Pinjar, most of Mariginiup and Jandabup, the eastern part of Wanneroo, Gnangara and south-west Lexia (Figure 1).

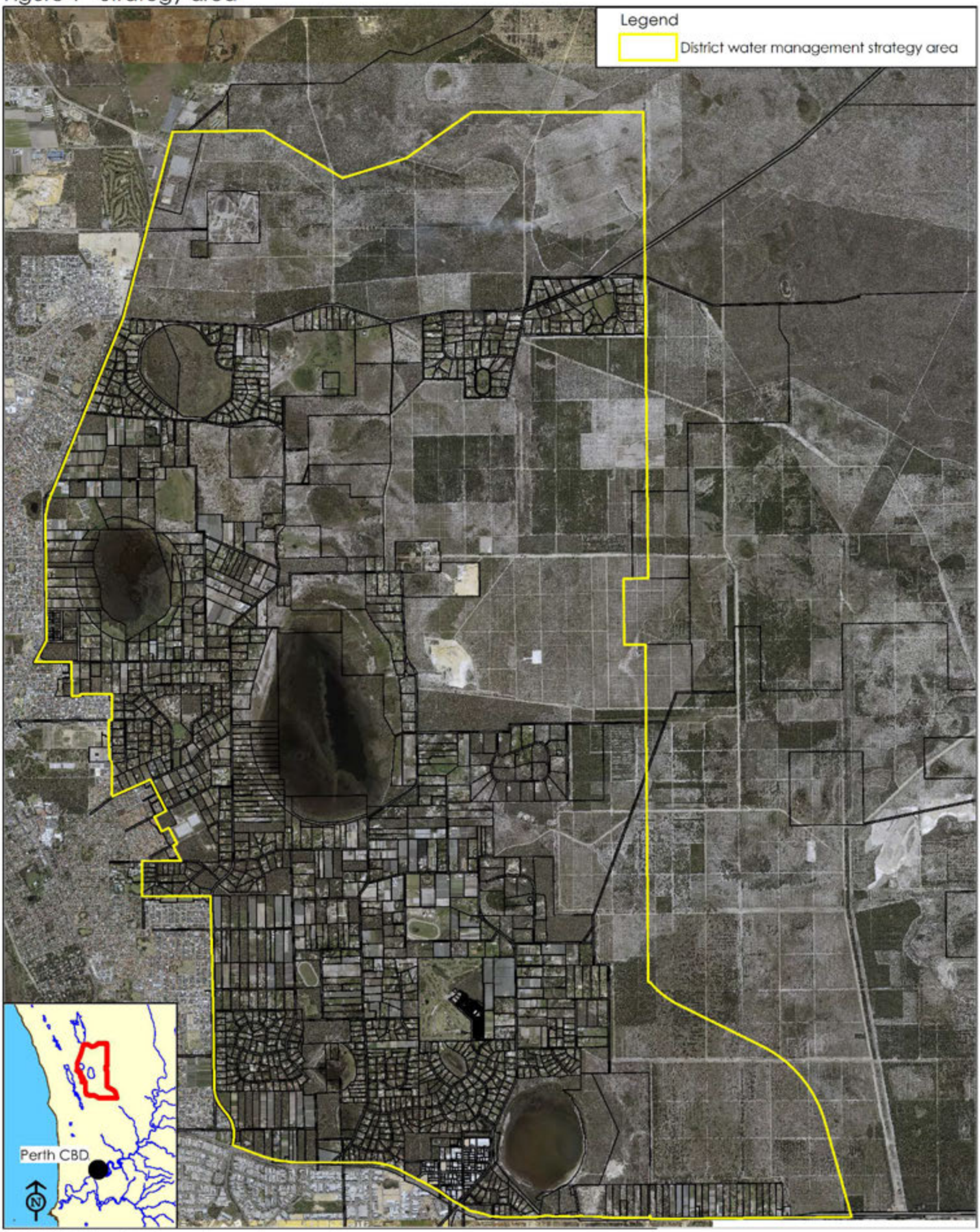
The site is located approximately 2 km east of the Wanneroo townsite, 6 km east of Joondalup and 25 km north of the Perth Central Business District. It currently has a mix of mainly rural land uses such as market gardens, equestrian activities, and rural lifestyle properties surrounding regional Parks, wetlands (many with significant environmental values), and some State Forest.

1.2 Water management principles

All future land use planning and development proposals will aim to:

- Consider water resources at all stages in the planning process, to integrate water and land use planning, protect important values and optimise total water cycle outcomes.
- Reduce potable water demand, increase water reuse and maximise water use efficiency and use of wastewater and harvested water.
- Design for the small (frequent), minor, then major rainfall events and aim to replicate how water moves through the natural landscape, noting local site conditions.
- Manage rainfall events to minimise runoff throughout the catchment by using multiple low cost 'in-system' management measures to reduce runoff volumes and peak flows.
- Retain and restore existing elements of the natural drainage system, including waterway, wetland and groundwater features, regimes and processes, and integrate these elements into the urban landscape, through multiple use corridors which provide protection to life and property from flooding.
- Minimise pollutant inputs through implementation of appropriate structural and non-structural source controls.
- Enhance social amenity through multiple use corridors, streetscape, lot landscaping and integrating water management measures into the landscape including public spaces to enhance visual, recreational, cultural and ecological values, while minimising development costs.
- Address issues that are relevant to the site and surrounds to a level of detail that is appropriate to the planning decision being made and reflective of the degree of significance of the issue and possible risk to the community and environment.

Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 1 - Strategy area



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1.3 Planning background

The Western Australian Planning Commission (WAPC) released the East Wanneroo DSP in 2020 to guide future development of the area (Figure 2). The East Wanneroo DSP will inform amendments to the Metropolitan Region Scheme (MRS) and provides a framework to guide future local structure plans, subdivision and development.

The Vision for East Wanneroo, developed by the East Wanneroo Community Reference Group, is as follows.

East Wanneroo will be a place which offers housing and lifestyle choice for all generations, that supports, links and protects natural flora and fauna and wetland systems, and celebrates local historic and cultural values.

The East Wanneroo DSP provides a framework for future amendments to the MRS and defines 28 precincts which form the basis for future local structure planning. The preparation of 20 local structure plans based on the 20 developing precincts is the mechanism through which the desired character and staging of new areas will be delivered.

The East Wanneroo DSP also sets out district level elements and outlines how these are to be addressed in each precinct. These elements are:

- a district centre;
- movement network;
- a neighbourhood centre;
- parkland network;
- urban neighbourhoods;
- water management;
- character areas;
- service commercial;
- special residential neighbourhoods;
- industrial areas;
- rural areas / tourism uses; and
- state forest.

It is noted that the protection of natural, historical and cultural values is a significant feature of the plan which highlights the elements necessary for the creation of functional and attractive neighbourhoods, serviced by high schools, activity centres and future employment opportunities.

The East Wanneroo DSP incorporates outcomes from previous studies including:

- East Wanneroo District Structure Plan draft for public consultation (WAPC, 2019);
- Technical studies to inform preparation of the DSP (see WAPC, 2019);
- Perth and Peel @ 3.5 million (WAPC, 2018a);
- Northwest Sub-Regional Planning Framework (WAPC, 2018b); and
- East Wanneroo Structure Plan (WAPC, 2011).

The strategy area is currently zoned Urban deferred, Industrial, Rural, Rural – Water Protection, Primary Regional Roads, and Other Regional Roads and is reserved for Parks and Recreation and Public Purposes in the MRS. Additionally, land is also denoted as Water Catchments and Bush Forever areas.

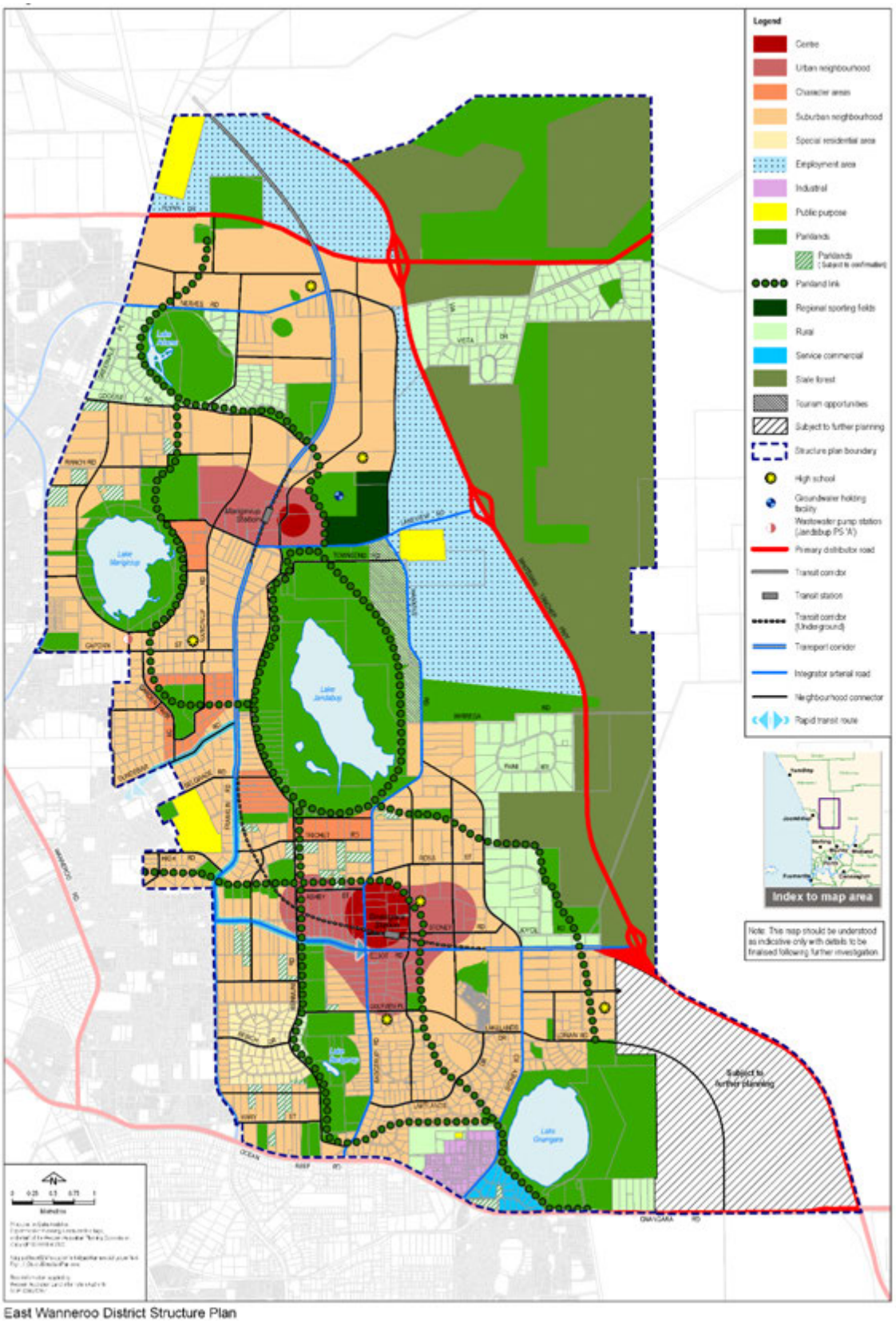

Figure 2: East Wanneroo District Structure Plan (WAPC, 2020)

Note: The potential groundwater holding facility identified in Figure 2 is co-located with an existing wetland. Evaluation and delineation of the existing values of this wetland and its future rehabilitation needs will be required prior to confirmation of the acceptability of this location.

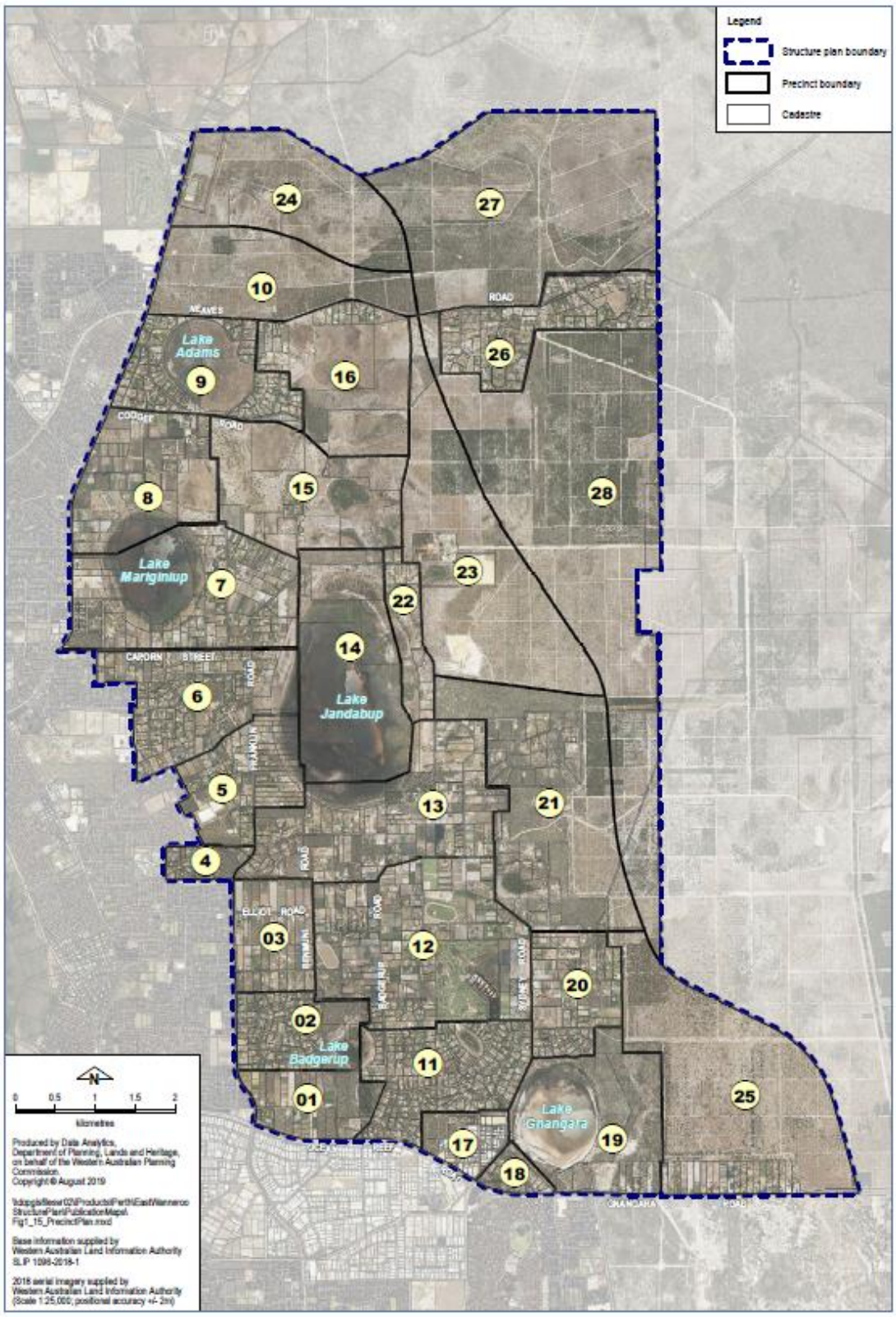

Figure 3: East Wanneroo DSP Precincts (WAPC, 2020)

It is noted that the land use provided for in the MRS is not reflected in the City of Wanneroo District Planning Scheme No2, which depicts large areas of Rural, Special Rural and Rural Resource. It is recognised that future amendments will be required to bring this land use in line with the MRS and allow for land use identified in the DSP. These amendments are required to be referred to the Environmental Protection Authority (EPA) for assessment under s48A of the Environmental Protection Act 1986.

The EPA received MRS Amendment 1308/41 to rezone 2099.8ha from Rural to Urban Deferred in 1996. The EPA considered that the environmental impacts of the scheme were not significant as to warrant formal assessment under Part IV of the Environmental Protection Act 1986 and provided advice on a number of environmental factors. The EPA noted the need for detailed management plans to address environmental factors prior to lifting of urban deferment and the need for the local scheme amendments to contain specific mechanisms and provisions to adequately secure, protect and manage the environmental values within the East Wanneroo area.

1.4 Guiding documents

Preparation of this DWMS has considered the following guiding and technical documents:

- East Wanneroo DSP draft for public comment (WAPC, 2019)
- East Wanneroo DSP Integrated Water Management Framework (RPS, 2019)
- East Wanneroo DSP Environmental Assessment Study (Emerge, 2018)
- East Wanneroo DSP Strategic Bushfire Hazard Level Assessment (Lush Bushfire and Planning, 2019)
- East Wanneroo DSP Engineering Servicing Report (Cossill Webley, 2019)
- East Wanneroo DSP Assessment of Proposed Environmental Outcomes (Emerge, 2019)
- East Wanneroo DSP Preliminary Environmental Assessment of Planning Investigation Areas (Emerge, 2018)
- North-West Sub-Regional Planning Framework (WAPC, 2018)
- Liveable Neighbourhoods (WAPC, 2015)
- State Planning Policy 2.2 Gnangara Groundwater Protection (WAPC, 2005)
- State Planning Policy 2.7 Public Drinking Water Source Policy (WAPC, 2003)
- State Planning Policy 2.9: Water Resources (WAPC, 2008)
- Better Urban Water Management (WAPC, 2008)
- Gnangara Land use and water management strategy (WAPC, 2001)
- Government Sewerage Policy (2018)
- Western Australian State Water Plan (Government of Western Australia, 2007)
- Stormwater Management Manual for Western Australia (DoW, 2004–2007)
- Decision Process for Stormwater Management in WA (DWER, 2017)
- Guidelines for district water management strategies (DoW 2013)
- Speciation Separation Distances for Groundwater Controlled Urban Development (IPWEA, 2016)
- Water Resource Considerations when Controlling Groundwater Levels in Urban Development (DoW, 2013)
- North-West Sub-Regional Water Management Strategy (Urbaqua, 2018)
- Strategic Policy, Protection public drinking water source areas in Western Australia (DoW, 2016)
- Recreation within public drinking water source areas on crown land (DoW, 2009)
- Our groundwater future in Perth: Securing Gnangara groundwater and adapting to climate change (DWER, 2018)
- Gnangara Groundwater Areas Allocation Plan (DWER, 2009)

- Gnangara Sustainability Strategy, Summary of Land Use Planning Investigations (DoW et al. 2009)
- Water quality protection note no. 25, Land use compatibility tables for public drinking water source areas (DoW, 2016)
- Water quality protection note no. 36, protecting public drinking water source areas (DoW, 2009)
- Water Quality Protection Note No. 38, Protecting Water Quality in P3* Areas (DWER, 2018)
- Water monitoring guidelines for better urban water management strategies and plans (DoW, 2012)
- Interim Position Statement: Constructed Lakes (DoW, 2007)
- Public Parkland Planning and Design Guide WA (Government of WA, 2014)
- Guidance Statement No.33 Environmental Guidance for Planning and Development (EPA, 2008)
- Australian Rainfall and Runoff: a guide to flood estimation (Geoscience Australia 2019).

2 SITE CHARACTERISTICS

The existing environmental conditions for the strategy area define the opportunities and constraints for water management. A summary of the conditions are provided in this section.

2.1 Climate

The climate of East Wanneroo District is typical of the Swan Coastal Plain, being warm and dry during summer and cooler and wetter during winter. The closest long-term Bureau of Meteorology (BoM) monitoring station is Wanneroo (station ref: 9105) which is located approximately 2 km west of the study area and has a record since 1906.

The most recent average data collected at this BoM station is presented in Chart 1which shows that both minimum and maximum monthly temperature averages vary by around 12 degrees Celsius (C) over the year with the minimum usually experienced in July and maximum in February. The reverse is true of rainfall which reaches its peak of 162.3 mm for the month of June and has a minimum of 9.8 mm in December.

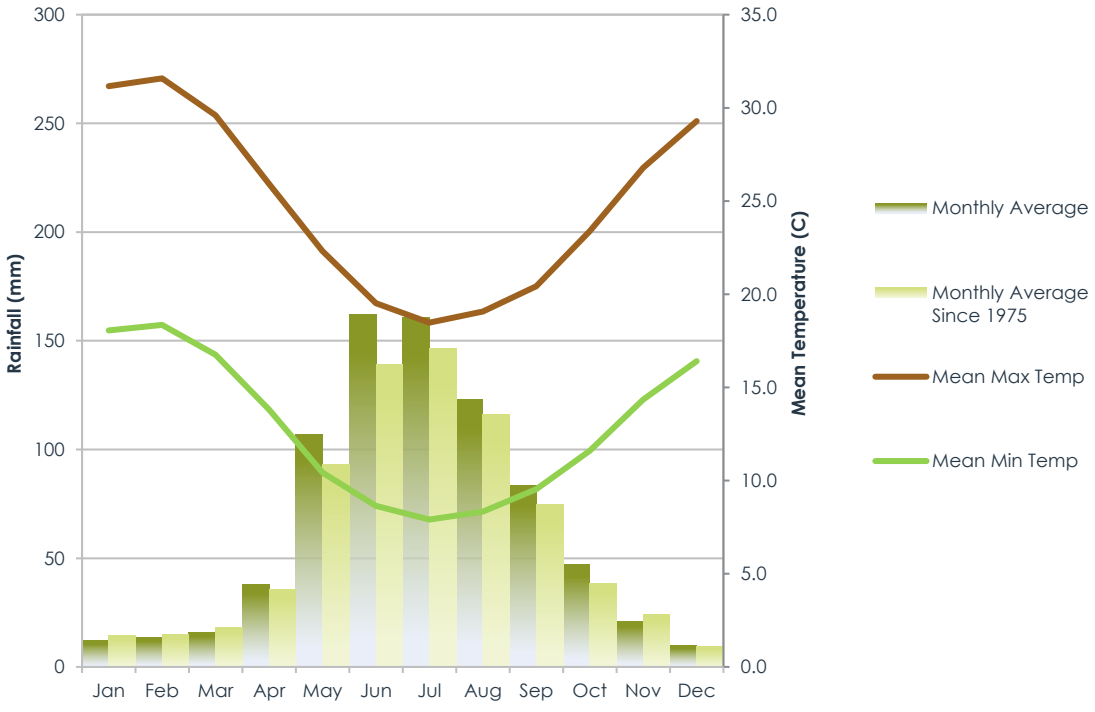

Chart 1: Temperature and rainfall data for Wanneroo (BoM reference 9105)

Longer term climate trends are presented in Charts 2, 3 and 4. These show that the climate has been steadily changing since the 1960s with the 30 year average rainfall declining some 50mm since 1964. This trend is typical of the south-west of Western Australia and has been accompanied by declining stream-flows and groundwater levels resulting in declining water availability for both environmental and human uses.

Decreasing rainfall is also noted in the *Selection of future climate projects for Western Australia* (DoW, 2015). Mean annual rainfall decreases projected by The Department of Water and Environmental Regulation (DWER), based on the 1961-1990 baseline, varies between -4% (wet scenario) and -25% (dry scenario) by 2050. This extends to -7% (wet) and -47% (dry) by 2090.

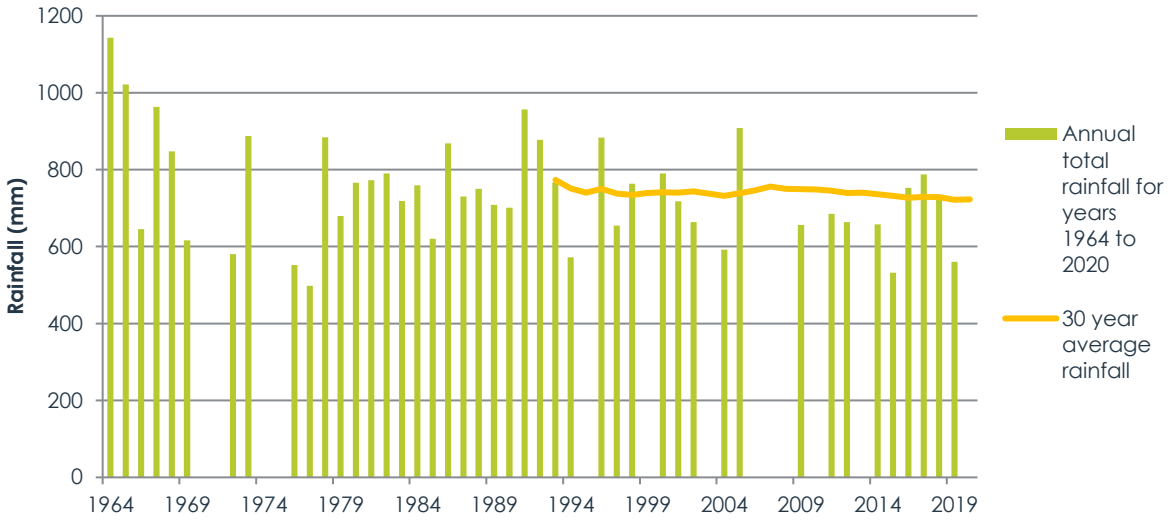

Chart 2: Historic rainfall trend-Wanneroo site no: 9105 (BoM, 2020)

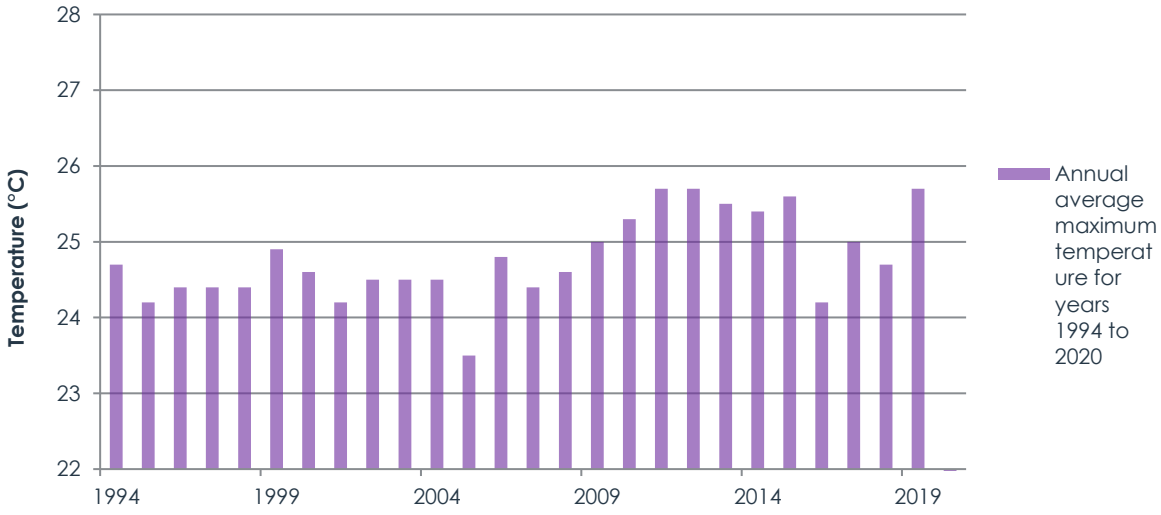

Chart 3: Historic maximum temperature trend-Perth Metro site no: 9225 (BoM, 2020)

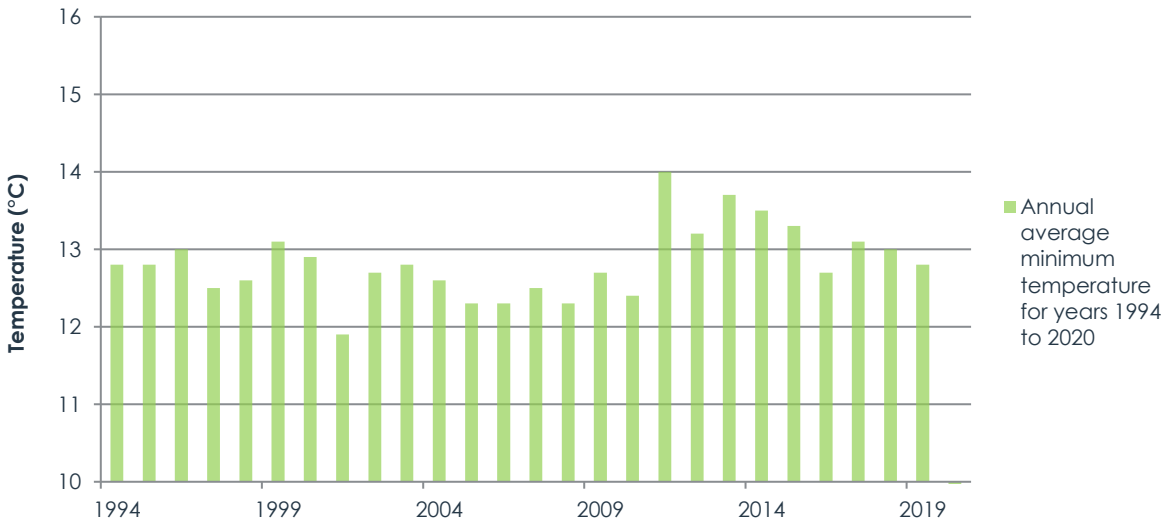

Chart 4: Historic minimum temperature trend-Perth Metro site no: 9225 (BoM, 2020)

Implications for future development

It will be important to consider historic, current and future climate as an integral part of water management investigations and modelling to inform development and validation of strategies. This should include an understanding of the representativeness of local monitoring results and demonstrated understanding of how future changes are likely to impact on the total water cycle.

2.2 Topography

The landform of the EWSP is comprised of undulating Spearwood and Bassendean low dune systems running in a north-south direction, with a prominent dunal ridge east of Wanneroo Road. An inter-dunal swale interface exists between the Spearwood and Bassendean soil systems along which the low-lying east Wanneroo wetlands and seasonally inundated areas are found (WAPC 2005b).

Surface elevation, as shown by topographic contours, range from approximately 45 m Australian Height Datum (AHD) in low lying wetlands to 100 m AHD on the western boundary of the site (Figure 4). As the site consists of a dunal system, there are several high and low points throughout the site (WAPC, 2019).

Implications for future development

Retention of topography and slope assists the movement of water across a site and reduces the need for earthworks. It also helps to retain mature trees which mitigate urban heat island effects. The East Wanneroo DSP also recognises the importance of landform in preserving distinctive local character. It will be important to consider retention of landform as part of local structure planning.

2.3 Geology and soils

Environmental geology mapping (Department of Mines and Petroleum) for the strategy area shows that the western portion of the site typically consists of Spearwood sands (S7) which are pale and olive yellow, medium to coarse grained, subangular quarts and trace feldspar of residual origin (Figure 4). The eastern portion of the site incorporates Bassendean sands (S8 and S10) which are very light grey at surface, yellow at depth, fine to medium grained sub-rounded quarts of eolian origin. Typically, near the wetland depressions, there is peaty clay (Cps) which is dark grey and black with variable sand content of lacustrine origin.

Implications for future development

The nature of soils, particularly permeability, is a critical element in determining an appropriate drainage strategy. Sandy soils are generally associated with high permeability, which tends to support infiltration strategies. However, development in areas where soils comprise sands with high permeability and low nutrient retention face challenges in preventing discharge of increased nutrient loads to the downstream environment.

Where heavier soils exist, management of surface water is likely to require a greater level of technical consideration.

The nature and form of developments surrounding wetlands requires specific water management practices that focus on resolving the conflicting objectives of maintaining hydrological cycles and providing suitably dry urban environments.

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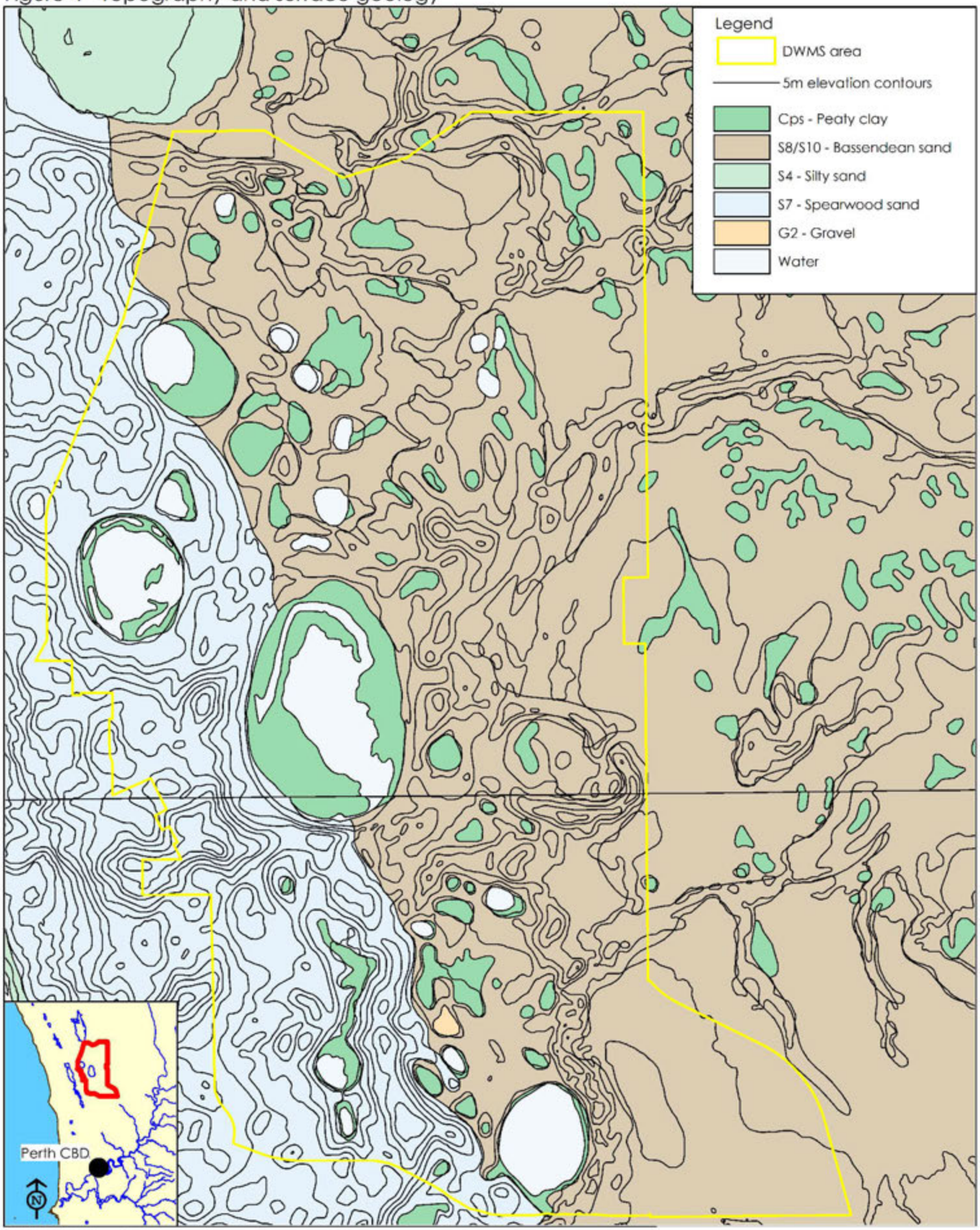
Figure 4 - Topography and surface geology



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2.3.1 Acid sulfate soils

Mapping of Acid Sulfate Soil Risk on the Swan Coastal Plain is maintained by the Department of Water and Environmental Regulation (DWER) (2020a) and is presented in Figure 5. This mapping identifies the majority of the eastern third of the site as having a moderate to low risk of acid sulfate soil occurring within 3 m of the natural soil surface. The western portion of the site has no known risk of acid sulfate soils occurring within 3 m of the natural soil surface. These areas are not considered to represent a significant impediment to the development of the study area.

Small areas of the site, typically associated with wetlands and peaty clay soils, are; however, classified as having a high to moderate risk of acid sulfate soils occurring within 3 m of the natural soil surface.

Implications for future development

Areas of acid sulfate soils cannot be confirmed or removed at this stage of the development process and will need to be determined by an acid sulfate soils investigation, potentially with sampling within the site. Acid sulfate soils can be managed through appropriate management plans, sampling and treatment, which is handled through a DWER approval process at local structure plan stage, prior to any subdivision.

2.3.2 Contamination

The strategy area currently contains no sites registered with the DWER as being contaminated under the *Contaminated Sites Act 2003*.

There is a registered contaminated site to the immediate north-west (ID 70488, 70489 and 12882), which is classified for restricted use (Figure 6). This site has been identified as being contaminated with metals and nutrients, as it was previously a municipal landfill site. As groundwater flows in a westerly direction, contamination from this site is not considered a risk to the site.

There are a number of sites where the former land use presents a contamination risk. These risks will need to be investigated as part of local structure planning.

Current land uses in the catchment are mapped in Figure 6. Land uses have been assessed using a combination of data sources. These include:

- Previous high-level land use assessments undertaken for development of the Department of Water and Environmental Regulation (DWER) groundwater management model; Perth Regional Aquifer Modelling System (PRAMS)
- Planning and cadastral information
- Web-based map records for businesses operating in the area
- Aerial imagery
- Mapping of horticultural activities in East Wanneroo and quantification of irrigated areas provided by the Department of Primary Industries and Regional Development.

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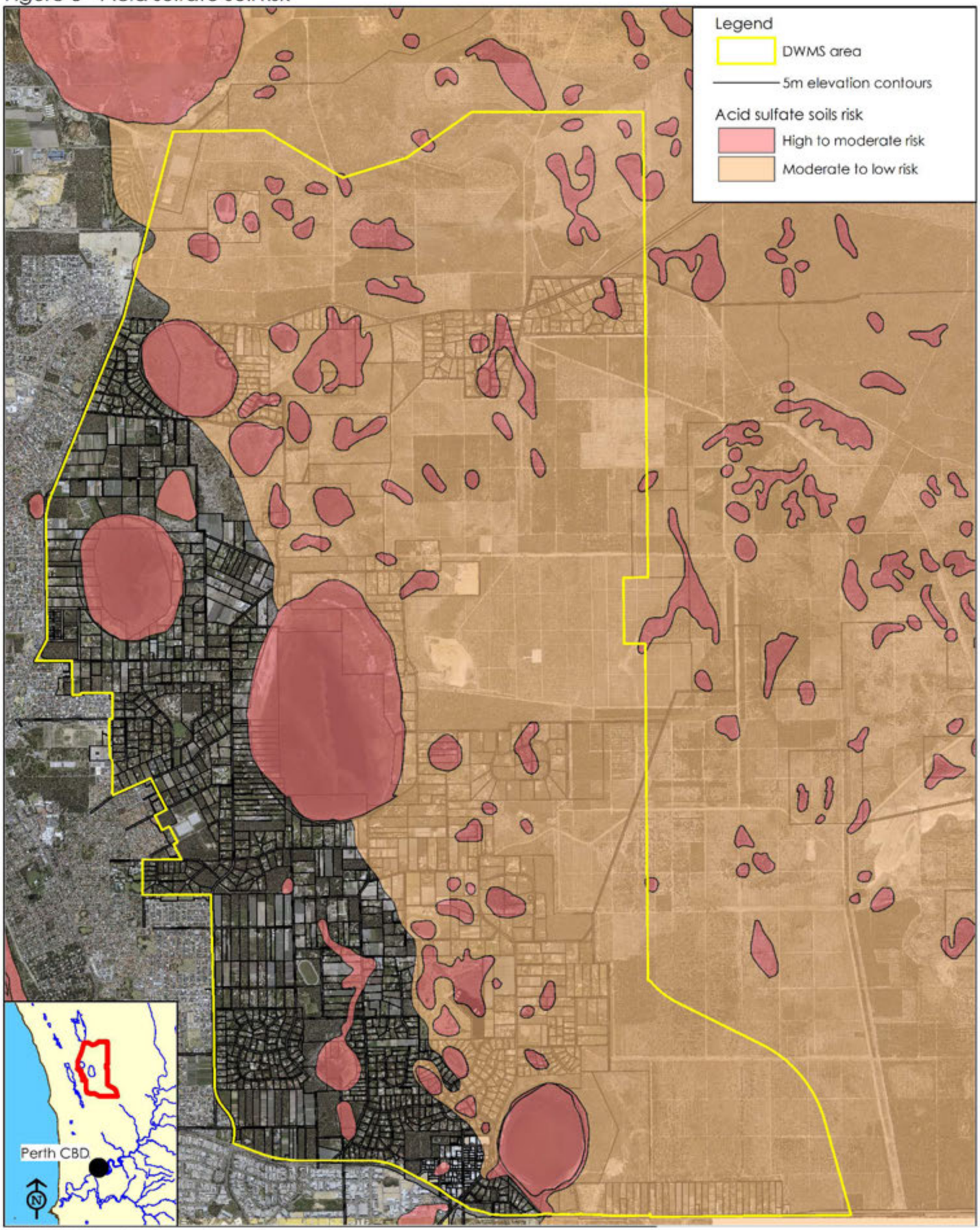
Figure 5 - Acid sulfate soil risk



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Land uses have been categorised broadly as follows. Those in bold are considered to represent a risk to water quality:

- aged care facilities
- **chicken farms**
- **fish farms**
- **fuel stations**
- **golf courses**
- **horticultural sites**
- **industrial land (mostly in the Northlink Industrial Park)**
- **lots believed to include equestrian activity (includes known agistments)**
- **lots believed to include kennels, catteries or other pet services**
- **lots believed to include manufacturing activity**
- **lots believed to include scrap material laydown areas**
- **plant nurseries**
- public open spaces
- public utilities land (includes water treatment plants)
- quarries
- Residential lots in various size ranges
- state forest areas
- **turf farms**
- undeveloped land (remnant bush or partially cleared land)

Figure 6 shows the contaminated site listed in the DWER contaminated sites database as well as sites where previous land use activities are considered to be potential sources of contamination. It should also be noted that existing (current) landuses may also pose a contamination risk which will need to be considered and potentially investigated as part of local structure planning.

Implications for future development

Further investigations are required to determine the extent of contaminated soil and/or groundwater, particularly where indicated as possible, as a result of current or past land use. A Preliminary Site Investigation (PSI) is recommended at Local Structure Plan stage. This should include consideration of high levels of nutrients (which generally fall outside the Contaminated Sites Act), faecal matter and pathogens if the site is within or adjacent to a public drinking water source area.

In order to protect the groundwater resources particularly where associated with public drinking water source areas, it will be important to ensure that the stormwater management strategy does not infiltrate 'clean' rainwater through 'dirty' soil.

2.4 Wetlands

The DSP area contains several very large wetlands, of which Lake Jandabup is the largest with a surface area of approximately 4.5km^2, this is followed by Lake Mariginiup at 1.5km^2, Lake Gnangara at 1.3km^2 and Lake Adams at 1km^2. There are also numerous other smaller wetlands in the area that are mapped as a part of the Department of Biodiversity, Conservation and Attractions' (DBCA) *Geomorphic Wetlands of the Swan Coastal Plain* dataset (Figure 7). These wetlands are listed in Appendix A.

It should be noted that many wetlands within the East Wanneroo DSP area are associated with cultural heritage values. It is recommended that Traditional Owners and Aboriginal people with knowledge of the area are engaged as part of local structure planning to understand and protect cultural heritage values.

Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
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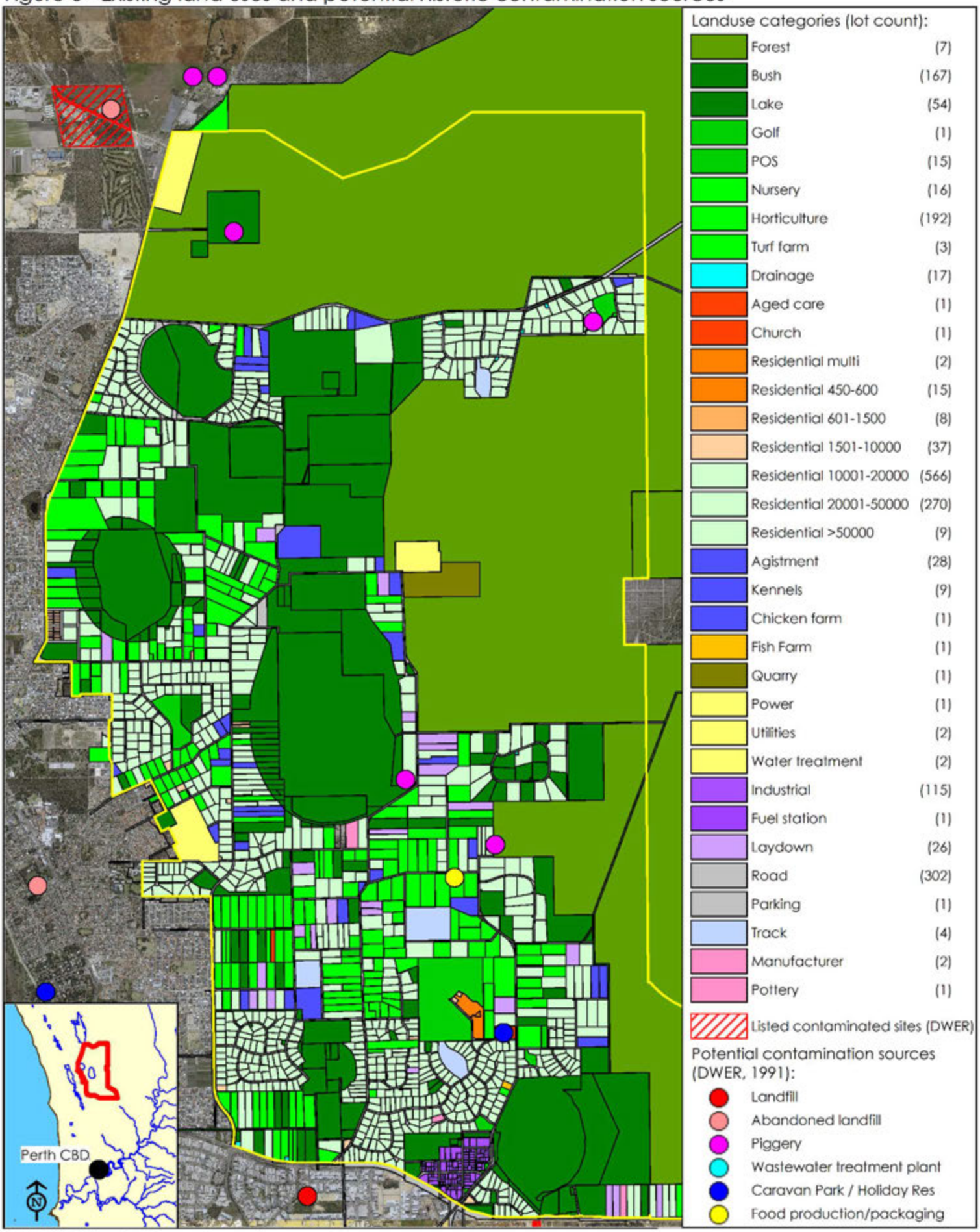
Figure 6 - Existing land uses and potential historic contamination sources



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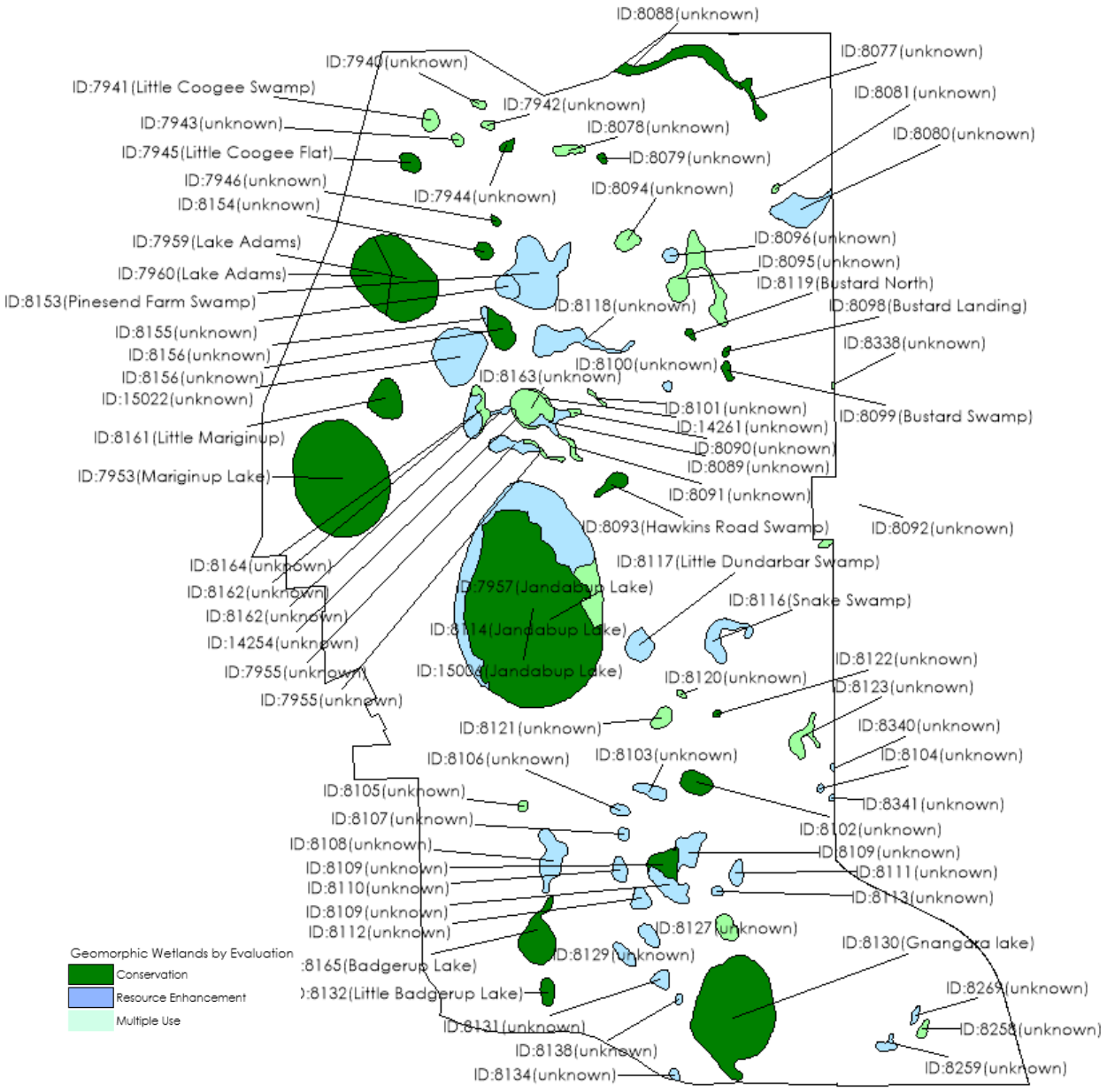


Figure 7: Existing wetlands

A revision to the *Geomorphic Wetlands of the Swan Coastal Plain* dataset was undertaken in 2017 by DWER and DBCA. Further updates to this dataset are currently underway. The updated dataset is likely to assist in informing future strategic planning decisions regarding the retention and protection of high conservation wetlands values within the East Wanneroo DSP area. Evaluation and delineation of the wetlands within individual precincts are required by proponents prior to the preparation of local structure plans including the allocation of adequate wetland buffers for those that are to be protected and/or restored.

2.4.1 Ministerial criteria sites

Ministerial statement no. 819 – Gnangara Mound groundwater resources [including East Gnangara Shire of Swan] establishes environmental conditions and commitments associated with the allocation of groundwater for public and private use under Part IV of the *Environmental Protection Act 1986*.

Some of the key conditions in *Statement no. 819* relate to environmental water provisions and set water level criteria for 30 representative sites across the Statement area. These include 14 wetland sites and 16 phreatophytic vegetation sites.

In the East Wanneroo District Structure Plan area there are two wetland sites (Lake Mariginiup and Lake Jandabup) and one phreatophytic vegetation site (MT3S) with water level criteria set in *Ministerial Statement no. 819*.

2.4.2 Lake Jandabup Nature Reserve

Lake Jandabup, encompassed by the Jandabup Nature Reserve (R7349), is the only wetland in the East Wanneroo DSP area that is currently managed by DBCA.

Preliminary stormwater modelling currently proposes to allow for minor (20%AEP) and major (1%AEP) flood events to be stored within Lake Jandabup and several other wetlands in the Waste Wanneroo DSP area. This strategy has the in-principle support of DBCA requiring the provision of relevant hydrological studies, ecological studies and appropriate stormwater and groundwater management.

Consultation with DBCA on the proposed water management strategy will be necessary in any precinct containing a wetland within existing or proposed DBCA managed reserves and/or where active or passive recreation or drainage facilities are likely to be proposed within or adjacent to a DBCA-managed reserve or other areas of proposed conservation estate.

Appropriate treatment including fencing, hard road edges and buffers, and planning for the urban interface abutting existing and proposed conservation reserves is important to ensure that impacts from changes in adjacent land uses are adequately managed and mitigated.

2.4.3 Lake Jandabup supplementation

In response to declining water levels in Lake Jandabup, that led to the acidification of the lake, supplementation with groundwater was commenced in 2000/01 and has occurred every year since then. Table 1 presents the supplementation volumes for each year.

It is likely, given the predicted groundwater level rises and reduced abstraction volumes following development, that there will be reduced need for supplementation in future.

Table 1: Jandabup supplementation volumes:

Water year	Supplementation volume (ML)	Water year	Supplementation volume (ML)
2000-01	1,111	2008-09	1,061
2001-02	963	2009-10	899
2002-03	1,110	2010-11	1,493
2003-04	973	2011-12	1,161
2004-05	924	2012-13	867
2005-06	899	2013-14	1,331
2006-07	1,403	2014-15	1,170
2007-08	1,249	2015-16	1,312

Water year	Supplementation volume (ML)
2016-17	1,226
2017-18	886
2018-19	1,304
2010-11	1,493
2011-12	1,161
2012-13	867

Water year	Supplementation volume (ML)
2013-14	1,331
2014-15	1,170
2015-16	1,312
2016-17	1,226
2017-18	886
2018-19	1,304

2.4.4 *Lake Adams*

It is noted that Lake Adams (east) has been identified as a new Parks and Recreation reserve in the East Wanneroo DSP. Prior to the reservation of this area, consideration should be given to the future protection and management of this wetland portion and the significant management resources required to restore its environmental values due to the impacts from historical rural land uses.

2.4.5 *Review of historic monitoring data*

Available water level data for the three sites with water level criteria set in Ministerial Statement No. 819 and other large wetlands have been reviewed alongside their respective water level criteria and, for the wetlands, a nearby groundwater level record (see Charts 4 to 8).

Chart 4: Lake Jandabup long term monitoring record

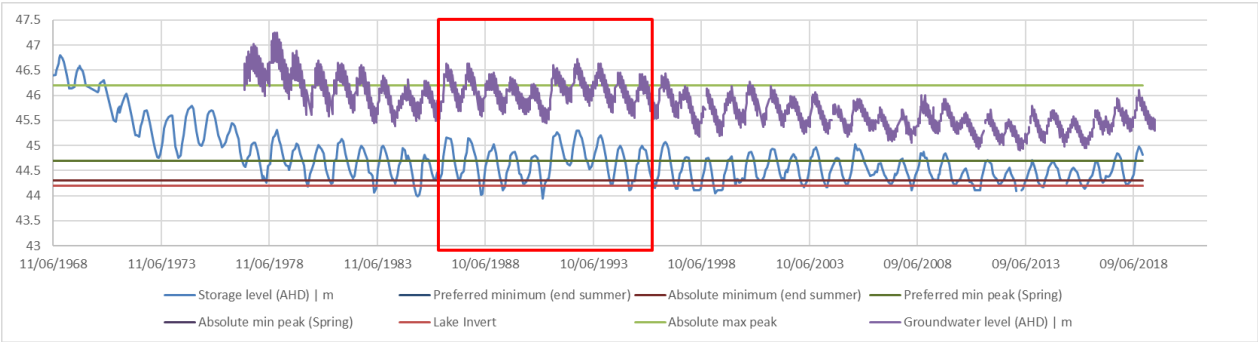


Chart 5: Mariginiup Lake long term monitoring record

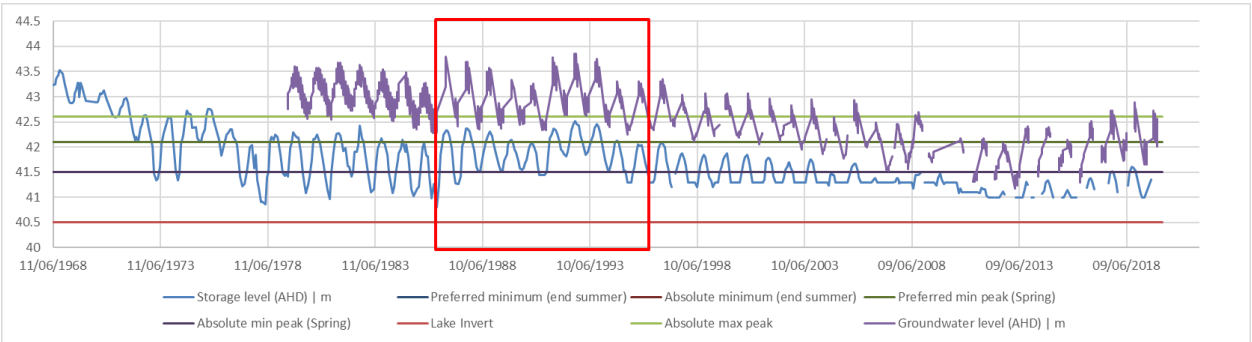


Chart 6: Vegetation site MT3S long term monitoring record

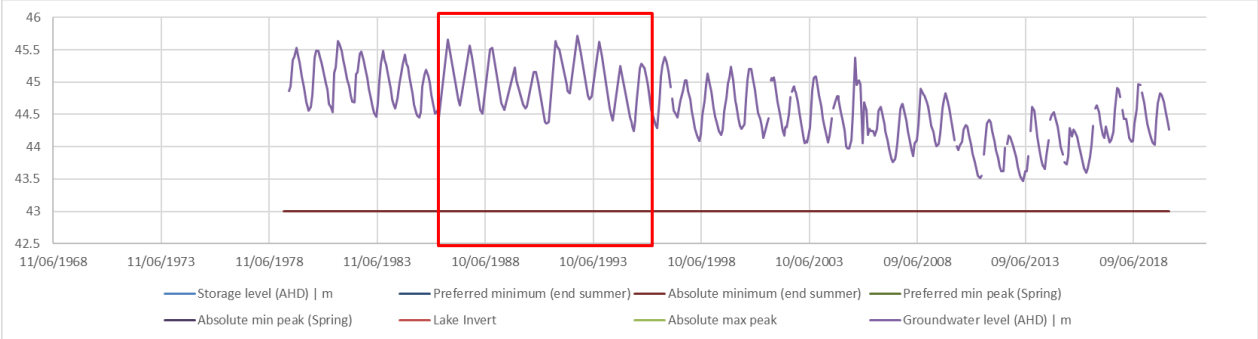


Chart 7: Lake Gnangara long term monitoring record

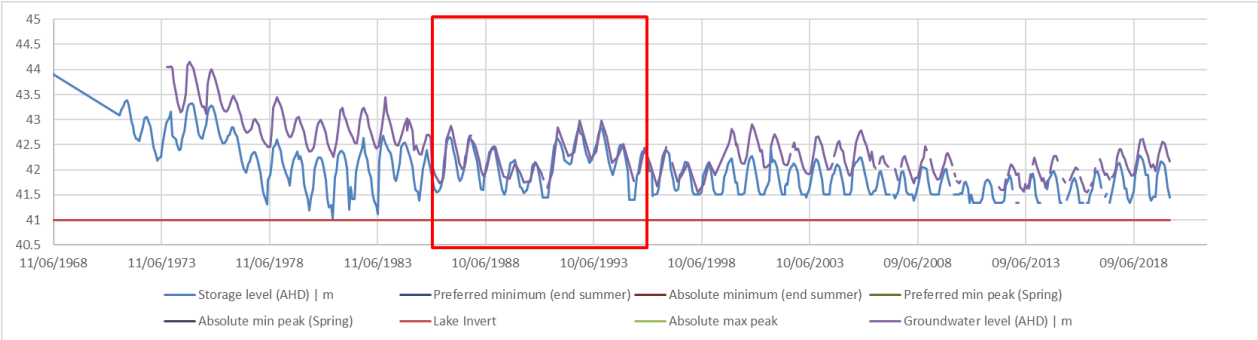
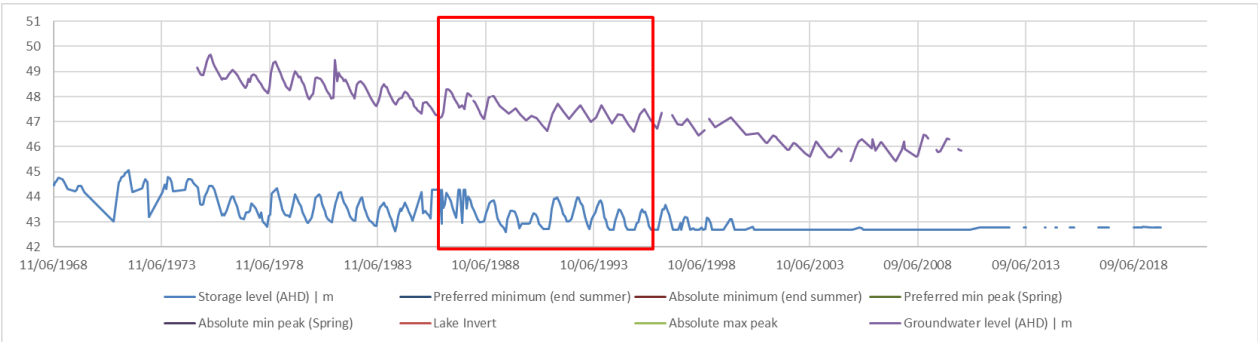


Chart 8: Lake Adams long term monitoring record



Although water level declines have been observed at each site, particularly since the mid 1990's, from 1978 to early 1990's, water levels were relatively stable at most sites and during this period levels were generally compliant with water level criteria.

For establishment of a suitable baseline period for hydrological assessment purposes for the East Wanneroo DSP area, it is desirable to select a period where, on average, water levels were compliant with criteria set in Statement 819. Generally, a thirty-year period of record would be preferred for this purpose. However, in this case it is preferable to exclude the period with declining water levels observed since 1994, during which time levels were far more often non-compliant with criteria set in Statement 819, and select a period of relative stability with good groundwater data availability throughout the DSP area. Therefore, a shorter ten-year period from 1986 to 1995 (marked in red on Charts 4 to 8) has been selected for assessment purposes with the following key reasons:

- Water levels were generally stable
- Water levels were compliant with criteria set in Statement 819 in at least five years from the ten-year period.
- 76 groundwater bores have at least 50 records over the ten-year period.
- 76 groundwater bores have at least four records in every year of the ten-year period.

Surface water and groundwater monitoring sites selected for use in the hydrological assessment are shown in Figure 8 and provide a good distribution throughout the East Wanneroo DSP area.

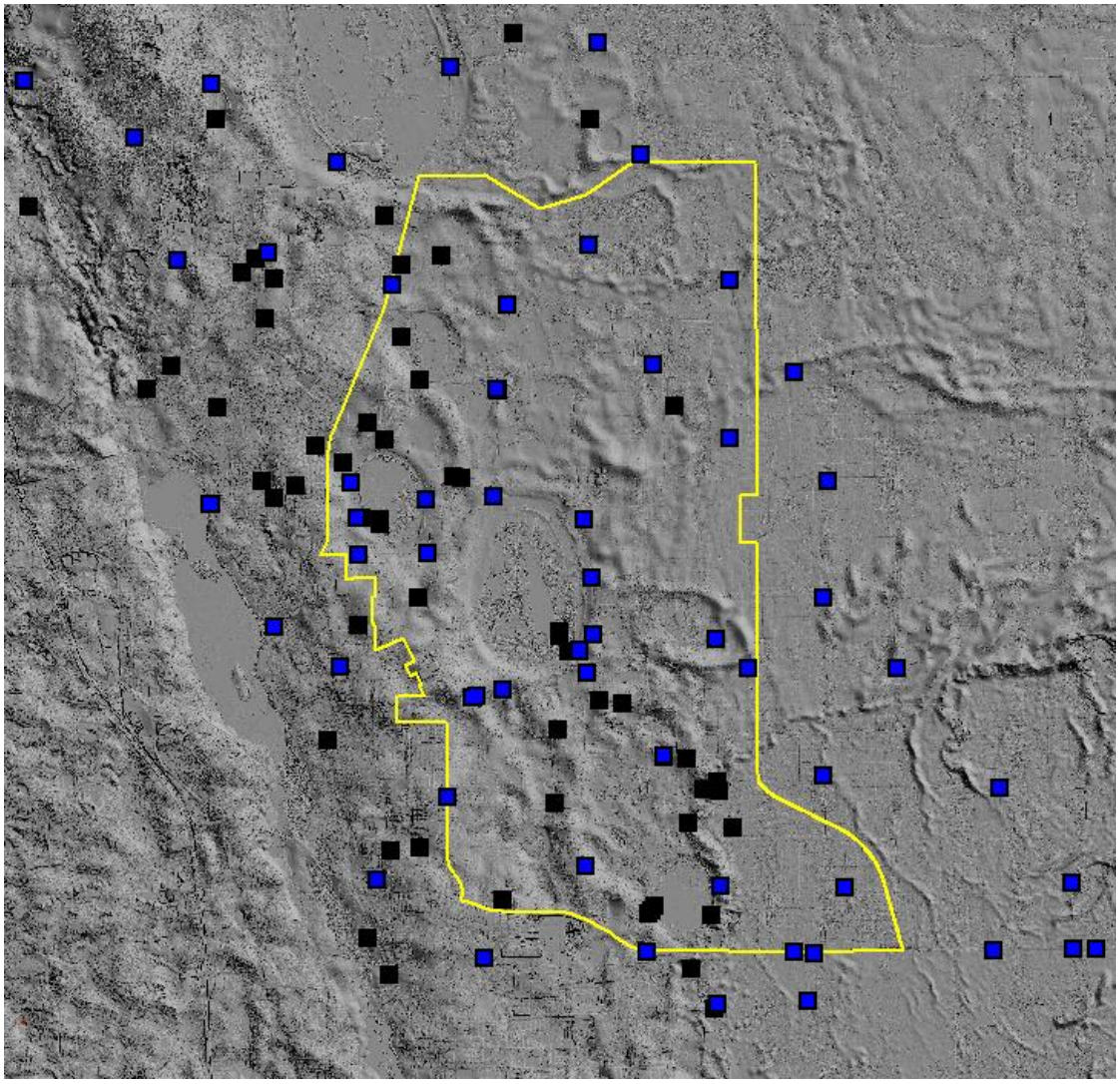


Figure 8: Surface water and groundwater monitoring sites showing selected sites for hydrological assessment highlighted in blue

Considering annual minimum and maximum water levels at each site in more detail for 25 years between 1977 and 2001(Table 2) it is observed that both Jandabup and Mariginiup have been non-compliant with their respective criteria consistently since 1994 and prior to that, Jandabup was non-compliant in nine of the seventeen years shown.

During the identified ten-year baseline period (1986-95) which is outlined in red in Table 2 it is observed that Mariginiup Lake was non-compliant with its preferred minimum peak criterion (41.2m) for two years but was compliant on average and fully compliant with its absolute minimum peak criterion (41.5m).

Lake Jandabup was non-compliant with its absolute minimum level criterion (44.3m) for five years and on average overall but fully compliant with peak criteria. It is therefore desirable that management of groundwater levels close to Lake Jandabup should aim to increase minimum water levels from this baseline whilst remaining consistent with maximum water levels.

Table 2: Annual maximum and minimum water levels at selected sites (all available data, 1977-2001 with the selected baseline period from 1986 to 1995 marked in red)

	Mariginiup		Jandabup		Adams		Gnangara		MT3S (groundwater)	
Year	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
1977	42.04	41.23	45.13	44.57	43.75	43.10	42.52	41.95	-	-
1978	42.26	40.87	45.31	44.26	44.34	42.81	42.61	41.31	-	-
1979	42.29	41.42	45.04	44.52	44.11	43.20	42.36	41.69	45.53	44.86
1980	42.24	41.09	45.01	44.18	44.10	42.95	42.25	41.19	45.83	44.56
1981	42.29	40.97	45.14	44.25	44.21	42.99	42.37	41.02	45.85	44.54
1982	42.42	41.41	44.99	44.34	43.98	43.05	42.63	41.20	45.70	44.69
1983	42.18	41.10	44.99	44.06	43.78	42.84	42.68	41.12	45.92	44.47
1984	42.14	41.08	44.95	44.24	43.78	42.63	42.54	41.77	45.80	44.59
1985	42.09	41.02	44.82	43.99	44.18	43.06	42.40	41.39	45.93	44.46
1986	42.33	40.80	45.16	44.30	44.15	42.93	42.64	41.55	45.93	44.46
1987	42.36	41.26	45.15	44.31	44.00	42.95	42.63	41.78	45.75	44.64
1988	42.31	41.50	45.03	44.02	43.86	42.98	42.44	41.59	45.88	44.51
1989	42.15	41.54	44.86	44.18	43.44	42.77	42.20	41.50	45.82	44.57
1990	42.07	41.56	44.80	44.24	43.34	42.74	42.14	41.54	45.79	44.60
1991	42.37	41.45	45.26	43.94	43.97	43.03	42.63	41.66	46.03	44.36
1992	42.52	41.82	45.30	44.60	43.97	43.02	42.73	42.10	45.72	44.67
1993	42.46	41.84	45.21	44.52	43.86	42.72	42.85	42.13	45.65	44.74
1994	42.13	41.50	44.99	44.19	43.51	42.81	42.50	41.90	45.98	44.41
1995	42.06	41.30	44.99	44.11	43.49	42.97	42.36	41.87	46.14	44.25
1996	42.07	41.35	45.07	44.16	43.68	42.85	42.38	41.48	46.10	44.29
1997	41.87	41.21	44.77	44.13	43.19	42.90	42.16	41.58	45.94	44.45
1998	41.85	41.40	44.75	44.11	43.16	42.71	42.15	41.55	46.30	44.09
1999	41.88	41.50	44.78	44.04	43.12	42.70	42.23	41.50	46.20	44.19
2000	41.85	41.53	44.88	44.19	42.81	42.81	42.28	41.54	46.11	44.28
2001	41.78	41.36	44.94	44.30	-	-	42.43	41.58	46.25	44.14
Ave. (full record)	42.16	41.32	45.01	44.23	41.99	41.18	42.44	41.58	45.92	44.47
Ave. (1986-95)	42.28	41.46	45.08	44.24	43.76	42.89	42.51	41.76	45.87	44.52

Note: values in red denote non-compliance with ministerial criteria

2.4.6 *Recommended wetlands for retention*

The East Wanneroo DSP proposes to retain all conservation category and resource enhancement wetlands plus one additional multiple use wetland that is associated with Jandabup lake. Several other multiple use wetlands will be unaffected by the land use change proposed in the East Wanneroo DSP. A listing of the wetlands currently proposed for retention is provided in Table 3 along with several additional wetlands recommended for investigation and/or retention as part of the stormwater management system.

Based on the 2017 revision to the *Geomorphic Wetlands of the Swan Coastal Plain* dataset, the larger wetlands in the East Wanneroo DSP area, identified and defined as having 'high value' and therefore worthy of protection, have been proposed as existing or proposed Parks and Recreation reservation.

A number of smaller 'high value' wetlands have not been specifically identified for protection in the East Wanneroo DSP (

Table 4). A site investigation/evaluation is required to be conducted for each of these at the precinct planning stage to identify the wetlands which should be protected. The guidance document *A methodology for the evaluation of wetlands on the Swan Coastal Plain, Western Australia* (DBCA 2017a) and associated information sheet *Wetland identification and delineation: information for mapping and land use planning on the Swan Coastal Plain* (DBCA 2017b) as amended, should be utilised by proponents and consultants reviewing wetland boundaries and management categories. Wetland assessments should be undertaken prior to structure plan development to inform proposed open space areas and future local structure plan design.

In addition, there are a number of lower value wetlands not identified for retention in the East Wanneroo DSP that are located where preliminary stormwater modelling suggests that storage should be provided. It is recommended that these sites are considered for retention with restoration of their ecological and hydrological function as part of the stormwater management system.

Table 3: Geomorphic wetlands proposed for retention in the East Wanneroo DSP

UFI	Management category	Wetland type	Landform	Name	Area (ha)
7944	Conservation	Sumpland	Basin	unknown	2.4
7945	Conservation	Dampland	Basin	Little Coogee Flat	5.4
7946	Conservation	Dampland	Basin	unknown	1.2
7953	Conservation	Lake	Basin	Mariginup Lake	145.3
7959	Conservation	Dampland	Basin	Lake Adams	56.8
7960	Conservation	Dampland	Basin	Lake Adams	33.3
8077	Conservation	Sumpland	Basin	unknown	4.9
8079	Conservation	Dampland	Basin	unknown	1.1
8088	Conservation	Dampland	Basin	unknown	27.3
8093	Conservation	Sumpland	Basin	Hawkins Road Swamp	6.2
8098	Conservation	Dampland	Basin	Bustard Landing	1.0

UFI	Management category	Wetland type	Landform	Name	Area (ha)
8099	Conservation	Dampland	Basin	Bustard Swamp	2.4
8102	Conservation	Dampland	Basin	Sydney Road	9.9
8109 (15901)	Conservation	Dampland	Basin	Lakelands Country club	10.5
8119	Conservation	Dampland	Basin	Bustard North	1.3
8122	Conservation	Dampland	Basin	Damian Road	0.8
8130	Conservation	Lake	Basin	Gnangara lake	117.5
8132	Conservation	Sumpland	Basin	Little Badgerup Lake	5.4
8154	Conservation	Sumpland	Basin	unknown	4.4
8156 (14241)	Conservation	Sumpland	Basin	Brozewing Grove	12.8
8161	Conservation	Sumpland	Basin	Little Mariginup	17.5
8165	Conservation	Sumpland	Basin	Badgerup Lake	23.7
15006	Conservation	Lake	Basin	Jandabup Lake	314.2
7940	Resource Enhancement	Dampland	Basin	unknown	1.8
7941	Resource Enhancement	Dampland	Basin	Little Coogee Swamp	5.1
7942	Resource Enhancement	Dampland	Basin	unknown	1.6
7943	Resource Enhancement	Dampland	Basin	unknown	1.9
7955	Resource Enhancement	Sumpland	Basin	Townsend Road	2.6
8078	Resource Enhancement	Dampland	Basin	unknown	4.4
8081	Resource Enhancement	Dampland	Basin	unknown	0.8
8090	Resource Enhancement	Dampland	Basin	Boundary Road	1.2
8091	Resource Enhancement	Dampland	Basin	Boundary Road	2.9
8092	Resource Enhancement	Dampland	Basin	Gnangara Pine Plantation	33.0
8094	Resource Enhancement	Dampland	Basin	Via Vista Drive	6.4
8095	Resource Enhancement	Dampland	Basin	Meadowlands Drive	27.1

UFI	Management category	Wetland type	Landform	Name	Area (ha)
8101	Resource Enhancement	Dampland	Basin	Gnangara Pine Plantation	1.1
8105	Resource Enhancement	Sumpland	Basin	Ashby Street	1.5
8114	Resource Enhancement	Lake	Basin	Jandabup Lake	17.6
8120	Resource Enhancement	Sumpland	Basin	Damian Road	0.9
8121	Resource Enhancement	Dampland	Basin	Damian Road	5.5
8123	Resource Enhancement	Dampland	Basin	Gnangara Pine Plantation	9.0
8127	Resource Enhancement	Dampland	Basin	Vintage lane	7.3
8162	Resource Enhancement	Dampland	Basin	Rousset Road	5.3
8163 (15443)	Resource Enhancement	Dampland	Basin	Boundary Road	17.3
8258	Resource Enhancement	Dampland	Basin	Gnangara Pine Plantation	2.3
8338	Resource Enhancement	Dampland	Basin	Gnangara Pine Plantation	1.2
14254	Resource Enhancement	Dampland	Basin	Boundary Road	1.6
14261	Resource Enhancement	Dampland	Basin	Boundary Road	1.4
7957	Multiple Use	Lake	Basin	Jandabup Lake	99.3

Table 4: Additional wetlands recommended for investigation and/or retention

UFI	Management category	Wetland type	Landform	Name	Area (ha)
8089	Multiple Use	Dampland	Basin	Boundary Road	6.4
8103	Multiple Use	Sumpland	Basin	Ross Street	5.9
8106	Multiple Use	Dampland	Basin	Carmignani Road	3.0
8107	Multiple Use	Sumpland	Basin	Stoney Road	2.0
8108	Multiple Use	Dampland	Basin	Jambanis Road	17.1
8112	Multiple Use	Dampland	Basin	Lakelands Country Club	5.5
8113	Multiple Use	Sumpland	Basin	Lenzo Court	1.5
8117	Multiple Use	Sumpland	Basin	Little Dundarbar Swamp	11.2

UFI	Management category	Wetland type	Landform	Name	Area (ha)
8118	Multiple Use	Dampland	Basin	Amarante Road	22.4
8128	Multiple Use	Sumpland	Basin	Louise Place	5.4
8153	Multiple Use	Dampland	Basin	Pinesend Farm Swamp	47.5
8155	Multiple Use	Sumpland	Basin	unknown	7.6
15022	Multiple Use	Dampland	Basin	Pennygum Place	38.3

Implications for future development

It will be necessary to understand any cultural heritage values associated with wetlands within each precinct.

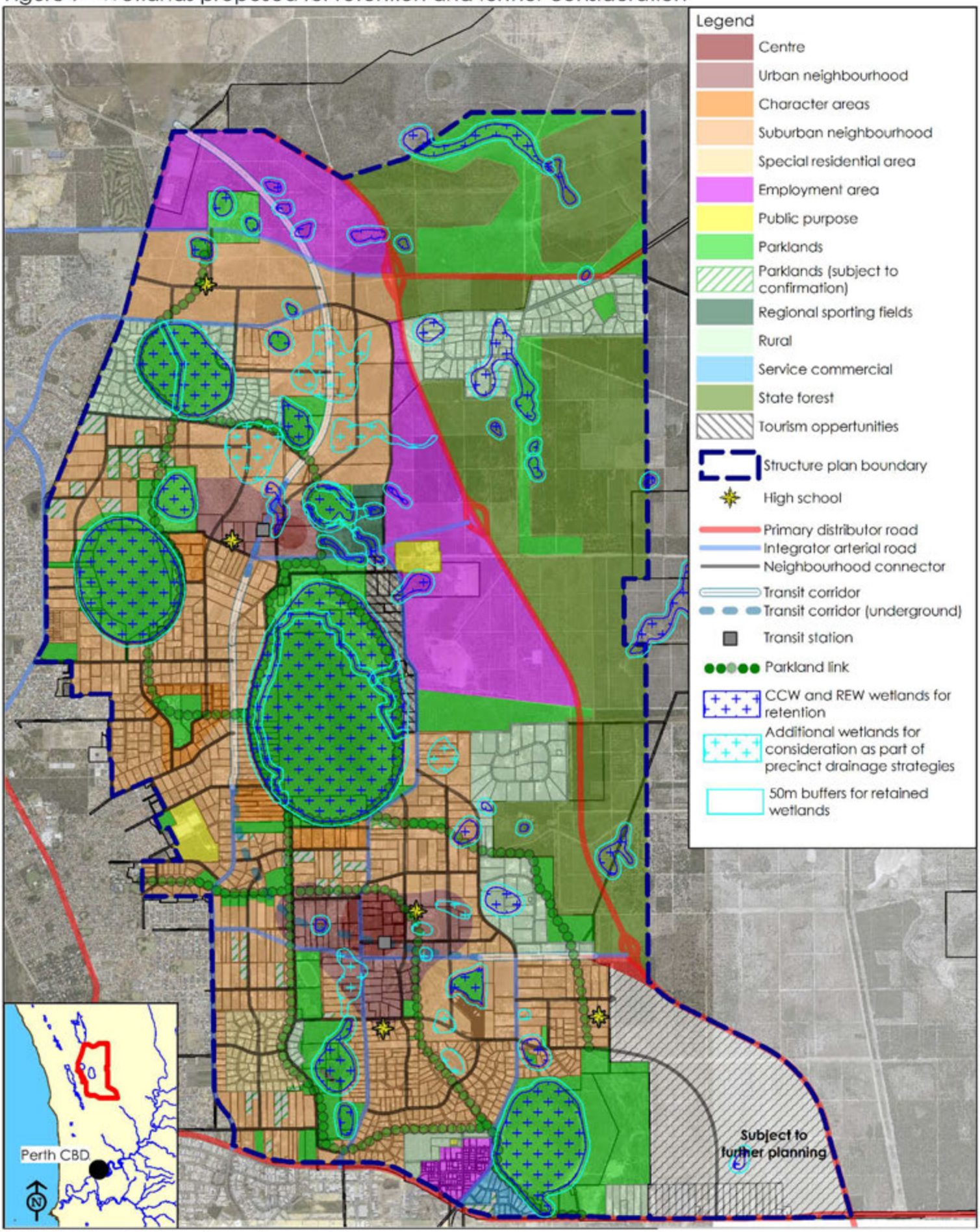
Local structure plans should reflect the proposed inclusion of the high value wetlands (Table 3 and Figure 9) in as reserves for Conservation or Parks and Recreation. Consistent with the East Wanneroo DSP.

Where a precinct contains a wetland identified in

Table 4 (see also Figure 9), a site investigation/evaluation is required to be conducted prior to local structure planning stage to assess wetland values consistent with *A methodology for the evaluation of wetlands on the Swan Coastal Plain, Western Australia* (DBCA 2017a) and *Wetland identification and delineation: information for mapping and land use planning on the Swan Coastal Plain* (DBCA 2017b). The assessment should inform proposed open space areas and future local structure plan design.

Any water management strategies should seek to protect and/or enhance the values of these wetlands. This will need to be demonstrated in Local Water Management Strategies prepared to support local structure plans. Consideration should also be given to the restoration of lower value wetlands that can provide a stormwater management function.

Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 9 - Wetlands proposed for retention and further consideration



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2.5 Surface water

The East Wanneroo DSP area contains no rivers, creeks or other significant waterways.

Surface water within the DSP area is confined to intermittent local flows in shallow agricultural and road drains and, more significantly, surface inundation at the numerous wetlands throughout the area (as discussed previously and shown in Figure 7), although these are more accurately described as surface expressions of the superficial groundwater system.

Implications for future development

Although no natural linear surface water systems currently exist in the study area, it is critical that the future surface water (drainage) strategy acknowledges and addresses the wetlands within the strategy area as discussed above

2.6 Groundwater

The East Wanneroo DSP area is situated on the Swan Coastal Plain approximately 20km north of Perth. The coastal plain in this area is characterised by a succession of north-south linear sand dunes interspersed with wetlands. The Yellagonga Regional Park, containing Lake Joondalup, lies to the west of the site and the Gnangara Underground Water Pollution Control Area overlies the eastern part of the site and extends further to the east.

The highly conductive sandy soils prevalent throughout the DSP area result in a local hydrology that is dominated by infiltration and evapotranspiration with almost no runoff. Infiltrated rainwater directly recharges the Gnangara groundwater system and surface water is generally confined to wetlands dispersed throughout the site which are surface expressions of the Superficial Aquifer in low lying land between elevated sand dunes.

Underlying the Superficial Aquifer are the Leederville and Yarragadee Aquifers and, although these aquifers are generally described as confined aquifers, both are recharged by downward leakage from the Superficial Aquifer at the crest of the Gnangara Mound. This vertical connectivity extends into northern parts of the DSP area. Figure 10 provides a schematic cross section through the East Wanneroo DSP area and underlying groundwater system.

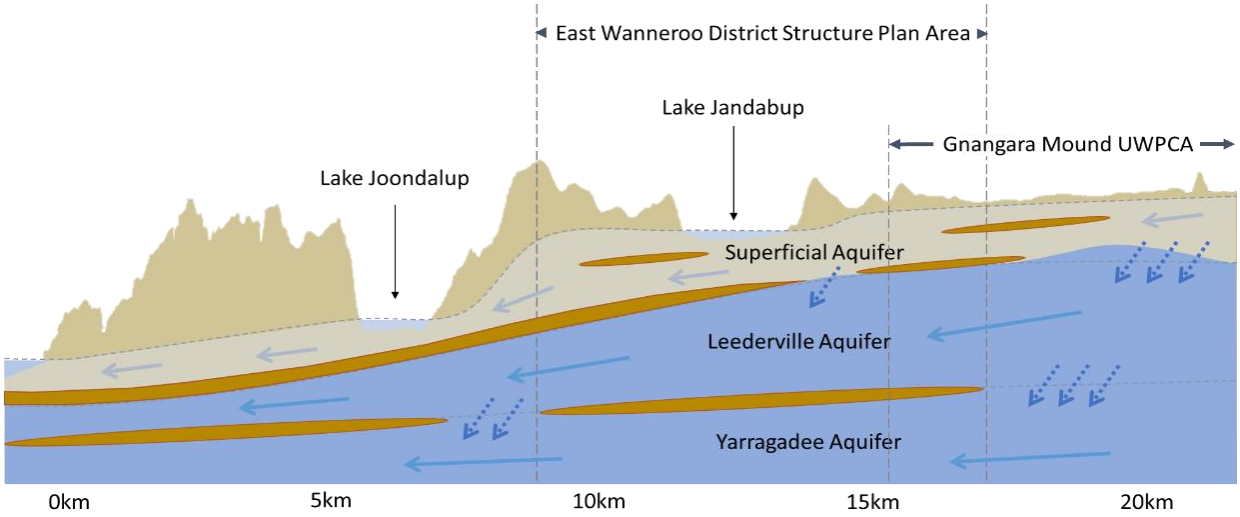


Figure 10: Schematic cross section through the site and underlying groundwater system

2.6.1 *Existing groundwater use*

Groundwater in the DSP area is used for a wide variety of purposes including public drinking water supply, irrigation of public open space and a variety horticultural and agricultural purposes.

Most of the groundwater demands in the DSP area currently are associated with horticultural and agricultural activities as shown in Table 5 which presents a summary of all groundwater licenses (excludes public water supply licenses).

Table 5: Summary of groundwater licenses in relevant subareas

Subarea	Agricultural		Other private users		POS & schools Irrigation		Total allocated volume (kL)
	No of licenses	Licensed volume (kL)	No of licenses	Licensed volume (kL)	No of licenses	Licensed volume (kL)	
Joondalup	15	422,590	8	133,700	3	*137,325	693,615
Mariginiup	171	3,760,240	16	212,835	1	*119,925	4,093,000
Lake Gnangara	171	5,024,997	54	1,226,865	4	35000	6,286,862
Adams	11	175,225	107	850,650	0	0	1,025,875
Jandabup	11	159,980	0	0	0	0	159,980
Total	379	9,543,032	185	2,424,050	8	292,250	12,259,332

* includes volumes held for irrigation of spaces outside the development area

Agricultural activities are likely to cease when development of the land for residential purposes commences. This will result in changing groundwater demands within the DSP area. It is important to consider the likely changes to groundwater demands associated with each stage of development and the potential changes to groundwater levels associated with these changes.

The East Wanneroo DSP identifies three stages of development (Figure 1.16, WAPC, 2019). Based on a review of groundwater licensing in the East Wanneroo DSP area undertaken by DWER, Table 6 summarises groundwater licenses held for agricultural type purposes in each of the proposed three stages of development

Table 6: Agricultural type groundwater licenses in proposed urban areas by stage (08/01/20)

Stage	Subarea	Number of licenses	Volume (kL/year)
1	Joondalup	15	422,590
	Mariginiup	83	1,888,090
	Lake Gnangara	37	1,218,105
	Stage 1 total	***135***	***3,528,785***
2	Mariginiup	88	1,872,150
	Lake Gnangara	72	2,134,117
	Adams	11	175,225
	Jandabup	4	72,380
	Stage 2 total	***177***	***4,253,872***

Stage	Subarea	Number of licenses	Volume (kL/year)
3	Lake Gnangara	62	1,672,775
	Jandabup	7	87,600
	Stage 3 total	***69***	***1,760,375***
Total		***379***	***9,543,032***

2.6.2 *Perth Regional Aquifer Modelling System (PRAMS)*

The Perth Regional Aquifer Modelling System (PRAMS) is a regional scale groundwater model that is used by the DWER to understand and predict changes in groundwater levels and facilitate the sustainable management of groundwater resources. The East Wanneroo DSP area lies within the PRAMS model domain and although the model is not intended to provide predictions of local groundwater level change, it is capable of providing an indication of the risk of groundwater level changes resulting from changes to the major hydrological processes represented in the conceptual water balance discussed above.

PRAMS has therefore been used to provide a preliminary understanding of predicted future groundwater levels in the East Wanneroo DSP area under a range of different scenarios. Some of these scenarios are aimed at understanding the potential outcomes for various possible interventions. In all future scenarios modelled, groundwater levels are predicted to rise with development.

Mapping of the predicted depth to groundwater level predicted by PRAMS modelling scenarios is shown in Figure 11 for the base future scenario (S01) and Figure 12 for the stage 1 developed areas only (S06).

These maps indicate that with no intervention, there will be larger areas where groundwater levels are within 2m of the natural surface and increased inundation of lakes and wetlands following development of stage 1 becoming even more extensive in the longer term following full development of the DSP area.

It is expected that a more detailed groundwater model of the East Wanneroo DSP area will be required to consider these predicted changes in more detail and quantify the likely groundwater level change at a more localised level. This future model can then be used as a design tool to understand the volume of groundwater that may need to be managed in future.

Implications for future development

The key risks to development are associated with predicted groundwater level rise and include waterlogging and loss of amenity or function in parks and other open spaces, damage to infrastructure such as roads, retaining walls and other paved areas, loss of capacity in stormwater management systems, and increased prevalence of mosquitoes and other nuisance insects.

In addition, predicted groundwater level rise has the potential to mobilise nutrients and other contaminants that will need to be managed through development of water management systems incorporating groundwater treatment strategies.

Managing the transition of groundwater use from agricultural needs to irrigation of future public open space will also be critical to ensure the health and wellbeing of the future community.

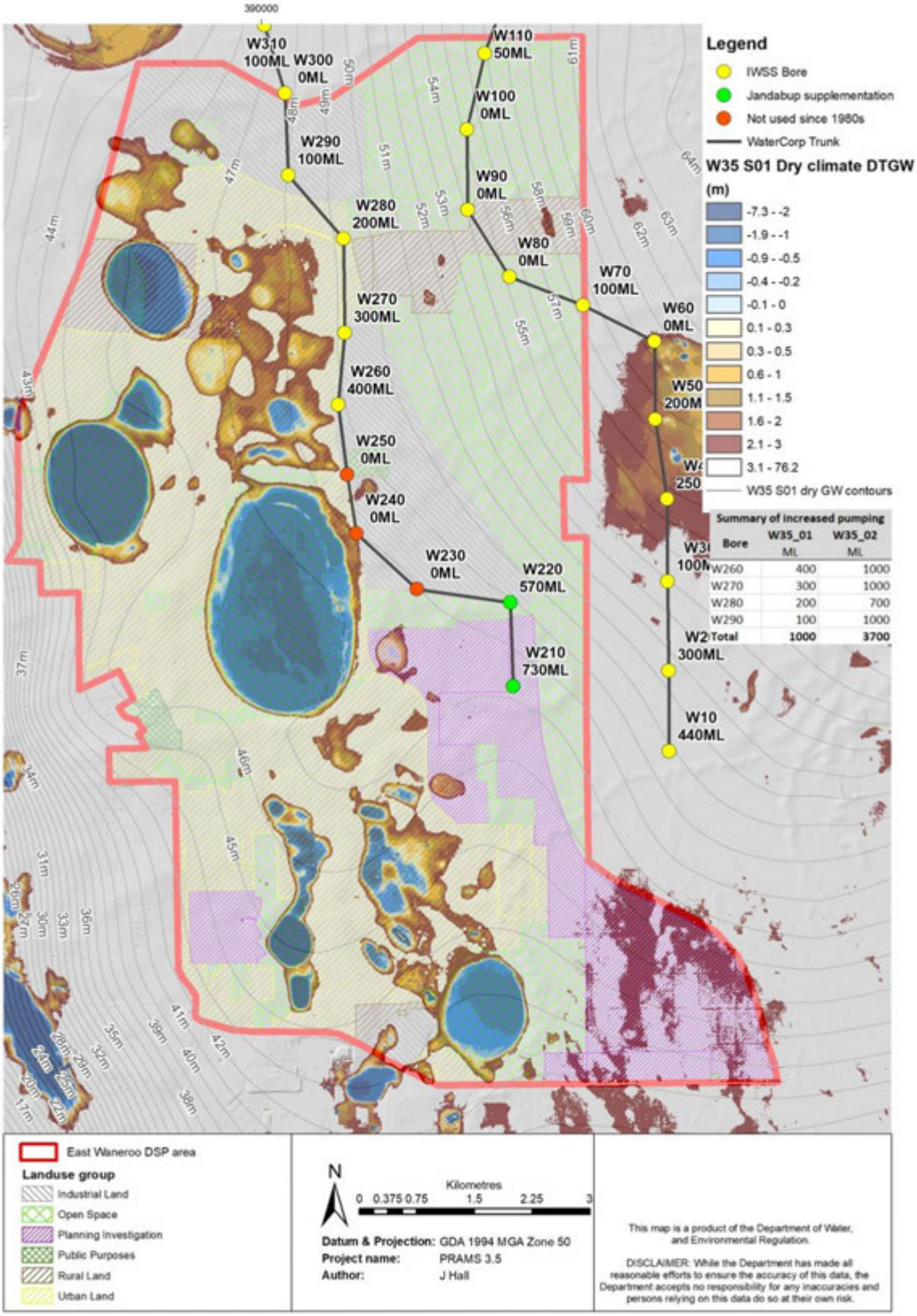


Figure 11: PRAMS Scenario – S01

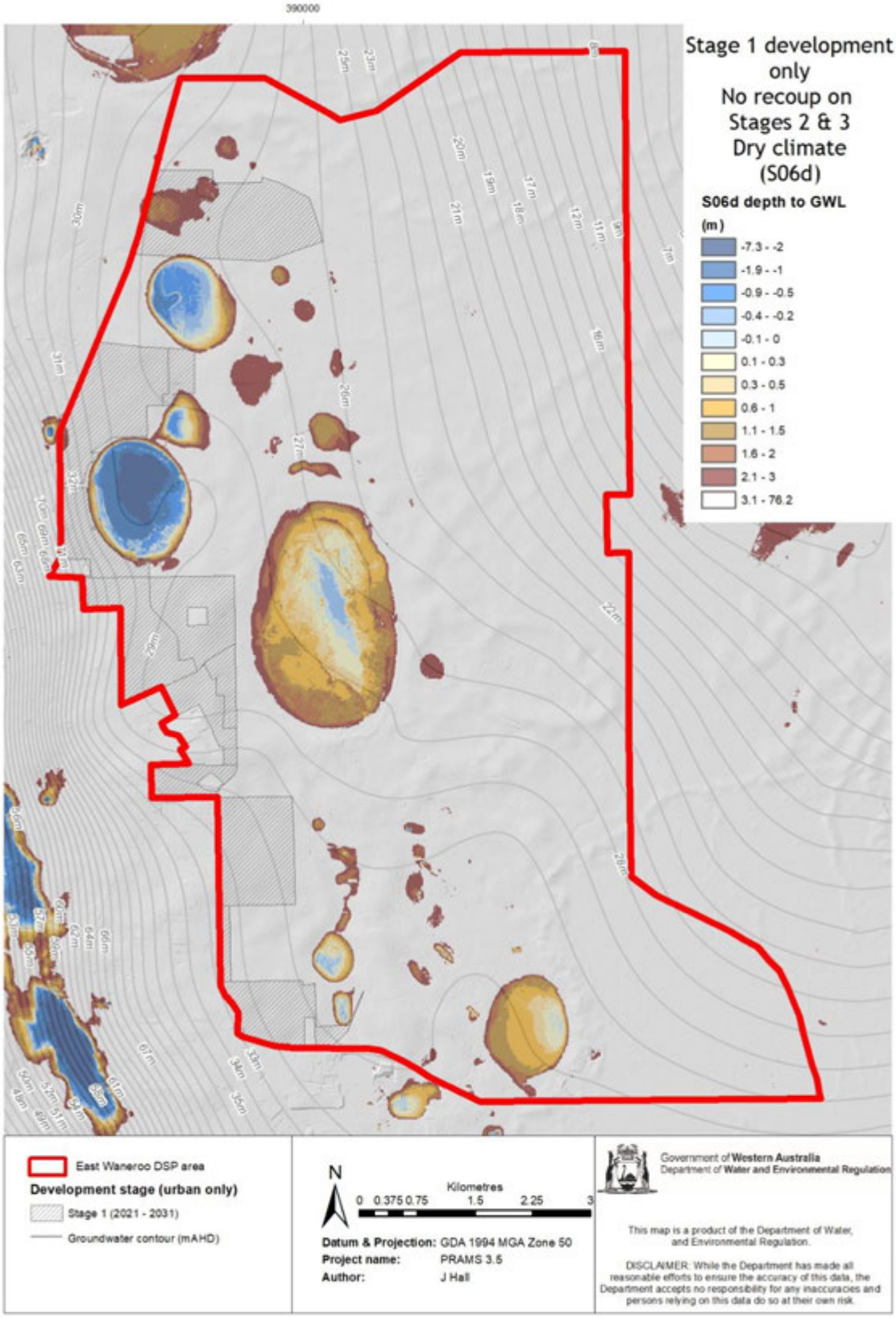


Figure 12: PRAMS Scenario – S06

2.7 Conceptual water balance

Conceptually, to estimate future groundwater level change, a simplified water balance can be utilised to consider the potential impacts of various major hydrological processes and the ways that they will change net recharge following development. The hydrological processes which need to be considered are rainfall, evapotranspiration, surface water runoff and infiltration, groundwater abstraction, lateral groundwater flow, leakage to and from deeper aquifers and infiltration of irrigation water (both returned groundwater and imported scheme water).

In East Wanneroo, where surface water runoff is virtually absent, the expected change in superficial groundwater storage can be represented by the following equation:

$$\Delta V = RE - EVT - \Delta L + \Delta H - A + Irr$$

Where:

- ΔV = change in superficial groundwater storage (net recharge)
- RE = gross recharge from rainfall
- EVT = evapotranspiration
- ΔL = net leakage to confined aquifers
- ΔH = net horizontal groundwater flow into the DSP area
- A = groundwater abstraction
- Irr = Re-infiltration of irrigation using groundwater and/or imported scheme water

In a stable system, where there is no observed change in superficial groundwater storage the equation above would approximately equal zero on an annual timestep.

With changing land use in the East Wanneroo DSP area, several of the hydrological processes identified above may change significantly at a local or district wide scale. The key changes that need to be considered are:

- Changing precipitation rates and patterns resulting from climate change
- Changing evapotranspiration from reduced vegetation cover and climate change
- Increased runoff conveyance and infiltration locations
- Changing groundwater abstraction rates and locations
- Scheme water use for irrigation of private lots

Implications for future development

An understanding of the pre- and post-development water balance is critical to inform development of water management strategies. Some variables also have the potential to significantly influence results and these must be understood, assessed and documented.

2.8 Summary of available water quality data

Available water quality data presented in this report is sparsely located throughout the East Wanneroo DSP area at sites shown in Figure 13. There is a good historic record of water quality information for the most significant wetlands in the DSP area although data is limited to a single site for each wetland. Groundwater quality information is highly limited but reasonable records exist for a selection of sites which have been chosen for the quality, duration and temporal relevance (data recorded within the past 20 years) of the available record.

Nitrogen and Phosphorous data for Lake Gnangara, Lake Jandabup and Mariginiup Lake are presented in Appendix B while available groundwater data close to each wetland is shown as a smaller inset where available.

Analysis of available surface water and groundwater data with reference to ANZECC water quality guidelines reveals the following key observations:

Gnangara

- pH is consistently below recommended levels
- Nitrogen is generally well above recommended levels
- NH4 and TKN appear to be slightly decreasing with time
- NO3/NO2 appears to be slightly increasing with time
- Phosphorous is generally within recommended levels
- There is no discernible trend in Phosphorous levels.

Jandabup

- pH is frequently below recommended levels
- Nitrogen is generally above recommended levels
- There is no discernible trend in Nitrogen levels
- Phosphorous is well within recommended levels
- There is no discernible trend in Phosphorous levels
- Nutrient levels in groundwater are generally lower than in surface water
- Nutrient levels in groundwater generally increase with depth.

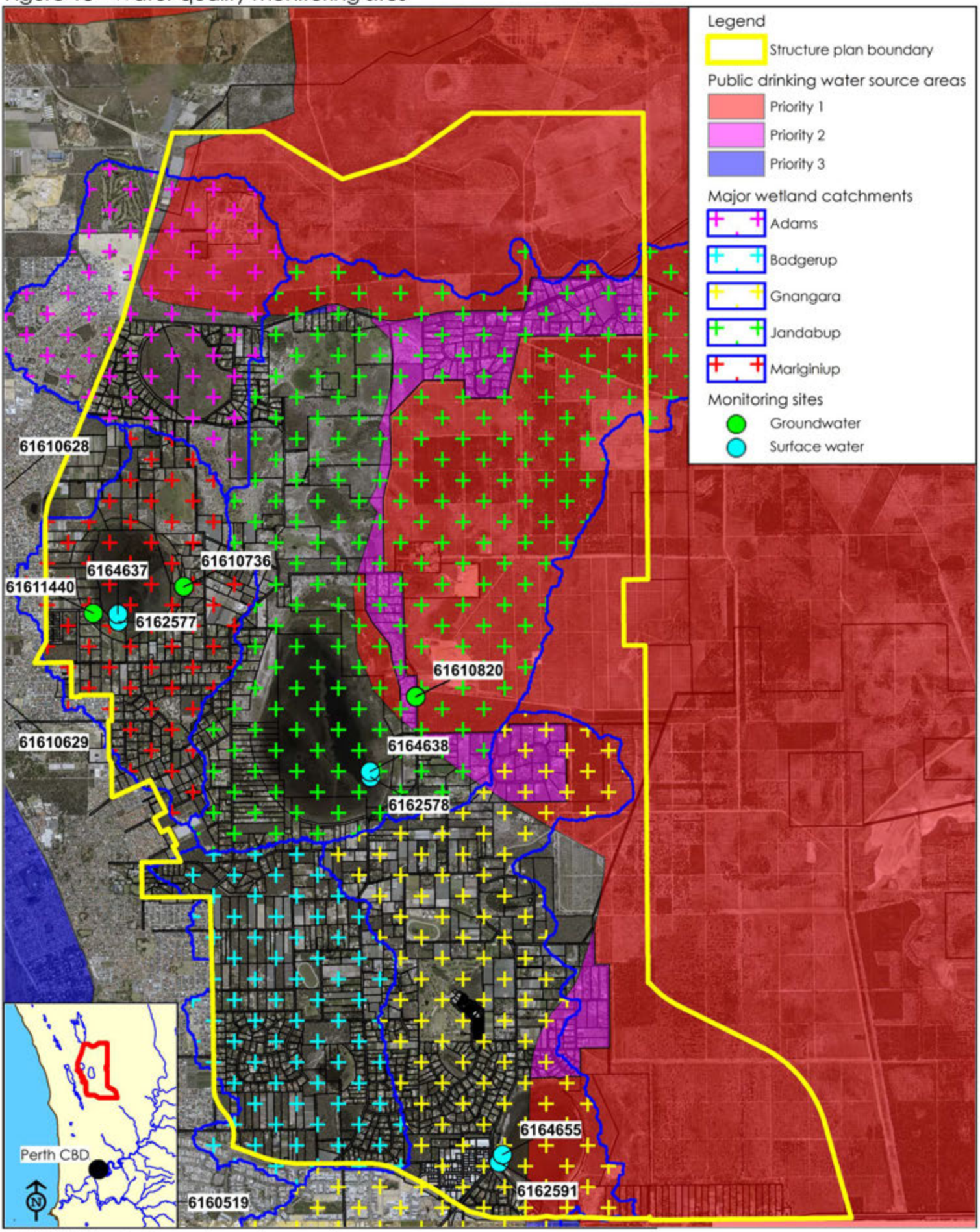
Mariginiup

- prior to 2005 pH was frequently below recommended levels
- Since 2005 pH is consistently below recommended levels
- Nitrogen is generally well above recommended levels
- NH4 and TKN appear to be slightly increasing with time
- There is no discernible trend in NO3/NO2 levels
- Phosphorous is generally within recommended levels
- TP appears to be slightly decreasing with time
- Nutrient levels in groundwater are generally lower than in surface water
- Nutrient levels in groundwater are generally highest at shallow depths and downstream of the lake.

Implications for future development

Areas of poor groundwater quality have the potential to impact on significant wetlands and public drinking water source areas where groundwater is proposed to be exported off site. An understanding of local groundwater quality is required to inform development of water management strategies at a local scale. This will require on-site sampling in all precincts.

Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 13 - Water quality monitoring sites



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2.9 Other environmental considerations

It is recognised that a number of other significant environmental values are present within the East Wanneroo DSP area. These include protected species of flora and fauna and ecological communities, as well as areas of vegetation with cultural or local environmental values. Some guidance is provided in the East Wanneroo DSP and the supporting documents, particularly:

- East Wanneroo DSP Environmental Assessment Study (Emerge, 2018)
- East Wanneroo DSP Strategic Bushfire Hazard Level Assessment (Lush Bushfire and
- East Wanneroo DSP Assessment of Proposed Environmental Outcomes (Emerge, 2019)
- East Wanneroo DSP Preliminary Environmental Assessment of Planning Investigation Areas (Emerge, 2018)
- EPA advice on Metropolitan Region Scheme Amendment 1308/41 in relation to the environmental factors of (a) flora and vegetation and terrestrial fauna (b) inland waters environmental quality, and (c) amenity and human health.

It is noted that the DSP area may contain 'Tuart (Eucalyptus gomphocephala) woodlands and forests of the Swan Coastal Plain' which has been listed as Critically Endangered under the Environment Protection and Biodiversity Conservation Act 1999. Any potential impacts on Matters of National Significance will require referral to the Commonwealth Department of Agriculture, Water, and the Environment.

Implications for future development

Future development will need to understand and address other environmental values within the East Wanneroo DSP area, having consideration of any requirements of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and the State *Environmental Protection Act 1986, Biodiversity Conservation Act 2016,* and *Conservation and Land Management Act 1984*. This may require site specific flora and vegetation surveys which may be associated with particular timings for completion.

3 EAST WANNEROO DISTRICT STRUCTURE PLAN

Delivery of the East Wanneroo DSP requires consideration of the risks of land use change on water resources as well as the potential for water resources to impact on the proposed development.

3.1 Assessment of risks to water resources

Land uses and land use change present water related risks to the environment and water resources. Land uses in the East Wanneroo DSP that have the potential to impact on water resources are as follows. These are mapped in Figure 14 based on the East Wanneroo DSP.

- District and neighbourhood centres (high density urban residential and commercial)
- Urban neighbourhoods and Character areas (medium to high density urban)
- Suburban neighbourhoods (low to medium density urban)
- Special residential neighbourhoods (low density urban)
- Remaining rural land
- Industrial
- Parkland and regional sporting fields
- Tourism opportunities

In East Wanneroo, the following risks to high value water resources from existing and proposed land uses and land use change have been identified:

Water quality risks to public drinking water source areas:

- Existing land uses incompatible with public drinking water source priority areas
- Proposed land uses incompatible with public drinking water source priority areas
- Installation of drainage systems potentially mobilising legacy contamination.

Water quantity risks to public drinking water source areas:

- Changing patterns of groundwater use resulting from land use change
- Changing patterns of groundwater recharge resulting from land use change.

Water quality risks to wetland health:

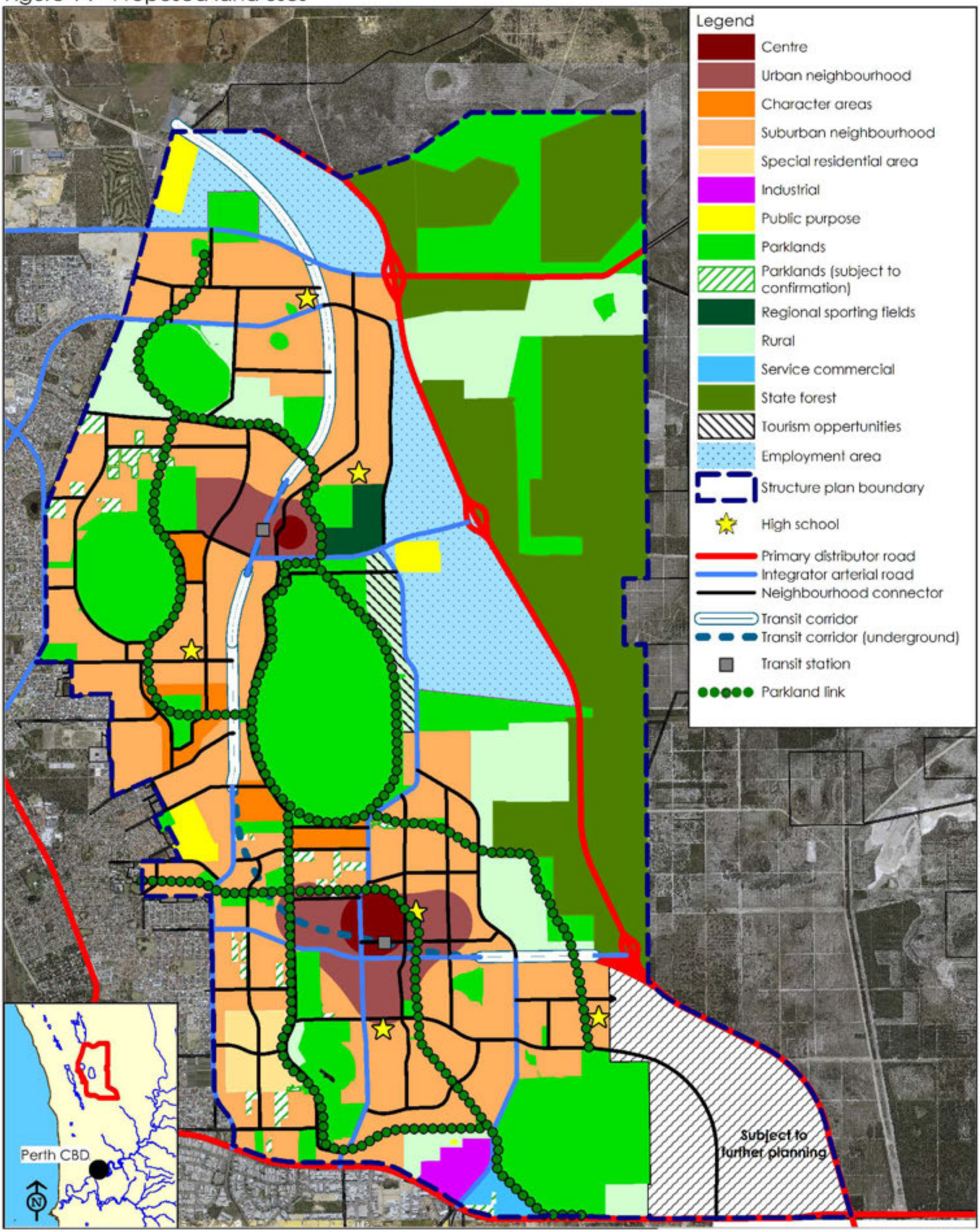
- Presence and management of existing land uses
- Presence and management of proposed land uses
- Installation of drainage systems potentially mobilising legacy contamination.

Water quantity risks to wetland health:

- Reduced groundwater abstraction, combined with reduced evapotranspiration and increased impervious areas potentially leading to groundwater level rise
- Topographic modification (cutting and filling the land) altering wetland hydrology
- Installation of drainage systems potentially altering wetland hydrology.

It is noted that many of these risks will be affected by and, in some cases, worsened by the effects of climate change. Whilst it is not intended to minimise the importance of this increased risk, the primary focus of this report is understanding and managing the risks presented by land uses and land use change. However, where a risk has the potential to be increased by climate change effects and/or where there is an opportunity for management strategies to contribute to mitigation of climate change effects, those issues and opportunities should be identified.

Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 14 - Proposed land uses



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3.1.1 *Water quality risks to Public Drinking Water*

As shown in Table 7, there are a number of land uses that have the potential to present risks to water quality and public health that are proposed to be located within public drinking water source areas.

It is noted that Industrial land uses are not supported in public drinking water source areas, therefore MRS rezoning to industrial land use would require the land to be excised from the public drinking water source area and public drinking water supply would cease from affected bores.

An assessment of land uses within mapped public drinking water source areas has been undertaken based on land use compatibility tables provided in *Water quality protection note no. 25: Land use compatibility tables for public drinking water source areas* (DWER, 2016) (WQPN 25) to consider the water quality risks presented by existing land uses. This assessment resulted in some changes to the land uses proposed in the draft East Wanneroo DSP.

Industrial land uses proposed in the draft East Wanneroo DSP have been removed and replaced with Employment areas. In these areas, land uses proposed in local structure plans and subdivisions are required to be compatible with WQPN 25 and WQPN 38.

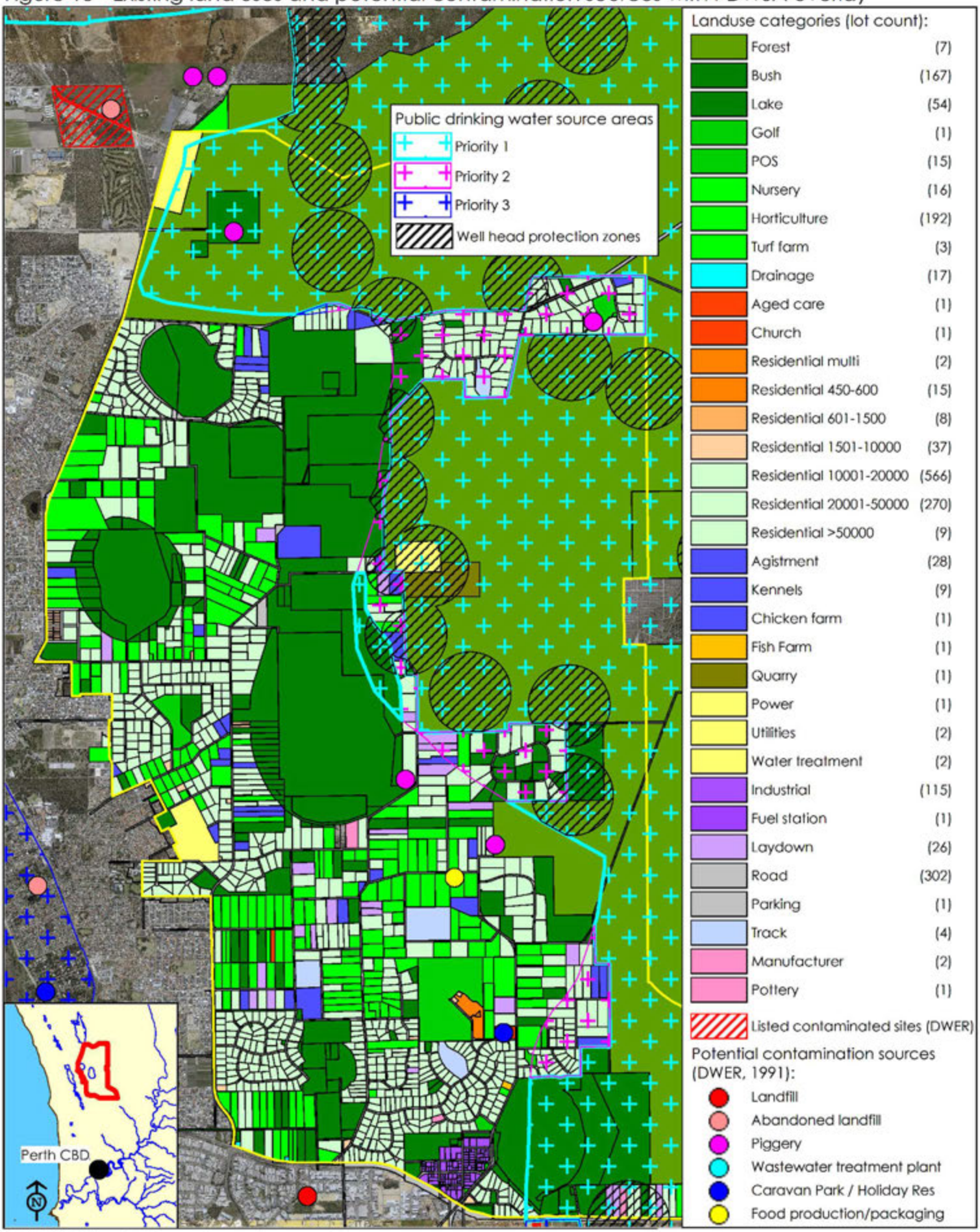
It is anticipated that rezoning of land within public drinking water source areas to any urban land uses will trigger reclassification of areas of P1 and P2 to P3*, as outlined in WQPN 38, and all developments will require connection to deep sewerage.

Table 7: Proposed land use category areas (Ha) by public drinking water source area priority

Land use category	P1	P2	P3	Other areas	Total
Centre	0	0	0	63	63
Character areas	0	0	0	129	129
High priority vegetation area	0	0	0	96	96
Employment areas	696	23	0	76	795
Intersection area	11	1	0	0	12
Public purpose	21	0	0	32	53
Regional open space	759	14	0	1149	1922
Regional sporting fields	0	13	0	34	46
Rural	27	384	0	268	680
Service commercial	2	0	0	24	25
Special residential area	0	0	0	81	81
State forest	1401	0	0	83	1484
Subject to further planning	545	0	0	0	545
Suburban neighbourhood	213	118	2	1975	2309
Urban neighbourhood	0	0	0	301	301
Totals	3674	552	2	4311	8539

Figure 15 and Figure 16 present mapping of existing and proposed land uses within public drinking water source areas.

Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 15 - Existing land uses and potential contamination sources with PDWSA overlay



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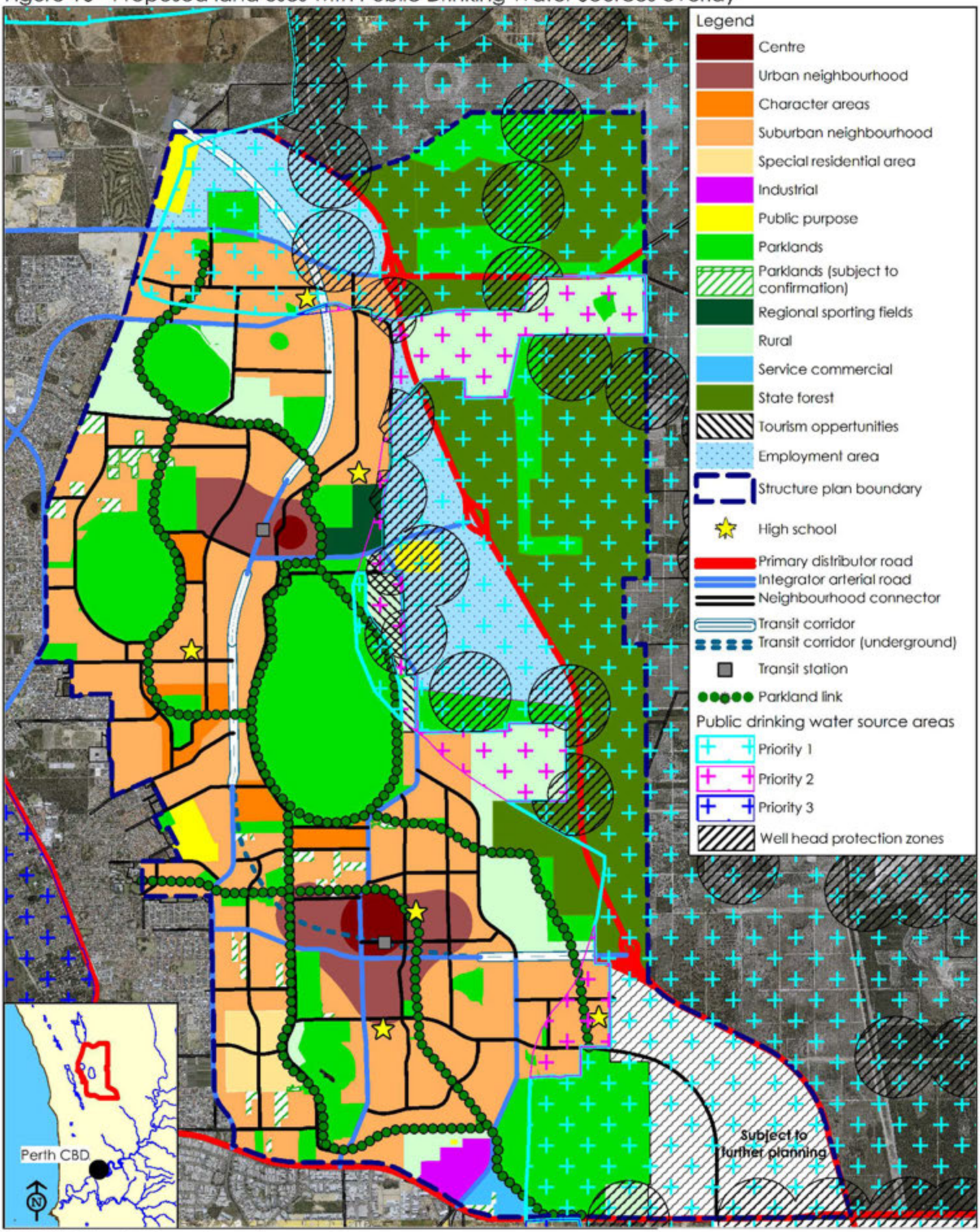
Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 16 - Proposed land uses with Public Drinking Water Sources overlay



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The land use breakdown currently proposed within public drinking water source areas is presented in Table 8 with an indication of its compatibility with current priority areas in accordance with WQPN 25 (red = incompatible, orange = compatible with conditions, green = acceptable). Areas currently shown as incompatible will require reclassification of areas of P1 and P2 to P3* and all developments will require connection to deep sewerage.

Table 8: Compatibility of proposed land use category (Ha) areas with current PDWSA priority

Land use category	P1	P2	P3	Notes
Regional sporting fields	0	13	0	
Suburban neighbourhood [2]	213	118	2	
Rural	27	384*	0	*Rural/smallholdings/agricultural lot sizes>4ha and rural living /rural residential lot sizes >2ha Smaller lot sizes are incompatible with both P1 and P2
Employment areas	696	23	0	
Service commercial	2	0	0	
Public purpose	21	0	0	
Intersection area	11	1	0	
State forest	1401	0	0	
Regional open space	759	14	0	
Subject to further planning	545	0	0	
Totals	***3,674***	***552***	***2***	

Within the boundaries of the public drinking water source areas, the East Wanneroo DSP proposes approximately 1,700Ha of land uses that have the potential to present current and future risks to the public drinking water source areas. Of these, approximately 1,000Ha could be considered likely to present risks based on their incompatibility with PDWSA priority areas taken from WQPN 25 which represents a ten-fold increase in high risk land uses. In addition, whilst the land uses proposed in precinct 25 have not yet been defined, there may be a further 500 hectares of potentially incompatible land uses proposed in this area.

Australian Drinking Water Guidelines V3.4 (NHMRC 2011) provides guidance for a structured approach to identification of potential water quality hazards and their sources. Table 9 presents the outcomes of applying this guidance to the land uses proposed in the East Wanneroo DSP that are incompatible with current priority levels and notes the recommended hazard reduction strategies required to mitigate the risks. This includes consideration of guidance provided in WQPN38 to enable land uses incompatible with P1 and P2 areas to be accepted in P3* areas.

It is noted that certain land uses, including light, heavy and rural industry, are not recommended in P3* areas. Therefore, these land uses will need to be excluded even with implementation of the hazard reduction strategies outlined in Table 9.

Table 9: Potential water quality hazards & hazard reduction strategies

Land use	Potential water quality hazards	Notes and hazard reduction strategies
Regional sporting fields	• Pesticides • Fertiliser nutrients • Mobilisation of legacy contaminants via urban drainage systems • Pathogens and nutrients from sewerage leaks and overflows	Best fertilizer and pesticide management practices should be applied to regional sporting fields within the PDWSA consistent with WQPN38. Where a previous land use presents a risk of legacy contamination (as identified in Table 8 and Figure 15), development will be required to undertake site specific investigations consistent with WQPN38 and remediate and/or provide additional treatment measures as required.
Suburban neighbourhood	• Lead and zinc from road runoff • Petrol/oil products from road runoff, accidents and storage/leaks • Microorganisms from pets • Pesticides and fertiliser nutrients from gardens • Pathogens and nutrients from sewerage leaks and overflows • Mobilisation of legacy contaminants via urban drainage systems	Implementation of best practice water sensitive urban design strategies to treat all urban runoff prior to infiltration or discharge will be required within PDWSAs consistent with WQPN38. Implementation of community education strategies to promote best practice landscape management will be a requirement of development within PDWSAs consistent with WQPN38. Sewerage plans for areas within PDWSA's will be required to include a risk assessment process consistent with WQPN38 that considers locations of wellhead protection zones (WHPZs, as shown in Figure 15) and gives them the highest protection. Where a previous land use presents a risk of legacy contamination (as identified in Table 8 and Figure 15), development will be required to undertake site specific investigations consistent with WQPN38 and remediate and/or provide additional treatment measures as required.
Rural	• Pathogens, nitrates/nitrites from septic tanks and livestock • Lead and zinc from road runoff • Petrol/oil products from road runoff • Microorganisms from pets and livestock • Pesticides and fertiliser nutrients	Rural areas proposed by the DSP are a continuation of the existing land use in a reduced area. ADWG notes that human and animal waste represent the largest sources of potential hazards in drinking water. There are opportunities for improved management of water quality in these areas as an outcome of surrounding planning and development including connection of existing rural properties to reticulated sewerage.
Employment areas*	• Heavy metals • Organic chemicals including halogenated organics • Other contaminants related to specific industries • Pathogens, nitrates/nitrites from septic tanks (where the area is unsewered) • Pathogens and nutrients from sewerage leaks and overflows • Mobilisation of legacy contaminants via urban drainage systems	Implementation of best practice water sensitive urban design strategies to treat all urban runoff prior to infiltration or discharge will be required within PDWSAs consistent with WQPN38. Where a specific activity presents a risk of contamination planning of service commercial areas within PDWSA's will be required to include a risk assessment process consistent with WQPN38. All employment areas within PDWSA will be required to connect to reticulated sewerage. Sewerage plans for areas within PDWSA's will be required to include a risk assessment process consistent with WQPN38 that considers locations of wellhead protection zones (WHPZs, as shown in Figure 15) and gives them the highest protection. Where a previous land use presents a risk of legacy contamination (as identified in and Figure 15), development will be required to undertake site specific investigations consistent with WQPN38 and remediate and/or provide additional treatment measures as required.

Land use	Potential water quality hazards	Notes and hazard reduction strategies
Service commercial*	• Lead and zinc from road runoff • Petrol/oil products • Other contaminants related to specific activities • Pathogens and nutrients from sewerage leaks and overflows • Mobilisation of legacy contaminants via urban drainage systems	Implementation of best practice water sensitive urban design strategies to treat all urban runoff prior to infiltration or discharge will be required within PDWSAs consistent with WQPN38. Where a specific activity presents a risk of contamination planning of service commercial areas within PDWSA's will be required to include a risk assessment process consistent with WQPN38. Sewerage plans for areas within PDWSA's will be required to include a risk assessment process consistent with WQPN38 that considers locations of wellhead protection zones (WHPZs, as shown in Figure 15) and gives them the highest protection. Where a previous land use presents a risk of legacy contamination (as identified in and Figure 15), development will be required to undertake site specific investigations consistent with WQPN38 and remediate and/or provide additional treatment measures as required.
Subject to further planning	• All of the above, depending on final land use mix	As above.

**Note: WQPN38 recommends that most Industrial and Service Commercial land uses are avoided in P3* areas.*

3.1.2 *Water quantity risks to Public Drinking Water*

As discussed above, the risks to public drinking water source areas from land uses considered in this report are principally associated with water quality. It is noted; however, that unmanaged changes to groundwater consumption resulting from land use change may present water quantity risks and opportunities.

DWER, as the state's water resource manager has responsibility for considering the implications of land use change in relation to water quantity in public drinking water source areas including setting and managing of groundwater allocation limits in these and other areas. Therefore, whilst the following risks are noted and their implications for drainage management within the entire DSP area will be considered as a part of future work, they are not addressed further by this report:

- Changing patterns of groundwater use resulting from land use change
- Changing patterns of groundwater recharge resulting from land use change.

3.1.3 *Water quality risks to wetlands*

Table 10 below provides a comparison of the proportion of higher risk land uses in major wetland catchments and the available water quality data. It can be observed that Lake Jandabup, which has the lowest proportion of exiting higher risk land uses, currently appears to be the healthiest of the wetlands. Lakes Gnangara and Mariginiup both have relatively high proportions of existing higher risk land uses and have generally higher levels of both Nitrogen and Phosphorous as well as experiencing acidic conditions more consistently.

No water quality data has been identified at this time for Lakes Adams and Badgerup. The proportion of higher risk land uses in their catchments may indicate that Lake Adams may be expected to reasonably healthy whilst Lake Badgerup may be expected to be less healthy, consistent with the observations at other wetlands.

Table 10 also includes an assessment of the proportion of higher risk land uses that are proposed in each catchment under the East Wanneroo DSP. Whilst these higher proportions do not necessarily indicate deteriorating wetland health it is important to consider this change as an increased risk to wetland health and implement actions to monitor and protect wetland health.

Table 10: Wetland land use and water quality snapshots

	Adams	Badgerup	Gnangara	Jandabup	Mariginiup
Total catchment area (Ha)	647	798	1352	2785	760
Existing higher risk land use areas (Ha)	237	642	885	731	517
% high risk land use	**37%**	**80%**	**65%**	**26%**	**68%**
pH	No data available		Acidic	Moderately acidic	Acidic
Nitrogen	No data available		High	Moderate	High
Phosphorous	No data available		Low	Low	Moderate
Proposed higher risk land use areas (Ha)	478	612	955	1557	491
% high risk land use	**74%**	**77%**	**71%**	**56%**	**65%**

Nutrient export assessment (applying UNDO)

An assessment of exported nutrients for each major wetland catchment has been undertaken using DWER's Urban Nutrient Decision Outcomes (UNDO) tool to provide an understanding of the baseline nutrient loads per hectare in each catchment. The land use breakdowns presented in Table 11 have been used to construct each UNDO catchment model assuming that all catchments have infiltration based drainage systems and Bassendean soils with an average of 3m to groundwater. Septic tanks have been included in this assessment of the pre-development conditions based on a simple allocation of 1 septic tank per residential or rural residential lot. For each wetland, an indicative objective has been assigned for both nitrogen and phosphorous and this has been informed by the water quality data summaries presented in section 2.8.

Table 11: Higher risk proposed land use areas (Ha) in wetland catchments

Land use category	Adams	Badgerup	Gnangara	Jandabup	Mariginiup
Centre	0	24	26	13	0
Character areas	0	5	22	46	56
Industrial	61	0	46	435	0
Public purpose	0	7	1	29	8
Regional sporting fields	0	0	0	46	0
Rural	108	11	211	321	0
Service commercial	0	0	25	0	0
Special residential area	0	81	0	0	0
Suburban neighbourhood	305	373	534	600	399
Urban neighbourhood	4	110	90	68	28
Totals	***478***	***612***	***955***	***1557***	***491***

The assessment presented in Table 12 aims to provide a preliminary basis for assessment of new development proposals only, noting that exported loads are estimated across whole catchments and will vary. Estimates of pre- and post-development exported nutrient loads and objectives for development should be refined in local water management strategies for each development precinct.

Table 12: Wetland UNDO results and water quality objectives

Wetland name	Exported nitrogen load (kg/hectare)	Objective for nitrogen	Exported phosphorous load (kg/hectare)	Objective for phosphorous
Adams	2.83	Maintain	0.06	Maintain
Badgerup	5.80	Reduce	0.14	Maintain
Gnangara	5.48	Reduce	0.11	Maintain
Jandabup	2.23	Maintain	0.04	Maintain
Mariginiup	4.99	Reduce	0.12	Maintain

3.1.4 Water quantity risks to wetlands

Current projections indicate that development in East Wanneroo will result in significant groundwater level rise. This is caused by a combination of increased local runoff and recharge from urban land uses and reduced local abstraction for irrigation as horticulture ceases. The modelled rises could be exacerbated by the discontinuation of current rates of drinking water abstraction from local bores which is the likely outcome of urbanisation as water quality risks are increased. The high value wetlands and areas of significant native vegetation, particularly Banksia woodland, in the East Wanneroo DSP area are highly vulnerable to changes in surface and groundwater beyond threshold levels. The ongoing health of these significant environmental assets will rely on the implementation of integrated and adaptive water and environment management systems across the entire East Wanneroo DSP area.

In order to assess the potential for groundwater rises to impact on wetlands (as well as future development, see next section), a broad scale water balance has been constructed. Table 13 and Chart 9 present a summary of the groundwater fluxes and the ways that they may change following development. This provides an indication of the potential increase to net recharge that may be expected in the East Wanneroo DSP area. This information should be used to inform future modelling and preparation of local water management strategies.

It should be noted that groundwater abstraction for scheme water supply has not been included in this summary and it is expected that this would reduce the net recharge.

The estimated 30% uptake of unlicensed backyard bores, and the demand from them is a critical component of the water balance shown in Table 13 and if abstraction rates are closer to the 800 kL/yr/dwelling estimated by Davidson and Yu in 2006, the balance could remain more consistent with the pre-development balance.

Table 13: Conceptual annual flux summary for the superficial aquifer in East Wanneroo

	Pre-development (ML)	Post-development (ML)
Rainfall	66,136	66,136
Inputs		
Gross recharge from rainfall	33,583 (93%)	38,964 (98%)
Groundwater recharge from irrigation returns	2,452 (7%)	929 (2%)
Outputs		
Evapotranspiration	19,554 (49%)	24,290 (55%)
Groundwater abstraction	12,547 (31%)	7,250 (22%)
Vertical leakage to deeper aquifers	6,234 (15%)	6,234 (18%)
Net horizontal through-flow	1,829 (5%)	1,829 (5%)
Net change in storage (net recharge)	-4,054 ML	7,228 ML

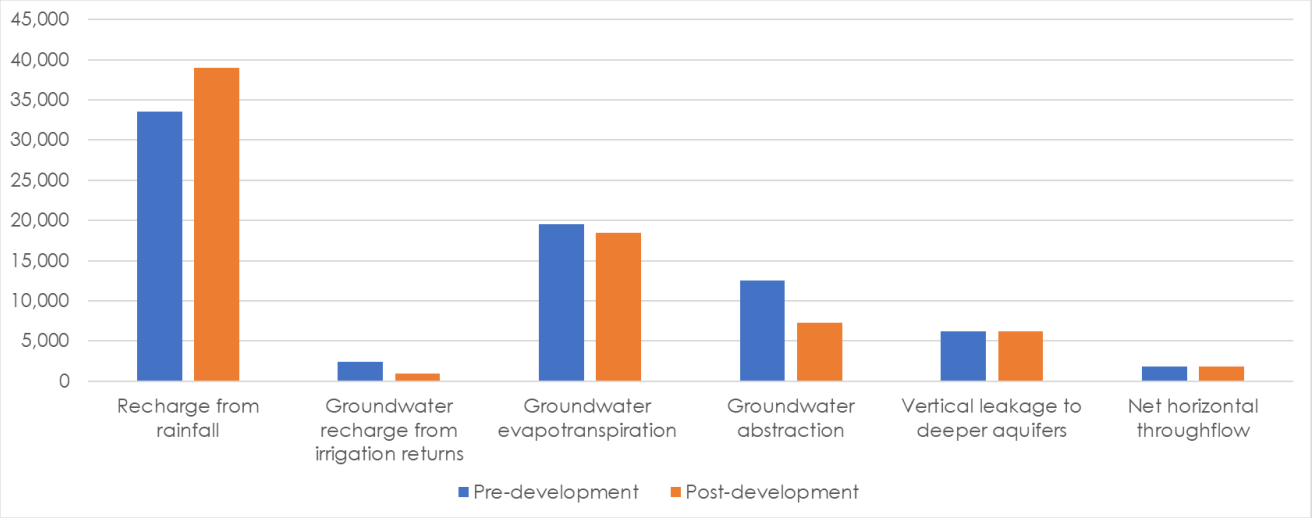

Chart 9: Conceptual annual flux summary for the superficial aquifer in East Wanneroo

A predevelopment 1-dimensional surface water model of the East Wanneroo DSP area has been constructed to provide an estimate of the likely volumes and top water levels in key wetlands during minor and major flood events. These top water levels and volumes are used for comparative purposes only to provide an understanding of the magnitude of likely change resulting from development. Appendix D provides further technical details of the surface water modelling undertaken for this study.

Table 14 provides a comparison between pre- and post-development modelled top water levels in key wetlands. Mapping showing a comparison of inundated areas is provided in Figure 17 to Figure 21. It is noted that the increase in top water levels from the storage of surface water from major and minor events is not considered to be significant.

Table 14: Comparison of top water levels in key wetlands resulting from stormwater storage

Wetland	Pre-development	Post-development	Difference
Adams	44.44	44.39	-50mm
Badgerup	42.46	42.34	-120mm
Gnangara	42.90	43.30	+400mm
Jandabup	45.40	45.42	+20mm
Mariginiup	42.86	43.00	+140mm

Note: this analysis considers the impact of storage of the 1% AEP stormwater event within wetlands associated with the antecedent groundwater level set at AAMGL (1986-95).

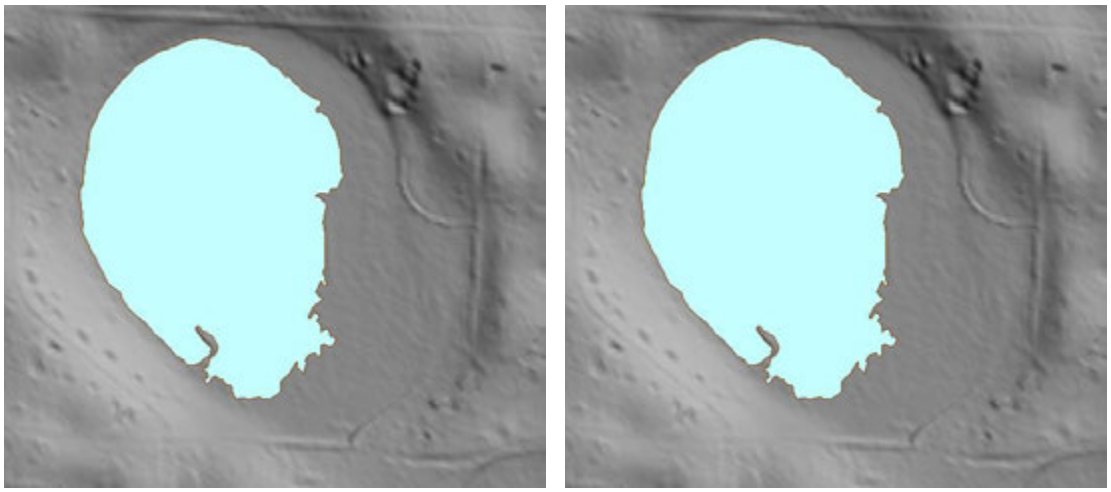

Figure 17: Lake Adams – predevelopment (left) and post-development (right) 1%AEP inundation

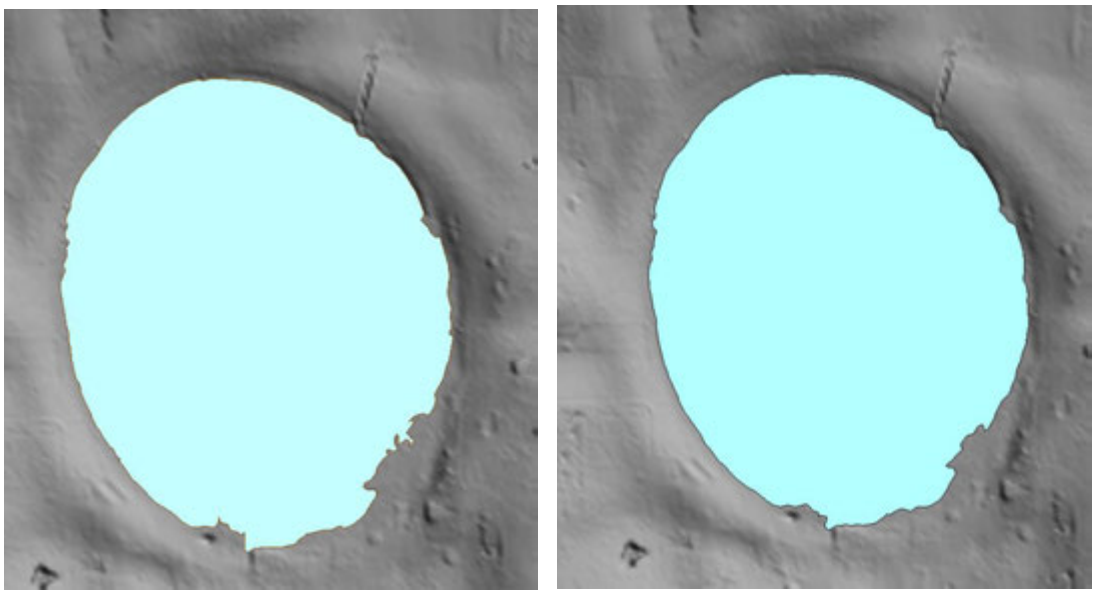

Figure 18: Mariginiup Lake – predevelopment (left) and post-development (right) 1%AEP inundation

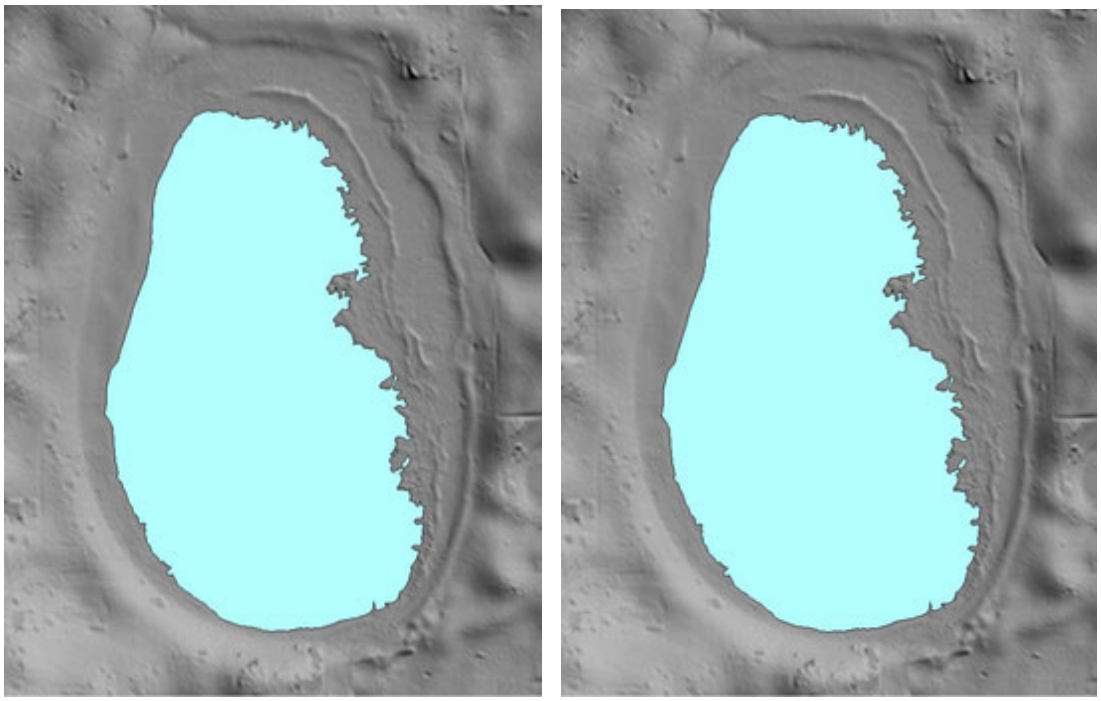

Figure 19: Jandabup Lake – predevelopment (left) and post-development (right) 1%AEP inundation

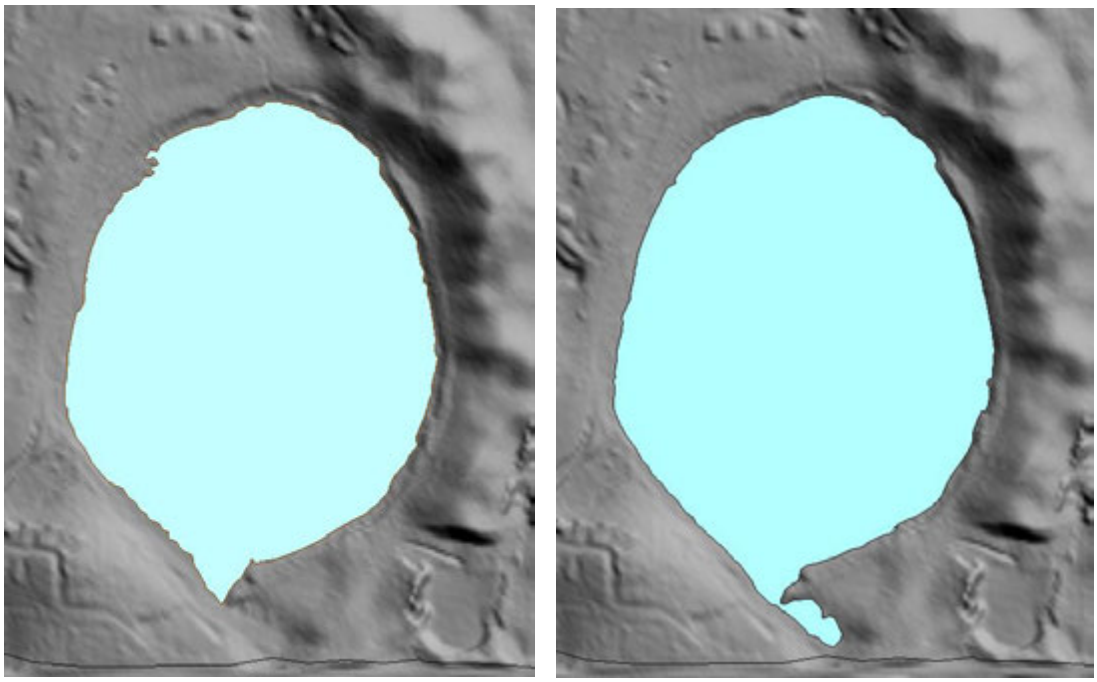

Figure 20: Lake Gnangara – predevelopment (left) and post-development (right) 1%AEP inundation

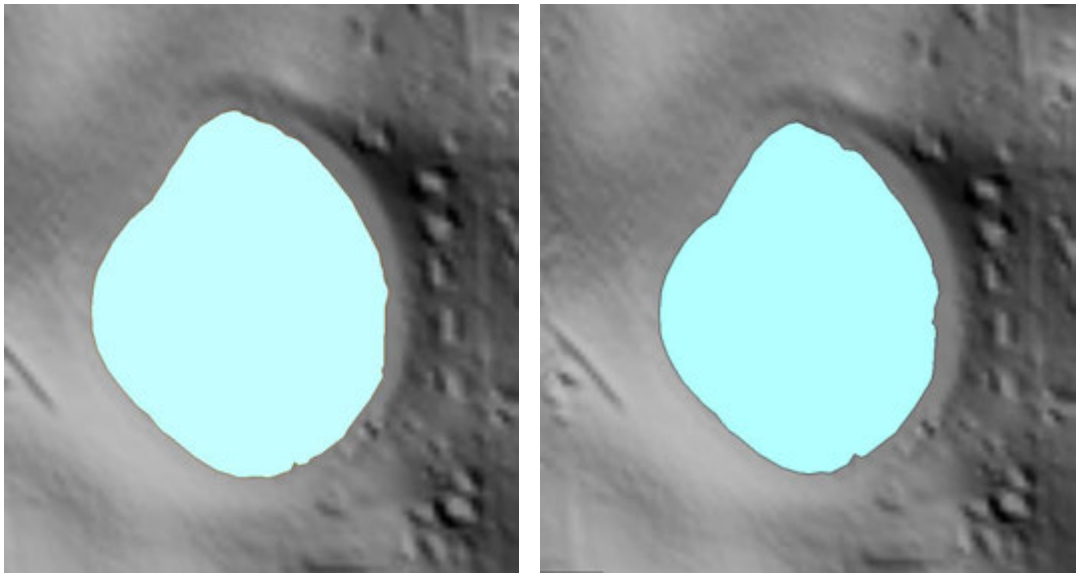

Figure 21: Badgerup Lake – predevelopment (left) and post-development (right) 1%AEP inundation

3.2 Assessment of risks to development

As noted above, the principal risk to development is the predicted rise in groundwater. This has been demonstrated through a broad-scale water balance which has assessed the water-related implications of the proposed land use change. Critical aspects of this assessment are outlined below.

Other risks from water resources on future development include:

- Flooding and inundation from small, minor and major flood events and impacts of rising groundwater on system capacity and performance;
- Acid Sulfate Soil risks from changes in groundwater levels including dewatering;
- availability of groundwater for irrigation of future public open space;
- Restricted infiltration of stormwater where inundated by groundwater; and
- Impacts to retained vegetation from future groundwater level rise.

These risks will need to be understood and addressed as part of local structure planning in order to meet the water management objectives contained in this Strategy (Section 4). Strategies for mitigating these risks are described in Section 5 and should be implemented in accordance with Section 6.

The DWMS will need to undergo periodic review to ensure that it remains relevant and can be changed if necessary, in response to the selection of a district level groundwater scheme which will be undertaken prior to local structure planning. This may include revision of design objectives to achieve targets, changes to size and location of land and infrastructure for stormwater and groundwater management and flooding, or revise the proposed land use and layout if initial performance is not as intended or another threat arises.

3.2.1 Water balance modelling

Future modelling will need to be undertaken to understand the way the area responds to rainfall and inform the land requirements and criteria for stormwater management and flooding in the urban form and interaction with district-scale groundwater management

approaches. This needs to be done before local structure planning to ensure the size and location of land is identified and mechanisms put in plan to secure the land.

Future modelling will need to consider and demonstrate an understanding of the major hydrological processes affecting the groundwater system in the East Wanneroo DSP area and how these will change with development. These include recharge, runoff, evapotranspiration, abstraction, scheme water use and groundwater flows. The following sections provide a summary for consideration as part of local structure planning.

Recharge

Recharge, in broad terms, is the proportion of rainfall that infiltrates into the ground and reaches the water table. There are several different terms used to describe recharge, each of which either include or exclude various hydrogeological processes. The terms most frequently encountered are:

- **Potential recharge** (also sometimes referred to as deep drainage) is the amount of rainfall that infiltrates beyond the rootzones of most vegetation and therefore is equal to rainfall minus runoff and surface evapotranspiration processes.
- **Gross recharge** is the amount of rainfall that reaches the water table after interflow losses and therefore is equal to the potential recharge minus interflow lost horizontally through the unsaturated zone. Interflow losses in East Wanneroo are expected to be close to zero.
- **Net recharge** is the net amount of water that is contributed to the water table over the timestep considered and therefore is equal to gross recharge minus evapotranspiration and other losses including abstraction, vertical leakage and drainage from groundwater into surface water systems. In a steady state system, net recharge is expected to be close to zero on an annual timestep but will vary seasonally.

The principal mechanisms that may be expected to result in changes to net recharge rates and distribution in East Wanneroo are:

- construction of impervious surfaces increasing runoff
- clearing of vegetation causing reduced evapotranspiration
- reduced abstraction resulting from changing land uses
- scheme water use for irrigation of residential lots

Gross recharge has been estimated for the purposes of this study by applying published recharge rates for existing and proposed land uses. The gross recharge rates applied in this calculation are presented in Table 15 below and result in gross recharge volume of 33,583 ML/yr (51% of total rainfall) increasing to 38,964 ML/yr (59% of total rainfall) after development.

Table 15: Summary of gross recharge rates

Land use category	Gross recharge	Reference
Banksia	0.38	Xu et al (2009)
Lake	1.1	Xu et al (2009)
Pasture	0.45	Xu et al (2009)
Market garden/parkland	0.4	Xu et al (2009)
Urban - industrial	0.7	Xu et al (2009)
Urban - residential	0.6	Xu et al (2009)

Runoff and drainage

The changes in land use proposed by the East Wanneroo DSP will result in increased impervious area and as a result is expected to lead to increased runoff generation. The application of water sensitive design principles to manage stormwater runoff through distributed infiltration systems is expected to minimise runoff increases and result in a negligible net change to the overall proportion of rainfall discharged into the ground.

In the East Wanneroo DSP area, runoff can be largely ignored in relation to the overall water balance because virtually all runoff is returned to the water table by infiltration. However, for local scale groundwater modelling, where infiltration of stormwater may result in localised mounding effects it may be necessary to explicitly account for runoff and consider the locations of distributed infiltration sites.

Evapotranspiration

Evapotranspiration is applied as a collective term for several different processes which include:

- interception of rainfall by leaves;
- evaporation of rainfall from impervious and vegetated surfaces;
- evaporation from open surface water bodies;
- evaporation from soils;
- uptake and transpiration of water from unsaturated soils by shallow rooted vegetation;
- evaporation from shallow groundwater (incl. surface expressions of groundwater); and
- uptake and transpiration of groundwater by deep-rooted vegetation and trees.

In groundwater modelling, evaporation from shallow groundwater systems and uptake and transpiration of groundwater by deep-rooted vegetation and trees are typically grouped as groundwater evapotranspiration. Surface evapotranspiration processes, meanwhile, are usually accounted for through estimation of gross recharge rates for different surface types.

The change in groundwater evapotranspiration resulting from development can be significant, resulting from increased areas of impervious surfaces preventing evaporation from parts of the underlying groundwater system and clearing of trees and other deep-rooted vegetation reducing groundwater uptake and transpiration.

Evapotranspiration can be estimated in different ways for different parts of the site.

In areas of bare soil and/or shallow rooted vegetation, groundwater evaporation can be determined by the Penman-Monteith evaporation rate and the extinction depth. Applying this method, the evaporation rate from the water table is equal to the corrected pan evaporation rate where the water table intersects ground level and zero at the extinction depth. A pan evaporation factor of 0.75 is applied to estimate the Penman-Monteith evaporation rate for open waterbodies and an extinction depth of 2m is commonly applied in sandy soils.

The major wetlands of East Wanneroo are seasonally inundated, principally as surface expressions of groundwater. Groundwater evaporation in these areas can therefore be estimated by applying the same methodology as areas of bare soil/shallow rooted vegetation.

In areas with deep rooted vegetation, evapotranspiration can be similarly approximated as pan evaporation multiplied by a vegetation factor. A vegetation factor of 1.1 has been applied for deep rooted vegetation in the East Wanneroo DSP area reduced to 0.2 during the summer months (December to February) when plants are likely to transpire less.

For estimation of evapotranspiration, monthly average groundwater levels for 1986-95 were prepared and monthly evapotranspiration for the areas of land with <2m, 1.5-2m, 1-1.5m, 0.5-1m 0-1.0 depth to groundwater was calculated. Monthly inundated areas were also used to calculate evaporation. Average monthly depth to groundwater maps are shown in Figure 22.

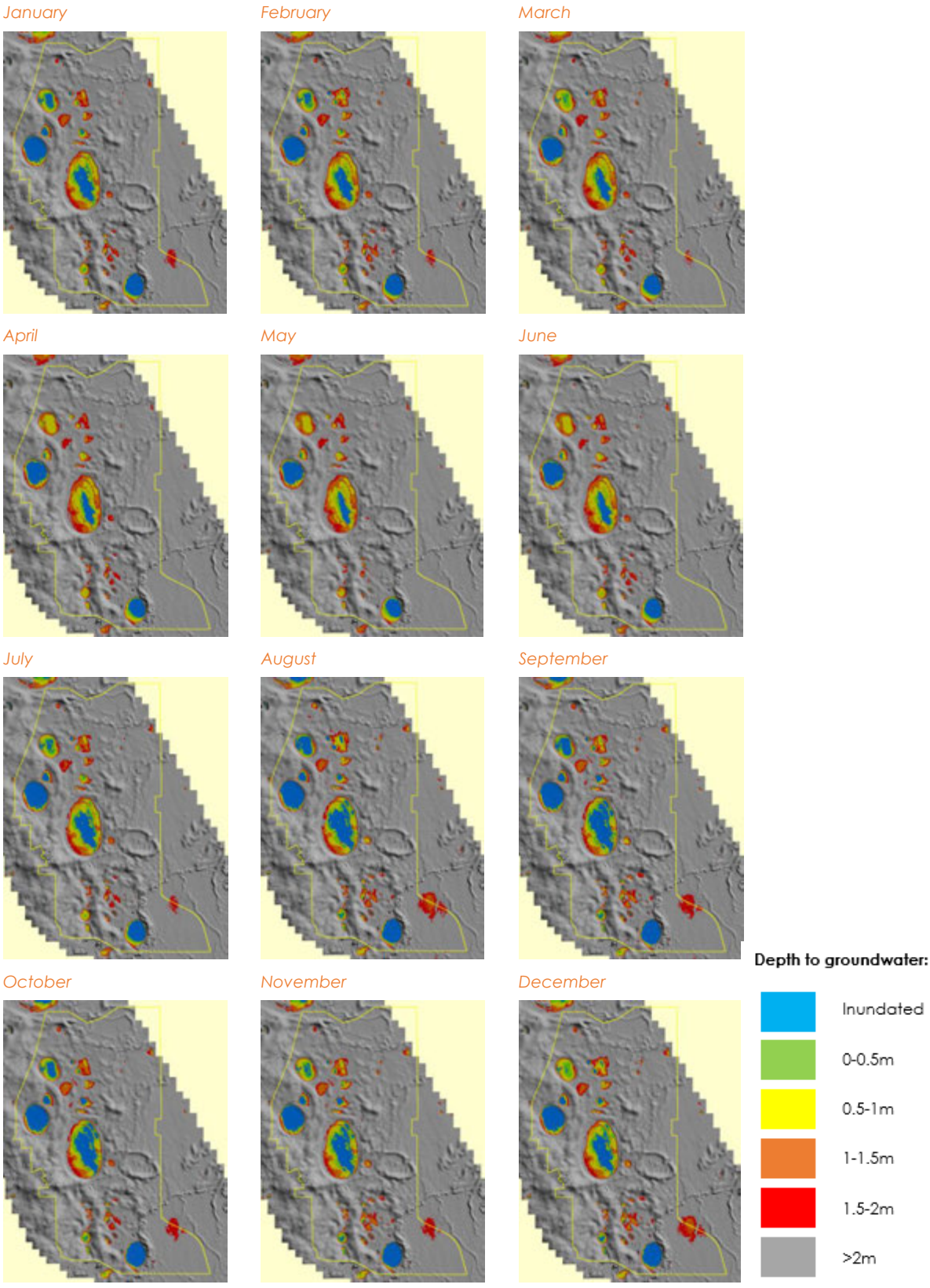

Figure 22: Average monthly depth to groundwater (1986-95)

Groundwater abstraction - Licensed abstraction

Based on the land uses proposed in the current East Wanneroo DSP an assessment of future groundwater demands was prepared by DWER and the City of Wanneroo and is summarised in Table 16 below.

Table 16: Groundwater demand by groundwater subarea and development stage

		Volume kL/year			
Stage	**Subarea**	**Schools**	**Local POS**	**Regional sports**	**Total**
1	Joondalup	-	31,185	-	31,185
	Mariginiup	32,400	164,903	-	197,303
	Lake Gnangara	16,200	75,600	-	91,800
	Wanneroo wellfield	36,450	80,798	-	117,248
	Stage 1 subtotals	***85,050***	***352,485***	***-***	***437,535***
2	Mariginiup	93,150	175,298	-	268,448
	Lake Gnangara	109,350	96,863	-	206,213
	Lake Adams	32,400	113,400	-	145,800
	Jandabup	8,100	40,635	202,500	251,235
	Wanneroo wellfield	-	17,010	-	17,010
	Stage 2 subtotals	***243,000***	***443,205***	***202,500***	***888,705***
3	Lake Gnangara	52,650	261,765	-	314,415
	Jandabup	8,100	37,800	-	45,900
	Stage 3 subtotals	***97,200***	***299,565***	***-***	***360,315***
Future (precinct 25)	Wanneroo wellfield	36,450	204,593	-	241,043
	Totals	**425,250**	**1,299,848**	**202,500**	**1,927,598**

It is noted that the DSP does not include a detailed assessment of local public open spaces and schools. Therefore, the following assumptions have been made in estimating the likely groundwater demands for these areas:

- 1 x 50 Ha regional sporting facility
- 60% irrigated at average rate of 6,750kL/ha/year
- 10% gross urban area provision for local POS
- 70% Irrigated for recreation and/or sport at average rate of 6,750kL/ha/year
- 6 government high schools consistent with DSP
- 10 Ha total area per school
- 30% Irrigated at average rate of 6,750kL/ha/year
- Distribution as shown in DSP mapping
- 2 Private high schools
- 10 Ha total area per school
- 30% Irrigated at average rate of 6,750kL/ha/year
- Distribution at rate of 1 per 2 public high schools
- 23 government primary schools consistent with DSP (3 additional for precinct 25)
- 4 Ha total area per school

- 30% Irrigated at average rate of 6,750kL/ha/year
- Distribution as shown in DSP table 1.2
- 5 private primary schools
- 4.5 Ha total area per school
- 30% Irrigated at average rate of 6,750kL/ha/year
- Distribution at rate of 1 per 3 public primary schools

Based on the groundwater demands presented in Table 6 and Table 16 there is a total anticipated reduction of approx. 7.5GL/year of groundwater licensing in the East Wanneroo DSP area at full build-out (which is anticipated to be over a 50 year timeframe). The combined effect of this reduced groundwater demand coupled with the development of East Wanneroo leading to reduced evapotranspiration and increased local recharge is considered likely to result in groundwater level rises. These rises have the potential to be significant and this would impact on the health of wetlands in the area.

Table 5 below presents a comparison of the predicted future groundwater demand with the various current demands including licensed agriculture and private users, public open spaces and schools, as well as abstraction for environmental supplementation. It should be noted that the need for this supplementation and the annual volume needed is likely to reduce as development progresses and groundwater levels rise.

It is recognised that there is also abstraction of groundwater for use in the public drinking water supply from bores located in the East Wanneroo DSP area however it is unlikely that this will change substantially in future.

Table 17: Summary of groundwater license volumes in relevant subareas

Subarea	Environmental supplementation		Agriculture and private users		POS & schools Irrigation		Total allocated volume (ML)	Total future demand (ML)
	Abstracted volume (ML)	Future demand (ML)	Licensed volume (ML)	Future demand (ML)	Licensed volume (ML)	Future demand (ML)		
Joondalup	-	-	556	134	*137	169	694	302
Mariginiup	-	-	3,973	213	*120	586	4,093	799
Lake Gnangara	-	-	6,252	1,227	35	647	6,287	1,874
Adams	-	-	1,026	851	-	146	1,026	996
Jandabup	1,400	-	160	-	-	297	160	297
Wanneroo Wellfield	-	-	-	-	-	375	-	375
Total	1,400	-	11,967	2,424	292	2,220	12,259	4,644

* includes volumes held for irrigation of spaces outside the development area

As shown in Table 5 above, there is 7,615 ML predicted reduction in groundwater license volumes following development of the East Wanneroo DSP area. Most of the groundwater licensed in East Wanneroo is for irrigation purposes and it is estimated that approximately 20% of water used for irrigation is assumed to return to the water table resulting in an existing return of 2,452 ML and a future return of 929 ML.

It should be noted that, in addition to an overall reduction in groundwater abstraction, it is likely that the locations where abstraction occurs will also change following development consistent with the locations of public open spaces.

Groundwater abstraction - Unlicensed abstraction

The use of private unlicensed 'backyard' bores for garden irrigation on residential properties is widespread in the Perth metropolitan area. It has been estimated that approximately 30% of households in Perth have a garden bore and the average bore pumps about 800 kL/yr (Davidson and Yu, 2006). More recent analysis by the Department of Water and Environment Regulation suggests that groundwater use from garden bores varies according to block size as summarised in Table 18. Given that the great majority of existing residential blocks in the East Wanneroo DSP area are larger than 10,000m^2 usage rates at the higher end of these may be expected. However, given the large number of properties holding groundwater licenses and the extension of sprinkler restrictions to households with backyard bores in recent years a single standard rate of 800kL/yr has been applied to 30% of existing residential blocks in the DSP area.

Table 18: Indicative water usage rates for domestic groundwater bores

Block size	Estimated annual usage
Urban block (<1,000 m^2)	300 to 420 kL / property
Rural block (<5,000 m^2)	970 kL / property
Rural block (>5,000 m^2)	3040 kL / property

There are approximately 1,200 existing residential properties in the East Wanneroo DSP area. Applying usage and uptake rates as described above, the unlicensed abstraction rate may be estimated at 288 ML/yr.

Following development, whilst uptake may be consistent with current rates it is expected that usage will be lower, associated with smaller lot sizes and compliance with waterwise messaging which emphasises the need for conservation and efficiency. Assuming compliance with current sprinkler restrictions and waterwise advice, a future average usage rate of 240 kL/yr/dwelling may be expected.

The East Wanneroo DSP proposes to deliver an estimated 50,000 new dwellings; however, it is considered unlikely that 30% of dwellings located in centres and urban neighbourhoods would have a garden bore. Therefore, considering only suburban neighbourhoods and special residential neighbourhoods, the total number of new dwellings is reduced to approximately 35,000. Assuming reduced average usage (240 kL/yr/dwelling) and bores installed on 30% of suburban and rural properties, the additional unlicensed abstraction rate may be estimated at 2,606 ML/yr.

There is significant uncertainty regarding the potential return to the aquifer of groundwater used for garden irrigation. If the rate applied to commercial irrigation were similarly applied to garden irrigation, the estimated returns would be 58ML prior to development and 521ML after development. However, it is considered unlikely that this level of return is realistic, and so this potential return has been excluded from the summarised fluxes presented in Section 3.1.4.

Scheme water use for irrigation

Considering the same existing and new dwelling figures and garden bore uptake estimates discussed above, it may be assumed that approximately 70% of dwellings use scheme water for irrigation of gardens. Based on consideration of only those dwellings in suburban neighbourhoods and special residential neighbourhoods the number of gardens irrigated using scheme water may be estimated at 840 currently, increasing by 24,500 to a future total of 25,340 dwellings.

According to the Water Corporation's *Perth Residential Water Use Study* (2008/09) approximately 39% of the average total scheme water consumption rate of 277 kL/yr/dwelling is used for irrigation. On this basis, it may be assumed that irrigation with scheme water in East Wanneroo will increase from approximately 91 ML/yr now to around 2,737 ML/yr in future with recharge returns estimated at 18 ML now and 547 ML in future.

Groundwater leakage to confined aquifers

A standardised leakage rate has been calculated using Darcy's Law based on a typical head difference of 20m between the Superficial and Leederville aquifers and an assumed vertical hydraulic conductivity for the confining layer of $1x10^{-5}$ m/day (Davidson 1995). It is recognised that the East Wanneroo DSP area is not uniform in this regard and that there are areas where greater connectivity between the two aquifers is expected.

This method of estimation indicates a net vertical leakage of 6,234 ML/yr from the Superficial Aquifer.

Horizontal groundwater flow

To develop an estimate of the lateral superficial groundwater flow into and out of the study area, a flow net analysis has been undertaken. A series of flow lines were drawn over the average annual minimum groundwater level contours map for 1986-95. Transmissivity was calculated as $400m^2$/day based on the typical saturated thickness of the superficial aquifer (20m) and the typical horizontal hydraulic conductivity of Gnangara sand (20m/day) and the dimensions of flow cells were measured directly using GIS.

Flow net calculations are provided in and showing that a net outflow of 1,829 ML/yr is estimated. The flow net is shown in Figure 23.

Table 19: Flow net calculations at inflow boundary

Flow net channel	Flow channel width (m)	Average length (m)	Upper level (m/AHD)	Lower level (m AHD)	Change in height (m)	Hydraulic gradient	Transmissivity (m2/day)	Q (m3/day)
1	800	1450	56	50	6	0.004	400	1324
2	1300	1750	57	50	7	0.004	400	2080
3	1600	2330	58	50	8	0.003	400	2197
4	1300	2170	55	50	5	0.002	400	1198
5	1000	780	52	50	2	0.003	400	1026
6	3700	1230	48	45	3	0.002	400	3610
Total inflow (m3/year)								4174

Table 20: Flow net calculations at outflow boundary

Flow net channel	Flow channel width (m)	Average length (m)	Upper level (m/AHD)	Lower level (m AHD)	Change in height (m)	Hydraulic gradient	Transmissivity (m2/day)	Q (m3/day)
1	700	900	45	43	2	0.002	400	622
2	1900	1300	45	42	3	0.002	400	1754
3	4000	2440	45	38	7	0.003	400	4590
4	4000	2844	45	40	5	0.002	400	2813
5	3200	4407	45	38	7	0.002	400	2033
6	6000	2590	45	40	5	0.002	400	4633
Total outflow (m3/year)								6003

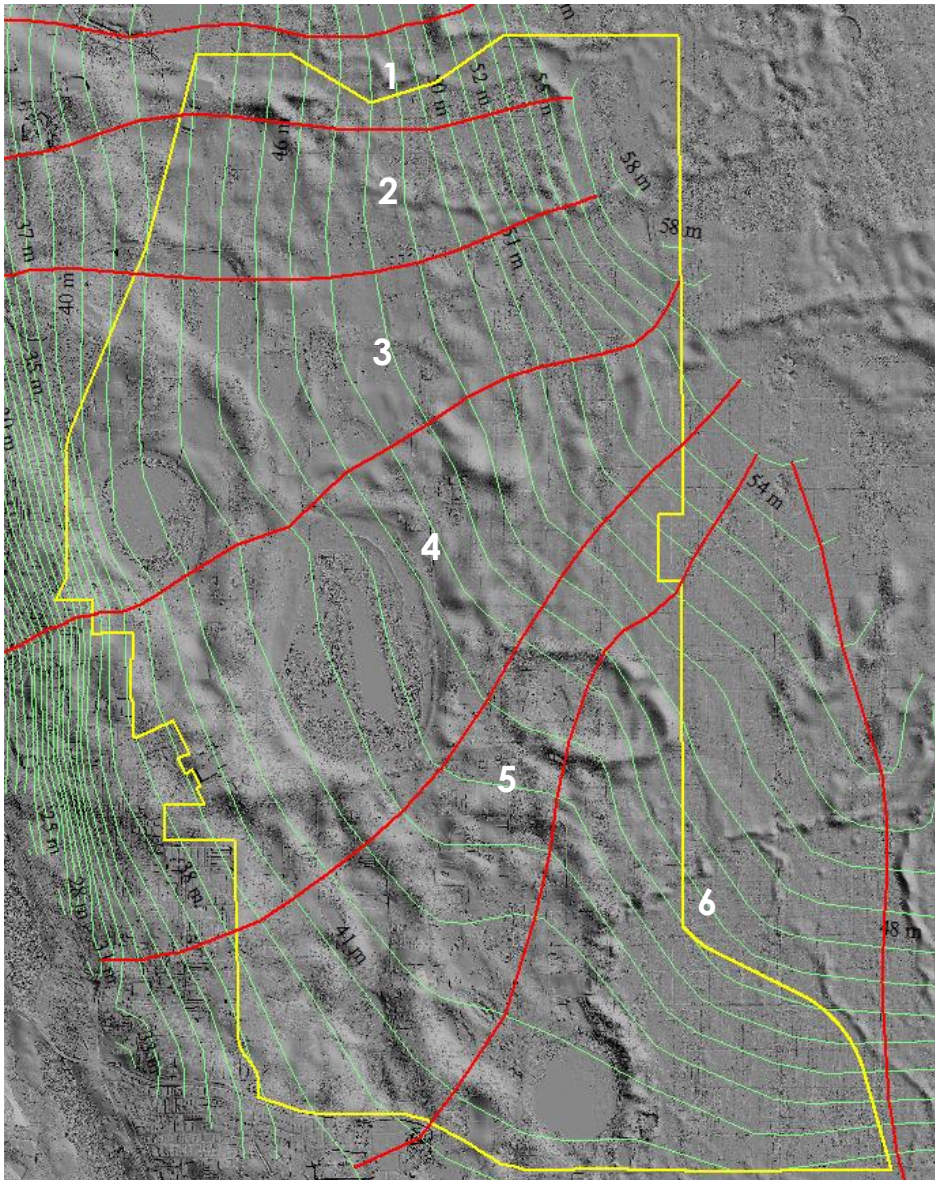

Figure 23: Flow net

3.3 Summary of risks and opportunities

The key water-related risk as a result of development within the East Wanneroo DSP area is associated with predicted groundwater level rise. Rises in groundwater results in risks to the environment from increased lake and groundwater levels causing excessive depths and durations of inundation and/or waterlogging of wetlands and vegetation, as well as risks to development. Key risks to development are waterlogging and loss of amenity or function in parks and other open spaces, damage to infrastructure such as roads, retaining walls and other paved areas, loss of capacity in stormwater management systems, and increased prevalence of mosquitoes and other nuisance insects.

In addition, existing land uses and proposed land use change has the potential to impact on the quality of water resources, which may result in declining health of wetlands and vegetation, as well as a reduced ability to abstract and use groundwater, particularly in public drinking water source areas.

As noted above, the assumptions used to develop the water balance may also provide an opportunity to mitigate these risks. Consideration of the total water cycle, such as the influence of abstraction on groundwater rise and drainage, will be critical to protect development and the important environmental values of the area. The water management objectives to be met as part of the future development of the East Wanneroo DSP area are outlined in Section 4. Section 5 describes the water management strategies that should be considered as part of local structure planning, and described in the implementation framework in Section 6.

4 WATER MANAGEMENT OBJECTIVES

The water management objectives in Table 21 have been adopted from the DWER's *Guidelines for district water management strategies* (DoW, 2013) and outcomes from other guiding documents and supporting investigations. They should be implemented as part of the future planning and development of the East Wanneroo DSP area, with concepts incorporated into local structure plans and local water management strategies and outcomes demonstrated to be met in urban water management plans consistent with the implementation framework in Section 6.

Table 21: Water management objectives

Item	Objective
Create liveable and resilient communities	• Improve social amenity by integrating water management measures into the street and lot landscape to increase visual, recreational, cultural, public health and ecological values; • Implement water management systems that are economically viable in the long term; • Safeguard the quality and availability of water resources for the future • Ensure the delivery of best practice water sensitive urban design through the planning and design of high-quality urban areas.
Protect important environmental assets and water resources	• Maintain or improve predevelopment groundwater quality in public drinking water source areas. • Manage, protect and restore waterways and wetlands: • Manage runoff from all rainfall events as high in the catchment as possible; • Manage post-development hydrology to maintain and/or improve hydrological, hydrogeological and ecological functions; • Minimise pollutant inputs through implementation of appropriate structural and non-structural controls; • Retain native vegetation and natural landforms (where possible Maintain or improve predevelopment surface water quality in all retained wetlands including the following specific targets o Implement strategies to manage pH and reduce the frequency of acidic conditions in Lakes Gnangara, Mariginiup and Jandabup. Principally it is expected that this will be achieved through increased water levels in these wetlands. o Using UNDO, demonstrate that development will maintain predevelopment exported phosphorous loads and reduce predevelopment exported nitrogen loads in Lakes Badgerup, Gnangara and Mariginiup o Using UNDO, demonstrate that development will maintain predevelopment exported nitrogen and phosphorous loads in Lake Adams and Lake Jandabup
Deliver functional and integrated public open space	• Integrate flood protection and drainage needs of development into public open spaces; • Ensure a suitable quantum of public usability within all public open space in responding to public expectations and needs; • Ensure passive open space areas require minimal irrigation and optimise the use of native bushland for passive recreation; and,

Item	Objective
	• Limit irrigation needs and ensure landscapes incorporate appropriate species and are designed for maximum irrigation efficiency, aiming for an average rate of less than 6,750 kL/ha/yr.
Manage flooding and inundation risks to human life and property	• Create innovative alternatives to traditional cut and fill construction practices, retaining the natural landform wherever possible to minimise changes in hydrology; • Design and manage stormwater systems that provide liveable streets and are low maintenance; • Provide adequate clearance from the 1% AEP flood level and surface water or groundwater inundation; • Design urban drainage systems to contain runoff from the 20% AEP event; • Design developments to provide buildings and critical infrastructure with adequate separation from maximum groundwater levels; and • Manage risks to public health from disease vector and nuisance insects.
Ensure the efficient use and re-use of water resources	• Minimise water use within developments, with a focus on efficient irrigation of public open space; • Seek opportunities for alternative water sources to provide for urban irrigation demands; • Increase community resilience to drought cycles and the changing climate, including impacts on all water sources; and • Achieve highest-value use of fit-for-purpose water, considering all available forms of water for their potential as a resource.

5 WATER MANAGEMENT STRATEGY

In order to achieve the water management objectives of this DWMS in a manner consistent with the water management principles in section 1.2, the following water management strategies need to be delivered as part of future planning and development of the East Wanneroo DSP area.

The strategies are to be incorporated into local structure planning and local water management strategies in accordance with the implementation framework in Section 6. Elements of this water management strategy will also need to be delivered at the district scale, coordinated by the City of Wanneroo, through developer contributions.

The water management strategies for the East Wanneroo DSP area address:

- Protection of important environmental assets and water resources
- Management of surface water and groundwater at precinct scale
- Management of surface water and groundwater at district scale
- Fit-for-purpose water supply and wastewater servicing

These key elements are explained further below.

5.1 Protection of important environmental assets and water resources

The key water resources requiring protection in the East Wanneroo DSP area are public drinking water source areas, important wetlands and other important environmental assets. Other important environmental assets include water dependent species and ecosystems such as vegetation in good or better condition, threatened and priority ecological communities and threatened flora and fauna. The following strategies are required to be incorporated into local structure plans and accompanying local water management strategies.

5.1.1 Land use activity requirements

It is anticipated that rezoning of land within public drinking water source areas to any urban land uses (if approved by WAPC) will trigger reclassification by DWER of areas of P1 and P2 to P3*. The local planning scheme will need to identify these P3* areas as special control areas, so that future land use planning will be appropriate for P3* areas, to protect water quality and ensure that the source can be used for drinking water as long as possible.

Land uses proposed in local structure plans and subdivisions in public drinking water source areas are required to be compatible with land use compatibility tables provided in Appendix C: *Appropriate land uses for future P3* areas* and *Water quality protection note no. 25: Land use compatibility tables for public drinking water source areas* (DWER, 2016) (WQPN 25).

There are public drinking water abstraction bores and associated well head protection zones (WHPZ's, as shown in Figure 15) located in Precincts 10, 14, 15, 16, 21, 22, 23, 24, 26, 27 and 28.

WHPZ's, sized in accordance with requirements set out in WQPN 25 and WQPN 38, are to be mapped and protected as part of local water management strategies and local structure plans. Consistent with the requirements of WQPN 25, WHPZ's are to be incorporated into public open space where possible, preferably in conservation open space.

All developments will require connection to deep sewerage and sewerage plans for areas within public drinking water source areas are required to include a risk assessment process

consistent with WQPN 38 that considers locations of WHPZs and gives them the highest protection.

5.1.2 Water quality management requirements

Actions to manage water quality risks to wetlands and public drinking water source areas have been identified in section 6.1 of this report including some land use activity restrictions and the implementation of water sensitive urban design approaches throughout the development. The selection and design of small event surface water and groundwater quality management strategies is a critical component of this, and the following table provides some preliminary guidance for suitable strategies in different parts of the site.

Table 22: Selection of water quality management strategies

System design element	Wetland catchments	Public drinking water source areas
Groundwater management system	Conveyance through vegetated swales at discharge points. Upgrade to treatment in biofiltration areas where legacy contamination has been identified in the subcatchment.	Treatment prior to discharge in contained biofiltration systems incorporating treatment media.
At source water management (public open space)	No treatment required. Limit use of fertilizers and pesticides.	Playing fields to incorporate a layer of amended soils. Facilities to be connected to deep sewerage. No use of fertilizers or pesticides.
At-source water management (residential lots)	Management of runoff from first 15mm of rainfall in soakwells, raingardens, rainwater tanks, buffer strips etc.	All lots to be connected to deep sewerage. Treatment of runoff from first 15mm of rainfall in soakwells with underlying amended soils or contained biofiltration systems incorporating treatment media.
At-source water management (commercial and industrial lots)	Management of chemicals, materials and equipment to prevent pollution (including bunding of washdown and storage areas). Treatment of all wastewater prior to discharge (including any runoff from washdown and storage areas). Management of runoff from first 15mm of rainfall in soakwells, raingardens, rainwater tanks, buffer strips etc.	No on-site use or storage of chemicals including fuels and oils. Management of materials and equipment to prevent pollution (including bunding of washdown and storage areas). All wastewater (including runoff from washdown and storage areas) to be discharged to deep sewerage. Management of runoff from first 15mm of rainfall in soakwells, raingardens, rainwater tanks, buffer strips etc.
At source water management (road reserves)	Management of runoff from first 15mm of rainfall in soakwells, raingardens, rainwater tanks, buffer strips etc.	Treatment of runoff from first 15mm of rainfall in soakwells with underlying amended soils or contained biofiltration systems incorporating treatment media.
Additional measures to manage legacy issues	Site remediation where required. Avoid locating infiltration systems in areas with known legacy contamination (including elevated nutrients). Provide additional treatment via biofiltration systems at outlets of subsurface drainage systems.	Site remediation where required. Avoid locating infiltration systems in areas with known legacy contamination (including elevated nutrients)

5.1.3 Wetland retention and management requirements

Wetlands currently proposed to be retained, and their associated implementation requirements are summarised in Table 23.

Management strategies for wetlands will need to be informed by wetland assessments and have consideration of landform integration, management of stormwater and drainage interfaces and landscape including bushfire risk.

Wetland assessments

A site investigation/evaluation is required to be conducted for wetlands at the precinct planning stage to confirm those which are to be protected.

The guidance document *A methodology for the evaluation of wetlands on the Swan Coastal Plain, Western Australia* (DBCA 2017) and associated information sheet *Wetland identification and delineation: information for mapping and land use planning on the Swan Coastal Plain* (DBCA 2017) should be utilised by proponents and consultants reviewing wetland boundaries and management categories.

Wetland assessments should be undertaken prior to local structure planning to inform proposed open space areas and local structure plan design.

In accordance with the EPA's Guidance Statement 33 *Environmental Guidance for Planning and Development* (2008), all wetlands that are to be protected should be allocated of a minimum 50 metre buffer to maintain wetland values and mitigate impacts from adjacent land uses.

In addition, as part of proposed precinct plans, wetland management plans should be prepared for wetlands to be protected to ensure ongoing maintenance and/or enhancement of wetland values and mitigation of impacts from changes in adjacent land uses.

Landform integration

The hydrological character of wetlands in the East Wanneroo DSP area is a function of a range of factors including climate, soils, topography, landform, and connectivity to the Gnangara groundwater system. Wetlands are typically found in the lower lying parts of the DSP area where there is strong connectivity to the underlying groundwater system and often there are associated regions of less permeable soils. As well as these key driving features, many of the wetlands have basin type landforms and are surrounded by dunes which create extended surface water catchments and may provide microclimate support to wetland ecologies.

Because of these inter-relationships between wetlands and surrounding landform it is important to the ongoing health of retained wetlands that development avoids modifying key supporting landforms. It is therefore recommended, that development related earthworks (cutting and filling) are avoided within the immediate upslope subcatchment boundary of wetlands where this extends beyond a standard 50m buffer distance as shown in Figure 24.

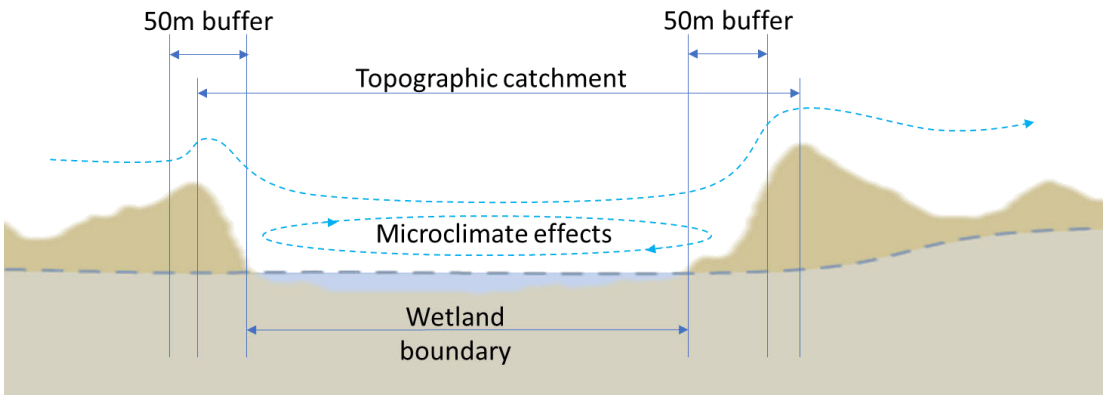

Figure 24: Protection of landform surrounding wetlands

Managing stormwater

Preliminary stormwater modelling has assumed that all categories of wetlands within precincts may be utilised for minor (20%AEP) and major (1%AEP) flood storage. Consistent with water sensitive urban design principles and in accordance *Decision Process for Stormwater Management in WA* (DWER 2017), systems for management of stormwater in more frequent rainfall events will be located outside wetlands and their buffers to minimise hydrological impacts. Any overflow of runoff towards waterways and wetlands will be via overland flow paths across vegetated surfaces.

The storage of flood events in wetlands in East Wanneroo represents a change in the longer-term hydrology of these systems. However, as noted in Section 3.1.3, a predevelopment 1-dimensional surface water model of the East Wanneroo DSP area was constructed to provide an estimate of the likely volumes and top water levels in key wetlands during minor and major flood events. This preliminary stormwater modelling indicated that the likely impact of these changes is small.

Ecological water requirements of receiving systems should be a primary consideration within any local water management strategy and where changes in hydrology are proposed then more detailed modelling will need to be undertaken at local structure plan (LWMS) stage to demonstrate that there will be no significant impacts to the ecology of the wetland system. This will need to include detailed analysis of pre-development and post-development water levels and flows into retained wetlands.

Stormwater systems that utilise wetlands for flood storage will need to be designed to maintain pre-development surface water flow rates, runoff volumes, water levels and shallow groundwater recharge rates for receiving water bodies during frequent rainfall events (up to and including one exceedance per year), unless otherwise established in an approved management strategy or plan and subject to the advice of the relevant agency.

Drainage system interface requirements

Open or piped drainage outlets from local drainage systems are required to terminate outside vegetated buffers of retained Conservation Category and Resource Enhancement wetlands.

Invert levels of drainage systems are required to match the natural surface elevation at the edge of the buffer and the use of imported or locally reclaimed fill material within the buffer is not supported.

Stormwater discharges to wetlands may require a sediment control pond and/or biofilter prior to discharge into a wetland, as shown in Figure 25. Where required, these systems are to be located entirely outside the buffer. However, it is reasonable to incorporate minor earthworks and small quantities of unmortared rock to stabilise an area immediately downstream of overflows from these systems to assist with transitioning flow from piped or channelised flow into overland flow and protect the area from erosion. Where required, this transition area should not extend into the buffer for more than 5 to 10 metres.

Landscaping, bushfire risk and infrastructure

The provision of infrastructure within retained wetlands and their buffers is generally not supported. However, in some cases, limited infrastructure consistent with the values of the wetland, designed to provide for community engagement with the environment and foster custodianship, may be permitted. Where proposed, designs developed at local structure plan (LWMS) stage will be required to demonstrate that there will be no significant impacts to the ecology of the wetland system.

Landscaping works within retained wetlands and their buffers should be limited to restoration works such as weed removal and revegetation and limited works for passive recreation such as paths, benches, or bird hides.

It is noted that revegetated wetland buffers may be associated with bushfire risk and are generally bushfire prone areas. These areas have implications for bushfire risk management and the design of future land developments in their vicinity. Accordingly, bushfire risk will need to be managed in accordance with *State Planning Policy 3.7 Planning in Bushfire Prone Areas* and it is likely that a bushfire management plan will need to be developed. The bushfire management plan must be developed after identification of the wetland buffer and consider any future wetland restoration and management plans. No bushfire mitigation strategies are to be contained within the wetland buffer.

Table 23: Wetland by wetland implementation plan

Wetland name	UFI	Management planning responsibility	Management planning timing	Management planning approval	Indicative restoration requirements	Restoration responsibility	Monitoring requirements	Monitoring responsibility	Likely ongoing manager
unknown	7944	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Little Coogee Flat	7945	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
unknown	7946	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Mariginup Lake	7953	Wetland and foreshore management plan to be prepared by DPLH funded by DCP	Following DWMS, funded by DCP	DCBA/DWER	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Included in district monitoring program funded by DCP	DWER/City of Wanneroo	City of Wanneroo
Lake Adams	7959	Wetland and foreshore management plan to be prepared by DPLH funded by DCP	Following DWMS, funded by DCP	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Included in district monitoring program funded by DCP	DWER/City of Wanneroo	City of Wanneroo
Lake Adams	7960	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
unknown	8077	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
unknown	8079	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
unknown	8088	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hawkins Road Swamp	8093	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Bustard Landing	8098	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Bustard Swamp	8099	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sydney Road	8102	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lakelands Country club	8109 (15901)	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Bustard North	8119	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Damian Road	8122	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Gnangara lake	8130	Wetland and foreshore management plan to be prepared by DPLH funded by DCP	Following DWMS, funded by DCP	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Included in district monitoring program funded by DCP	DWER/City of Wanneroo	City of Wanneroo
Little Badgerup Lake	8132	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo

Wetland name	UFI	Management planning responsibility	Management planning timing	Management planning approval	Indicative restoration requirements	Restoration responsibility	Monitoring requirements	Monitoring responsibility	Likely ongoing manager
unknown	8154	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Brozewing Grove	8156 (14241)	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Little Mariginup	8161	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Badgerup Lake	8165	Wetland and foreshore management plan to be prepared by DPLH funded by DCP	Following DWMS, funded by DCP	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Included in district monitoring program funded by DCP	DWER/City of Wanneroo	City of Wanneroo
Jandabup Lake	15006	Wetland and foreshore management plan to be prepared by DPLH funded by DCP	Following DWMS, funded by DCP	DCBA/DWER	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by DBCA, funded by DCP	Included in district monitoring program funded by DCP	DWER/City of Wanneroo	DBCA
unknown	7940	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Little Coogee Swamp	7941	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
unknown	7942	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
unknown	7943	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Townsend Road	7955	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
unknown	8078	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
unknown	8081	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Boundary Road	8090	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo

Wetland name	UFI	Management planning responsibility	Management planning timing	Management planning approval	Indicative restoration requirements	Restoration responsibility	Monitoring requirements	Monitoring responsibility	Likely ongoing manager
Boundary Road	8091	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Gnangara Pine Plantation	8092	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Via Vista Drive	8094	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Meadowlands Drive	8095	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Gnangara Pine Plantation	8101	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Ashby Street	8105	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Jandabup Lake	8114	Wetland and foreshore management plan to be prepared by DPLH funded by DCP	Following DWMS, funded by DCP	DCBA/DWER	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by DBCA, funded by DCP	Included in district monitoring program funded by DCP	DWER/DBCA	DBCA
Damian Road	8120	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Damian Road	8121	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Gnangara Pine Plantation	8123	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Vintage lane	8127	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Rousset Road	8162	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Boundary Road	8163 (15433)	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Gnangara Pine Plantation	8258	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Gnangara Pine Plantation	8338	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Boundary Road	14254	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and	Developer	City of Wanneroo

Wetland name	UFI	Management planning responsibility	Management planning timing	Management planning approval	Indicative restoration requirements	Restoration responsibility	Monitoring requirements	Monitoring responsibility	Likely ongoing manager
					Buffer establishment and vegetation		continuing for 3 years from approx. 80% buildout		
Boundary Road	14261	Wetland and foreshore management plan to be prepared by developer	Local structure plan	City of Wanneroo	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by developer	Water levels & WQ commencing with development and continuing for 3 years from approx. 80% buildout	Developer	City of Wanneroo
Jandabup Lake	7957	Wetland and foreshore management plan to be prepared by DPLH funded by DCP	Following DWMS, funded by DCP	DCBA/DWER	Weed removal Revegetation Buffer establishment and vegetation	Restoration to be undertaken by DBCA, funded by DCP	Included in district monitoring program funded by DCP	DWER/DBCA	DBCA
Additional wetlands recommended for investigation and/or retention									
Boundary Road	8089	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				
Ross Street	8103	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				
Carmignani Road	8106	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				
Stoney Road	8107	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				
Jambanis Road	8108	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				
Lakelands Country Club	8112	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				
Lenzo Court	8113	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				
Little Dundarbar Swamp	8117	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				
Amarante Road	8118	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				
Louise Place	8128	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				
Pinesend Farm Swamp	8153	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				
unknown	8155	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				
Pennygum Place	15022	Wetland to be considered for retention as integrated part of drainage system	Local structure plan	City of Wanneroo/DWER	To be considered if retained				

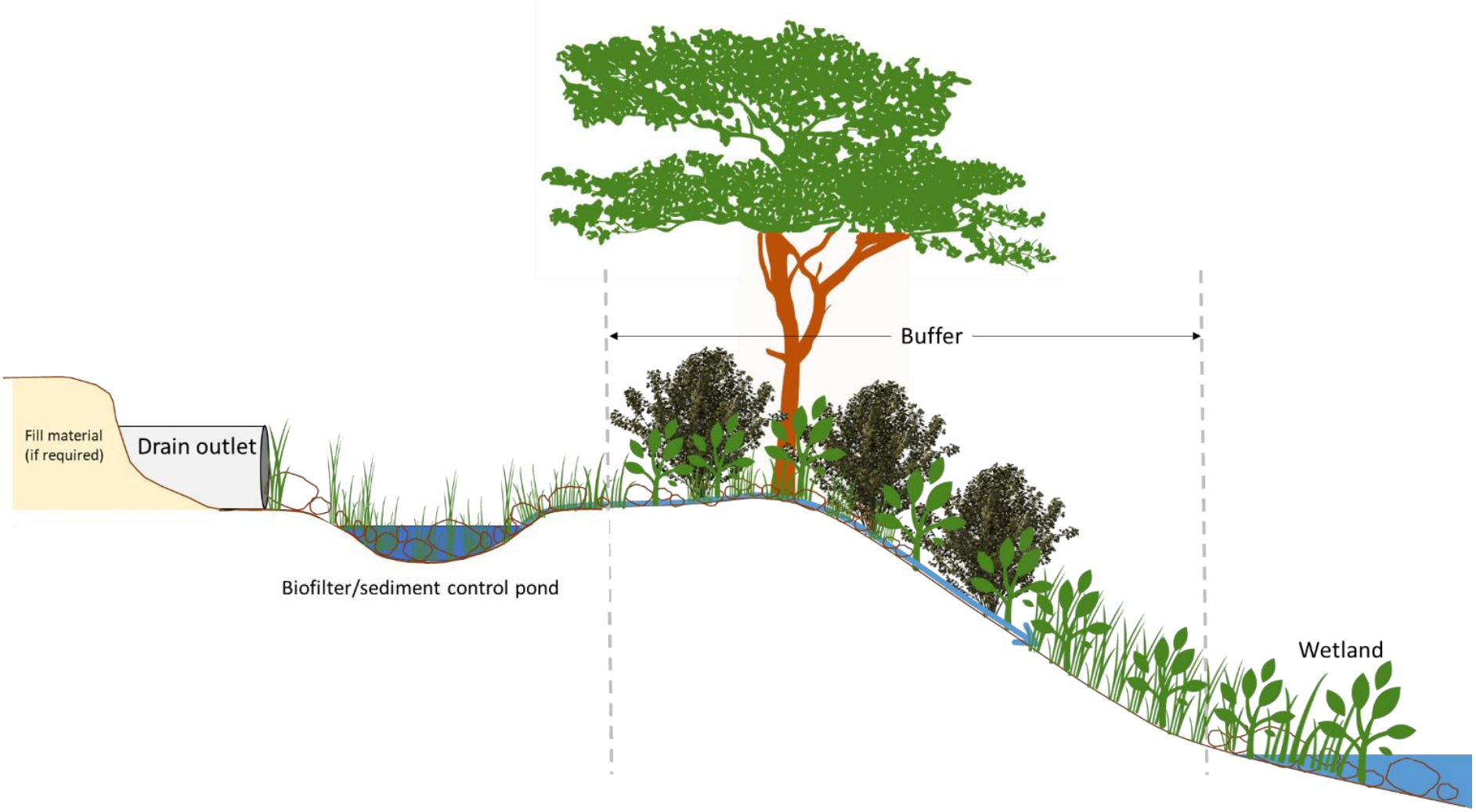

Figure 25: Wetland interface treatment

5.2 Management of groundwater at district scale

The nature of the groundwater system in the East Wanneroo DSP is such that changes in hydrology in one precinct of the DSP area have the potential to impact significantly on groundwater levels in another precinct, as well as on the health of the important wetlands in the area. Although this DWMS has been supported by a preliminary broad scale water balance and groundwater modelling, it is necessary to undertake further work to design and test the district groundwater management system to ensure impacts of groundwater level changes will not impact on wetlands and/or the proposed development.

It is proposed that a district-scale groundwater system is designed in more detail prior to local structure planning. This modelling will be funded and coordinated through developer contributions. Critical aspects of the system to be designed are:

- Collection system – how excess groundwater will be collected from developed areas
- Treatment and transfer system – where the water is treated and stored for use and how it gets there
- Use – who will use the water, for what purpose and where they are located; and
- Construction and governance arrangements – who will build and manage the various elements of the system.

As part of the preparation of this water management strategy, DPLH and their consultant have worked with DWER on the first step – a concept to control groundwater via subsoil drains and a pumping scheme to remove water from the district structure plan area. This will involve a treatment and transfer system. The next steps of project development including prefeasibility, feasibility, design and governance are yet to be progressed.

5.2.1 Collection system

Subsoil drains will most likely be required in most, if not all, development areas to provide a suitable level of protection for public and private infrastructure and assets. These systems are well understood by industry and are generally accepted as a reasonable part of the normal subdivision design and construction process.

It is noted that the continuation and expansion of pumping from the Water Corporation's drinking water supply bores in East Wanneroo has the potential to limit the amount of future groundwater level rise. Changes in the pumping of Water Corporation infrastructure will need to be modelled to understand the sensitivity of this activity on future groundwater levels.

Subsoil drains will be implemented as a groundwater collection system in large parts of the EWDSP area as the most practical, cost-effective and trusted option for protecting private property and infrastructure from the risks of groundwater level rise.

5.2.2 Treatment and transfer system

A combination of local hubs with a small amount of local storage and a pump station to convey flows to a district scale site for treatment, storage and transfer is the preferred strategy. This strategy provides flexibility to design and implement local systems aligned to development staging while limiting the land take in individual precincts.

5.2.3 Use options

Preliminary discussions with DWER, Department of Biodiversity, Conservation and Attractions and the City of Wanneroo have identified a number of potential use options that will need to be investigated. It is likely that a combination of uses may be considered including use for environmental supplementation and for irrigation of new and expanded horticultural areas elsewhere in the City of Wanneroo.

5.2.4 Construction & Governance options

Preliminary discussions with DWER and the City of Wanneroo have identified a number of potential construction and governance options that will need to be considered. It is likely; however, that the model will involve a partnership of State and Local government agencies and will be funded from the proposed Developer Contributions Scheme.

In addition, a district scale monitoring program will need to be implemented to inform the design, construction and management of the system and will be funded through inclusion in a district wide developer contributions scheme.

5.3 Management of surface water and groundwater at precinct scale

Within the East Wanneroo DSP area, groundwater and surface water management are integrated and delivered at both the district and precinct scale. Guidance for strategies at the precinct scale, delivered through local structure plans and local water management strategies is contained below. The following summary of general requirements and criteria will need to be addressed by developers in the preparation of local structure plans and local water management strategies.

5.3.1 Baseline for assessment

The ten-year period from 1986 to 1995 has been selected as the baseline period for assessment of water resource conditions in the East Wanneroo DSP area with the following key reasons:

- Ministerial sites are compliant with criteria in at least five years from the ten-year period.
- 76 groundwater bores have at least 50 records over the ten-year period.
- 76 groundwater bores have at least four records in every year of the ten-year period.

The most significant elements of the East Wanneroo DSP area water balance are groundwater abstraction (31%) and evapotranspiration (49%). Given the risks associated with potential future groundwater rise in East Wanneroo there is a significant opportunity for the delivery of green infrastructure and retained natural vegetation to deliver a future community that is liveable, walkable and water wise.

5.3.2 Small event and groundwater management requirements

Management of the risks to development associated with potential future groundwater level rise is likely to require the installation of subsurface drainage systems to manage groundwater levels and may require the use of imported or re-distributed fill. In these areas it is necessary to consider how both small rainfall events and the shallow groundwater system will be managed.

Small rainfall event management at-source

Small rainfall events are to be managed at source (in lots and streets) wherever possible.

All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.

Where the depth to groundwater is limited and subsurface drainage systems are required, the design of at-source stormwater infiltration systems should be informed by consideration of the interaction between infiltrated stormwater and the controlled groundwater level. The (surface water and groundwater management) systems should be designed to ensure that they both systems will function appropriately to prevent damage to property and infrastructure and maintain reasonable levels of amenity.

Where it is not feasible to retain or infiltrate small rainfall events at source without impacting amenity, the use of systems such as rainwater tanks, raingardens and detention tanks should be considered as alternatives to more traditional systems. Examples of these types of alternative approaches are shown Figure 26.

Figure 26: Examples of at-source management of small rainfall events

Controlled groundwater levels

Where it is necessary to manage shallow, or potentially increasing groundwater levels, it may be necessary to install a subsurface drainage system to control or limit groundwater levels. The invert level of an installed subsurface drainage system is typically referred to as the controlled groundwater level and the minimum controlled groundwater level should be determined through consideration of the ecological water requirements of local high value wetland systems and vegetation.

As previously discussed in section 2.4.1, *Ministerial statement no. 819 – Gnangara Mound groundwater resources [including East Gnangara Shire of Swan]* establishes environmental conditions and commitments associated with the allocation of groundwater for public and

private use under Part IV of the *Environmental Protection Act 1986*. These conditions are described as water level criteria which represent the environmental water provisions of 14 wetland sites and 16 phreatophytic vegetation sites.

In the East Wanneroo District Structure Plan area there are two wetlands (Lake Mariginiup and Lake Jandabup) and one phreatophytic vegetation site (MT3S) with water level criteria set in *Ministerial Statement no. 819*.

Other large wetlands in the structure plan area with some surface water level monitoring data include Lake Gnangara and Lake Adams.

To derive a suitable controlled groundwater level throughout the East Wanneroo DSP area, available water level data from the three sites with water level criteria set in Ministerial Statement No. 819 and other large wetlands was reviewed alongside their respective water level criteria and, for the wetlands, a nearby groundwater level record (see Charts in section 2.4.5).

A suitable period for definition of controlled groundwater levels would ideally facilitate compliance with water level criteria set in Statement 819. This could be achieved through application of conditions, as discussed in section 2.6.5, observed in the ten-year period from 1986 to 1995 (marked in red on Charts in section 2.6.5) and may be represented by average annual maximum groundwater level (AAMGL) or maximum groundwater level (MGL). However, a preliminary assessment of the volume of fill that would be required to achieve a controlled groundwater level of MGL throughout the development would be significant and is likely to be prohibitively expensive. Therefore, the proposed CGL for the East Wanneroo DSP area is AAMGL (1986-95).

In addition, as discussed in section 2.4, because of non-compliance with minimum water level criteria at Lake Jandabup during the baseline period, it is desirable that management of groundwater levels close to the Lake should aim to increase minimum water levels from this baseline whilst remaining consistent with maximum water levels. The use of fill and subsurface drainage systems to control groundwater levels for development is typically associated with a small rise in minimum groundwater levels as well as the expected reduction in maximum groundwater level. In part, this change, as shown in Figure 27, can be attributed to a shift in the extinction depth for evapotranspiration effects.

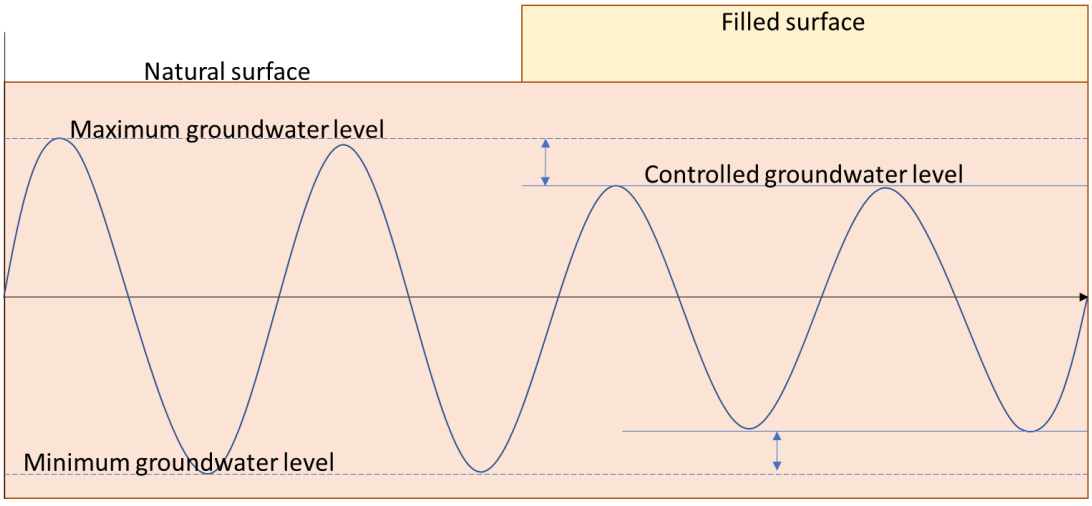

Figure 27: Visualisation of changing minimum and maximum groundwater levels following development

Groundwater management guidance for local water management strategies

The proposed controlled groundwater level (CGL) for the East Wanneroo DSP area is represented by AAMGL (1986-95). The impacts of using an AAMGL rather than MGL as the CGL near wetlands and important environmental values will require further consideration when detailed modelling is undertaken for the preparation of the local water management strategy for each precinct.

Approximately 140 hectares of stage 1 precincts may require groundwater management in future generating a potential flow rate of around 44L/s based on preliminary estimates of groundwater level rise following full build-out.

Approximately 2,400 hectares of stage 2 and 3 precincts may require groundwater management in future generating a potential flow rate of around 360L/s based on preliminary estimates of groundwater level rise following full build-out.

A detailed local groundwater model of the East Wanneroo DSP area will be prepared to consider predicted hydrological changes in more detail and quantify the likely groundwater level change at a more localised level. This future model will be funded and coordinated by developer contributions to be used as a design tool to provide more detailed estimates of the volume of groundwater that may need to be managed in future.

If local structure planning proceeds before the development of the district groundwater management, retrofitting will not be sufficient to control the groundwater and will reduce the amount of land available for development in remaining precincts. Addressing this retrospectively would be further complicated given there are many small landowners involved.

Where local structure planning is proceeding in advance of the detailed local groundwater modelling being available, the local structure plan must:

- Install groundwater management systems (subsoil drains) at invert levels based on the determined controlled groundwater level in areas where the predicted future groundwater level is within 2m of the future design surface.
- Set aside land areas for suitable groundwater pump station sites and upstream storage to remove sediment, which incorporate a buffer for pump operation and provide for emergency shutdowns. Groundwater pump station and storage sites may be located adjacent to public open space, but land should be provided in addition to normal POS spatial requirements. Storage may be incorporated with stormwater storage systems but must remain outside of retained wetlands and their buffers.

It is generally preferred that subsurface drainage systems are separate from surface water management systems. However, it is accepted that there may be some potential for surface water and groundwater systems to be integrated at an individual precinct level. Where this is proposed it will be necessary to demonstrate that the integrated system design can function effectively for both purposes without loss of performance. For example, where a groundwater drainage system discharges into a combined stormwater and groundwater drain, the groundwater system outlet should be unsubmerged in normal winter baseflow conditions.

5.3.3 Local arterial drainage system

Preliminary local arterial drainage system layouts and subcatchments have been developed for each precinct of the East Wanneroo DSP area based on natural topography and proposed road layouts. The subcatchments and network layouts for each precinct are presented in Figures 33 to 51 in Appendix C. These subcatchments consider the existing topography of the site in combination with existing and proposed roads and may change in future stages of

planning and design through further consideration of other factors such as modified road layouts and connections to services.

Detailed surface water modelling will be required to support future local structure plans and presented in local water management strategies. This modelling will need to include consideration of the risks associated with surface and groundwater interaction both now and in the future. The establishment of appropriate antecedent conditions in drainage infiltration basins and wetlands functioning as part of the surface water management system will need to consider changing groundwater levels and the performance of subsurface drainage systems under flood conditions.

A preliminary post development 1-dimensional surface water model of the East Wanneroo DSP area has been developed using InfoWorks ICM, incorporating proposed local arterial drainage system layouts and subcatchments. The model includes retained wetlands modelled as 'pond nodes' to provide a comparison with the pre-development wetland volumes and top water levels. This model has been used to determine storage volumes, drainage system dimensions, peak flow rates and top water levels. These critical elements of the proposed arterial drainage system are presented in Table 26, Table 27, and Figures 33 to 51 in Appendix C. Technical details of the modelling and sensitivity testing undertaken are presented in Appendix D.

Runoff rates for each subcatchment were assessed based on the estimated proportions of pervious and impervious areas in each land use. Four different surface types have been allocated:

Effective impervious areas (EIA) – these areas are directly connected to a drainage system and may include areas such as roads, driveways and carparking areas.

Indirectly connected areas (ICA) – these areas are indirectly connected to a drainage system and may include some connected pervious areas. Typically, the connection to the drainage system will be via overland flow from a soakwell, raingarden, buffer-strip, or other form of pervious infiltration system.

Rural pervious areas – these are undeveloped pervious areas.

Urban pervious areas – these are developed pervious areas such as public open spaces and private gardens.

The runoff characteristics for each surface type have been defined with an initial and continuing loss model as recommended by Australian Rainfall and Runoff 2019. The applied loss model is presented in Table 24.

Table 24: Surface type loss model

Surface type	Initial loss (mm)	Continuing loss (mm/hr)
Indirectly Connected Areas	15	3.0
Effective Impervious Areas	2	0.0
Rural pervious areas	42	3.1
Urban pervious areas	21	3.1

The proportions of each surface type applied to existing land uses and each of the land uses defined in the East Wanneroo District Structure Plan are presented in Table 25 along with the total estimated Fraction Impervious (FI) for each land use. The resulting surface type

breakdown for each pre- and post-development subcatchment in the East Wanneroo DSP area are presented in Appendix D.

Table 25: Surface type breakdown for existing and DSP land uses

Land use category	ICA	EIA	Total FI	Rural pervious	Urban pervious
DSP land uses					
Centre	0.3	0.3	0.6	0.0	0.4
Character areas	0.3	0.3	0.6	0.0	0.4
High priority vegetation area	0.0	0.0	0.0	1.0	0.0
Industrial	0.2	0.4	0.6	0.0	0.4
Intersection area	0.0	0.7	0.7	0.0	0.3
Public purpose	0.3	0.0	0.3	0.0	0.7
Regional open space	0.0	0.0	0.0	1.0	0.0
Regional sporting fields	0.2	0.0	0.2	0.0	0.8
Rural	0.2	0.0	0.2	0.8	0.0
Service commercial	0.6	0.0	0.6	0.0	0.4
Special residential area	0.2	0.0	0.2	0.8	0.0
State forest	0.0	0.0	0.0	1.0	0.0
Subject to further planning	0.2	0.2	0.4	0.0	0.6
Suburban neighbourhood	0.3	0.2	0.5	0.0	0.5
Urban neighbourhood	0.3	0.3	0.6	0.0	0.4
Existing land uses					
Roads	0.7	0.0	0.7	0.3	0.0
Urban land uses (incl. aged care and industrial)	0.6	0.3	0.3	0.0	0.4
Suburban land uses (lots 600-1,500m2)	0.4	0.3	0.1	0.0	0.5
Suburban land uses (lots 450-600m2)	0.5	0.3	0.2	0.0	0.5
Rural land uses (lots >2ha)	0.1	0.1	0.0	0.9	0.0
Rural land uses (lots <2ha)	0.2	0.2	0.0	0.8	0.0
POS, conservation areas and state forest	0.0	0.0	0.0	1.0	0.0

Conveyance system requirements

Preliminary modelling has assumed that the arterial drainage system is formed as a network of open vegetated swales integrated with road reserves and linear public open spaces. The actual dimensions of swales will vary but preliminary modelling indicates that swales with 1:6 side slopes that are 1m wide at the base and up to 1m deep are likely to be sufficient in most locations.

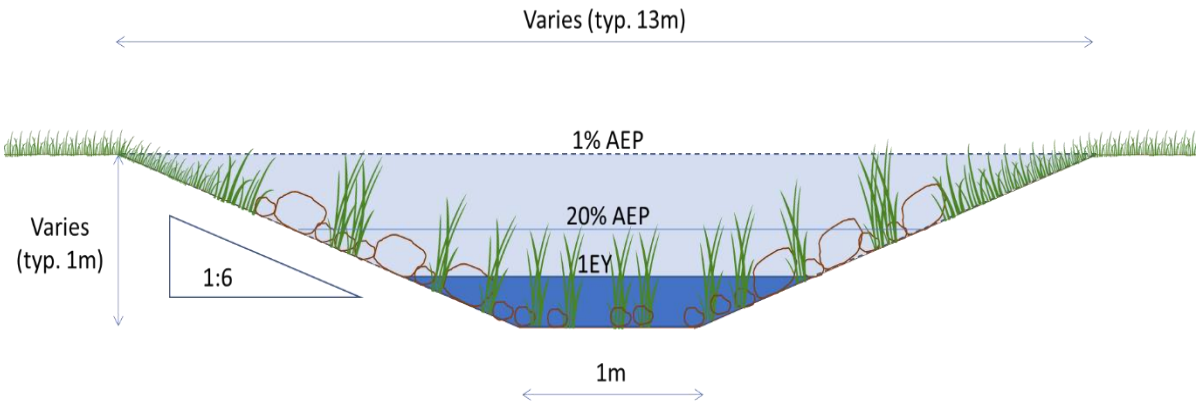

Figure 28: Modelled arterial drainage swale

Preliminary stormwater modelling indicates flows across precinct boundaries will be required in some locations, whilst others may be able to manage all minor (20%AEP) and major (1%AEP) events with their boundaries. Indicative peak flow rates across precinct boundaries are presented in Table 26. However, it will be necessary to undertake more detailed modelling to determine cross-boundary flows to be accommodated within precincts for reporting at the local structure planning (LWMS) stage. Controlled groundwater levels at each crossing locations are also provided in Table 26 and it is recommended that the invert levels of stormwater drainage systems are set at least 0.3m above the local controlled groundwater level.

Table 26: Indicative peak flows crossing precinct boundaries

Location (refer to Figures 32 to 51 in App. C)	Controlled groundwater level (mAHD)	20% AEP Peak flow (m^3/s)	1% AEP Peak flow (m^3/s)
1a	39.63	0.15	0.45
2a	40.54	0.32	1.02
3a	41.27	1.10	3.31
3b	42.58	0.45	1.52
4a	41.38	0.41	1.54
4a	41.38	0.19	0.42
5a	42.31	1.57	5.82
6a	41.66	2.40	8.92
6b	43.03	2.20	8.60
10a	46.50	0.36	1.26
12a	42.86	0.39	1.20
12b	45.22	0.54	1.35
13a	41.86	1.18	4.35
13b	42.66	0.32	1.18
13b	42.66	0.14	0.37
13c	43.07	0.86	3.04
13d	45.40	0.28	0.70
13e	45.22	0.19	0.47
15a	44.51	0.25	0.66

Location (refer to Figures 32 to 51 in App. C)	Controlled groundwater level (mAHD)	20% AEP Peak flow (m^3/s)	1% AEP Peak flow (m^3/s)
15b	44.73	0.63	1.67
15c	44.63	0.18	0.43
15d	42.40	0.37	1.27
17a	41.33	0.79	2.67
23a	44.20	0.53	2.04
23b	41.74	0.64	2.60
23c	42.75	0.68	2.63
23c	42.75	0.17	0.52
23d	44.11	0.49	2.06
24a	49.29	0.25	1.01

Storage requirements

Preliminary stormwater modelling indicates that new infiltration or detention storages will be required in some precincts, whilst others may be able to manage all minor (20%AEP) and major (1%AEP) events with the capacity available in existing wetlands. Indicative volumes are provided for new storages in Table 27. However, it will be necessary to undertake more detailed modelling to determine storage volumes and locations to be accommodated within precincts for reporting at the local structure planning (LWMS) stage. Controlled groundwater levels are provided in Table 27 at the location of each storage and it is recommended that the inverts of stormwater storages are set at least 0.3m above the local controlled groundwater level.

Detailed surface water modelling will be required to support future local structure plans and presented in local water management strategies. This modelling will need to include consideration of the risks associated with surface and groundwater interaction both now and in the future. The establishment of appropriate antecedent conditions in drainage infiltration basins and wetlands functioning as part of the surface water management system will need to consider changing groundwater levels and the performance of subsurface drainage systems under flood conditions.

Table 27: Indicative constructed storage volumes

Location (refer to Figures 32 to 51 in App. C)	Controlled groundwater level (mAHD)	20% AEP Volume (m^3)	1% AEP Volume (m^3)
S1a	39.51	4,400	13,300
S1b	38.38	4,600	5,400
S2a	38.32	4,600	4,600
S3a	41.34	7,500	22,800
S4a	39.66	4,600	5,600
S4b	39.24	4,600	5,500
S6a	39.46	300	4,100
S10a	42.88	1,300	46,800
S10b	43.38	3,200	13,600

Location (refer to Figures 32 to 51 in App. C)	Controlled groundwater level (mAHD)	20% AEP Volume (m^3)	1% AEP Volume (m^3)
S11a	42.60	6,700	43,800
S12a	44.53	11,900	61,300
S12b	44.45	100	10,500
S12c	44.12	12,900	54,100
S12d	43.16	6,400	34,200
S12e	42.86	1,500	57,600
S12f	42.80	8,600	41,600
S12g	41.44	3,200	16,700
S13a	45.14	4,500	15,900
S14b	44.98	200	11,900
S15a	46.00	3,800	23,000
S16a	42.42	7,700	39,800
S16b	39.62	10,300	48,000
S16c	38.43	10,600	49,400
S20a	43.20	600	14,200
S20b	44.36	3,200	13,200
S23a	47.49	2,300	92,100
S23b	48.72	3,400	10,700
S23c	49.61	2,000	8,700
S23d	49.44	1,800	6,900
S23e	48.56	3,900	12,400
S24a	44.03	2,600	11,400
S24c	47.58	4,400	15,800
S25a	41.93	800	145,700

Where existing wetlands are proposed for integration with the arterial drainage system and/or will receive floodwaters during minor or major flood events it is important that the design of the system and its outlets is consistent with protection of wetland values. Guidance for the design of drainage system discharges at their interface with wetlands is provided in section 5.1.3.

Summary of precinct drainage system requirements

Table 28 provides a summary of stormwater and groundwater drainage system requirements for each precinct.

Table 28: Summary precinct drainage requirements

Precinct	Land Use Context	Wetlands	Stormwater management (Small rainfall events)	Stormwater management (Minor and Major rainfall events)	Groundwater management
P1	Residential area with access to regional reserves and wetland system	Little Badgerup Lake (CCW) is located in the eastern portion of the precinct.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains four catchments. Part of this precinct drains into Little Badgerup Lake located in the east of the precinct, part drains to the north into Precinct 2 via two discharge locations and part drains offsite to the west and may require detention capacity of up to 5ML prior to discharge into the existing adjacent drainage system. The remainder, and largest part of this precinct drains into an infiltration basin located in the south of the precinct with a capacity of up to 15ML.	Approximately 17 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 9L/s. A 24hour shutdown storage volume of 760m3 will need to be accommodated at three potential pump station locations.
P2	Low Density Residential area with access to regional reserves and wetland system	Badgerup Lake (CCW) is located in the eastern portion of the precinct.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains two catchments. Runoff from Precinct 1 enters this precinct at 2 locations on the southern boundary. precincts. The majority of this precinct discharges into Badgerup Lake located partially within the precinct in the east. A very small portion of the precinct drains into a detention basin that may need to have capacity of up to 5ML located in the south west of the precinct prior to discharge offsite.	Approximately 27 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 10L/s. A 24hour shutdown storage volume of 830m3 will need to be accommodated at one potential pump station location.
P3	Residential area. Access is available to regional reserves, however wetland system is some distance to the precinct boundary.	N/A	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains two catchments. Runoff from parts of Precinct 4 and Precinct 13 enters this precinct from the north and a portion of this Precinct drains into Precinct 12 to the east. The majority of this precinct drains to a centrally located infiltration basin with capacity of up to 26ML.	Groundwater management is not expected to be required in this precinct
P4	Residential area	N/A	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains three catchments. Runoff from part of this precinct drains into Precinct 3 via Precinct 13 precincts. A portion of the precinct in the west drains offsite and will require one or two detention basins of up to 5ML capacity each to protect the downstream system.	Approximately 8 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 6L/s. A 24hour shutdown storage volume of 500m3 will need to be accommodated at one potential pump station location.
P5	Residential area bisected by road and rail corridor. Eastern section has access to regional reserves and wetland systems. Includes area of public purpose reserve (water supply tanks).	Lake Jandabup (CCW) is partially located in this precinct to the east.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains three catchments. Runoff from the western side of this precinct drains into Precinct 6 to the north. The majority of runoff generated within this precinct drains into Lake Jandabup which is partially within the precinct in the east. The precinct is bisected by the proposed rail transit corridor and may require additional detention on the western side of the corridor prior to discharge.	Groundwater management is not expected to be required in this precinct
P6	Residential area including large park and recreation area in the centre. Access to Lake Mariginiup is available through reserve 46711.	Lake Jandabup (CCW) is partially located in this precinct to the east.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains four catchments. The majority of the precinct drains to the north into Precinct 7 within a regional open space corridor prior to discharging into Mariginiup Lake located in Precinct 7. Most of the remaining precinct area drains to the east into Lake Jandabup located partially within the precinct. A very small portion of the precinct drains into a detention basin of up to 5ML capacity located in the south west of the precinct prior to discharge offsite.	Approximately 3 hectares of the precinct may require groundwater management in future generating a potential flow rate of less than 1L/s. A 24hour shutdown storage volume of 30m3 will need to be accommodated at one potential pump station location.
P7	Residential area bisected by road and rail corridor. Access to regional reserves and wetland systems is available both sides of the corridor.	Mariginiup Lake (CCW) is located in this precinct and a small portion of Lake Jandabup is also within the eastern portion of the precinct	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains two catchments. Runoff from Precinct 6 enters this precinct from the south and a small portion of Precinct 15 from the north east. The majority of the precinct drains into Mariginiup Lake which is located partially within the precinct. A small portion of the precinct area to the east of the proposed rail transit corridor drains into Lake Jandabup located partially within the precinct.	Groundwater management is not expected to be required in this precinct
P8	Residential area with access to regional reserves and wetland system	The northern portion of Mariginiup Lake (CCW) and the whole of Little Mariginiup	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management	Contains two catchments. Runoff from portions of Precinct 15 enters this precinct from the east at two locations. The majority of the precinct drains into Mariginiup Lake which is	Approximately 50 hectares of the precinct may require groundwater management in future generating a potential flow rate of around

Precinct	Land Use Context	Wetlands	Stormwater management (Small rainfall events)	Stormwater management (Minor and Major rainfall events)	Groundwater management
		Lake (CCW) are located in this precinct. There is a small REW located just outside the precinct to the west.	systems are to be accommodated outside of retained wetlands and their buffers.	located partially within the precinct. The remainder of the site drains into a wetland to the west of the precinct and is likely to require detention prior to discharge offsite. There is potential for a small portion of the precinct to drain northward into Lake Adams.	15L/s. A 24hour shutdown storage volume of1,300m3 will need to be accommodated at two potential pump station locations.
P9	Low density residential area with access to regional reserves and wetland system. No changes proposed to Rural zoned lots.	Lake Adams (CCW) is centrally located in this precinct.	NA	Contains two catchments. The majority of the precinct drains into Lake Adams. A relatively small portion of the precinct drains into Precinct 16 to the east.	NA
P10	Residential area affected by mining tenements. Topography may be subject to change. Precinct bisected by road and rail reserve.	There are two CCW's located in this precinct, both of which are proposed to be utilised as part of the precinct drainage system.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains five catchments. Runoff from small portions of this precinct drains into Precinct 16 to the south and drainage from a small portion of Precinct 24 drains into this precinct. The central portion of this precinct drains into infiltration or detention basin of up to 54ML capacity located within the precinct while two other portions of the precinct drain into existing wetlands located within the precinct to the north west and south east.	Approximately 98 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 27L/s. A 24hour shutdown storage volume of r2,300m3 will need to be accommodated at two potential pump station locations.
P11	Residential area with access to regional reserves and wetland systems	The precinct contains four MUW's and a portion of Badgerup Lake (CCW) to the west. One of the MUW's is proposed for integration with the precinct drainage system.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains three catchments. A small portion of Precinct 12 drains into this precinct from the north. Runoff from the western side of this precinct drains into Little Badgerup Lake which is located on the western boundary of the precinct. The majority of runoff generated within this precinct drains into Lake Jandabup which is partially within the precinct in the east. A small portion of this precinct, together with part of Precinct 12, drains into an existing wetland located inside the precinct to the north.	Approximately 96 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 37L/s. A 24hour shutdown storage volume of 3,200m3 will need to be accommodated at three potential pump station locations.
P12	District Activity Centre including a City park. Higher density development expected.	This precinct contains one CCW, one REW and several MUW's. The REW and five MUW's are proposed for integration with the precinct drainage system.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains seven catchments. Runoff from Precinct 3 drains into this precinct from the west and Precinct 13 from the north in three locations. There is potential for a small portion of this precinct to drain into Precinct 13 to the north. Runoff from a small portion of the precinct drains into Lake Badgerup to the west while the remainder of the precinct drains into existing wetlands located throughout the precinct.	Approximately 260 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 129L/s. A 24hour shutdown storage volume of 11,200m3 will need to be accommodated at six potential pump station locations.
P13	Residential area with access to regional reserves and wetland systems.	Lake Jandabup (CCW) is partially located in this precinct to the north. There are two REW's and one MUW also located in this precinct. One MUW and one REW are proposed for integration with the precinct drainage system.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains six catchments. Runoff from parts of this precinct drain into Precinct 12 to the south at three locations and there may be a small return of flows from a small portion of Precinct 12. A small part of the precinct also drains to precinct 3 to the south along with some inflows from precinct 4. The majority of the precinct drains to Lake Jandabup located partially in the precinct in the north. The remaining precinct area drains into existing wetlands located within the precinct and one new infiltration basin of up to 22ML capacity.	Approximately 78 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 23L/s. A 24hour shutdown storage volume of 2,000m3 will need to be accommodated at two potential pump station locations.
P14	Lake Jandabup and associated regional reserves.	Lake Jandabup is located in this precinct.	NA	The precinct drains internally into Lake Jandabup.	N/A
P15	Neighbourhood Centre precinct. Higher residential density expected. 50ha regional sporting facility proposed in eastern part of precinct. Precinct bisected by road and rail reserve.	This precinct contains several REW's and MUW's, some of which are proposed for integration with the precinct drainage system.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains six catchments. Runoff from parts of this precinct drain west into Precinct 7, Precinct 8 and Lake Mariginiup. A small portion drains to the south into Lake Jandabup and the remainder of the precinct drains into two existing wetlands.	Approximately 150 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 34L/s. A 24hour shutdown storage volume of 3,000m3 will need to be accommodated at three potential pump station locations.

Precinct	Land Use Context	Wetlands	Stormwater management (Small rainfall events)	Stormwater management (Minor and Major rainfall events)	Groundwater management
P16	Residential area. Precinct bisected by road and rail reserve.	This precinct contains two CCW's and two MUW's, all of which are proposed for integration with the precincts drainage system.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains six catchments. Runoff drains into the precinct from Precinct 23 to the east and Precinct 10 to the north. All of the various catchments drain to existing wetlands with some additional detention storage provided where necessary.	Approximately 180 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 63L/s. A 24hour shutdown storage volume of 5,500m3 will need to be accommodated at four potential pump station locations.
P17	Existing Industrial and Bush Forever area subject to approved Local Structure Plan	N/A	NA	N/A	N/A
P18	Large Format Service Commercial Area with access to regional reserves and wetland systems.	This precinct contains one small MUW and is bounded to the north east by Lake Gnangara.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Runoff from this catchment drains to Lake Gnangara	Approximately 15 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 2L/s. A 24hour shutdown storage volume of 200m3 will need to be accommodated at one potential pump station location.
P19	Lake Gnangara and associated reserves. No changes proposed to Rural zoned lots in south east corner.	Lake Gnangara is located in this precinct.	NA	The precinct drains internally into Lake Gnangara.	N/A
P20	Residential area with access to regional reserves and wetland systems.	This precinct contains one REW and two MUW's. The REW and one MUW are proposed for integration with the precincts drainage system.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains three catchments draining to existing wetlands and one new infiltration storage of up to 15ML.	Approximately 43 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 10L/s. A 24hour shutdown storage volume of 900m3 will need to be accommodated at one potential pump station location.
P21	Rural area and State Forest. Subject to Bush Forever. No land use change.	The precinct contains two CCW's, one REW and one MUW.	NA	NA	NA
P22	Residential area with access to regional reserves and wetland system.	The precinct contains part of Lake Jandabup and part s of one other CCW and one REW.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Runoff from this catchment drains to Lake Jandabup	Approximately 36 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 4L/s. A 24hour shutdown storage volume of 340m3 will need to be accommodated at two potential pump station locations.
P23	Long term strategic industrial area affected by mining tenement. Topography may be subject to change.	This precinct contains one CCW, one REW and one MUW. Only the CCW is currently proposed to be integrated with the precinct drainage system.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains nine catchments. Runoff from parts of this precinct drains to Precinct 15, Precinct 16, and Lake Jandabup via Precinct 22. The remainder of the precinct drains to existing wetlands and five new infiltration storages of up to 15ML capacity each.	Approximately 99 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 22L/s. A 24hour shutdown storage volume of 1,900m3 will need to be accommodated at four potential pump station locations.
P24	Long term strategic industrial area affected by mining tenement. Topography may be subject to change.	There is one CCW and five REW's within this precinct. The CCW and two of the REW's are proposed to be integrated with the precinct drainage system.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	Contains eight catchments. A small portion of the precinct drains into Precinct 10 to the south. The remainder of the precinct drains to existing wetlands and three new infiltration storages of up to 15ML capacity each.	Approximately 30 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 3L/s. A 24hour shutdown storage volume of 300m3 will need to be accommodated at two potential pump station locations.

Precinct	Land Use Context	Wetlands	Stormwater management (Small rainfall events)	Stormwater management (Minor and Major rainfall events)	Groundwater management
P25	Long term planning investigation area.	The precinct contains one small REW and two small MUW's.	Small rainfall events are to be managed at source (in lots and streets) wherever possible. All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.	The majority of the precinct drains south and if developed may require infiltration storages or detention basins with a combined volume of up to 200ML prior to discharge offsite.	Approximately 68 hectares of the precinct may require groundwater management in future generating a potential flow rate of around 7L/s. A 24hour shutdown storage volume of 600m3 will need to be accommodated at two potential pump station locations.
P26	State Forest	The precinct contains three REW's and two MUW's.	NA	NA	NA
P27	Rural Residential precinct. No land use change	The precinct contains three CCW's, parts of five REW's and four MUW's	NA	NA	NA
P28	State Forest	The precinct contains two CCW's, parts of two REWs and part of one MUW.	NA	NA	NA

5.3.4 Local groundwater management system

As discussed in section 5.2, the preferred approach to control groundwater levels in precincts is implementation of subsurface drainage systems terminating at central collection points or 'hubs' where collected groundwater can be harvested for treatment and reuse.

As noted in the section above, it is generally preferred that subsurface drainage systems are separate from surface water management systems. However, it is accepted that there may be some potential for surface water and groundwater systems to be integrated at an individual precinct level. Where this is proposed it will be necessary to demonstrate that the integrated system design can function effectively for both purposes without loss of performance. For example, where a groundwater drainage system discharges into a combined stormwater and groundwater drain, the groundwater system outlet should be unsubmerged in normal winter baseflow conditions.

Subsurface drainage systems, providing drawdown and control of local groundwater levels and locally infiltrated stormwater, will need to be conceptually designed and presented in local water management strategies for precincts. However, it is also important to consider the effectiveness and environmental implications of subsurface drainage systems at district scale. Therefore, this strategy establishes design criteria for subsurface drainage systems including:

- preliminary arterial layouts and locations for local collection points or 'hubs';
- controlled groundwater levels based on ecological water requirements for local wetlands and vegetation; and
- preliminary sizing of storages and pumping rates at hubs based on estimated groundwater flows and volumes.

Preliminary arterial groundwater management system layouts

The arterial layout of precinct groundwater management systems are expected to be generally aligned to the arterial stormwater system layouts as shown in Figures 33 to 51 in Appendix D. In each precinct, there are one or more local collection points indicated and it is envisaged that these would be co-located with local public open space.

Pipe invert levels have been determined for each network by working backwards up each local system from the minimum controlled groundwater level to provide a minimum pipe gradient of 1:1000. Two minimum controlled groundwater level scenarios have been considered for this exercise: AAMGL (1986-95) and MGL (1986-95) as discussed in section 5.3.1.

It is highly likely that local subsurface drainage systems will be aligned and, in some places, combined with local stormwater systems. As noted previously, at the terminus of each local system, storage will need to be provided to meet stormwater detention requirements and to act as buffer and emergency shutdown storage for transfer pumps.

Harvested volume estimates

Preliminary subsoil drainage system layouts and invert levels discussed in above have been used to derive a controlled groundwater level digital elevation model (DEM). The volume of water represented by the difference between the controlled groundwater level DEM and the predicted future groundwater level DEM from the PRAMS regional groundwater model (Scenario S01) has been calculated to provide a preliminary estimate of the volumes of groundwater that would be collected by this proposed system. This method of estimation is presented schematically in Figure 29.

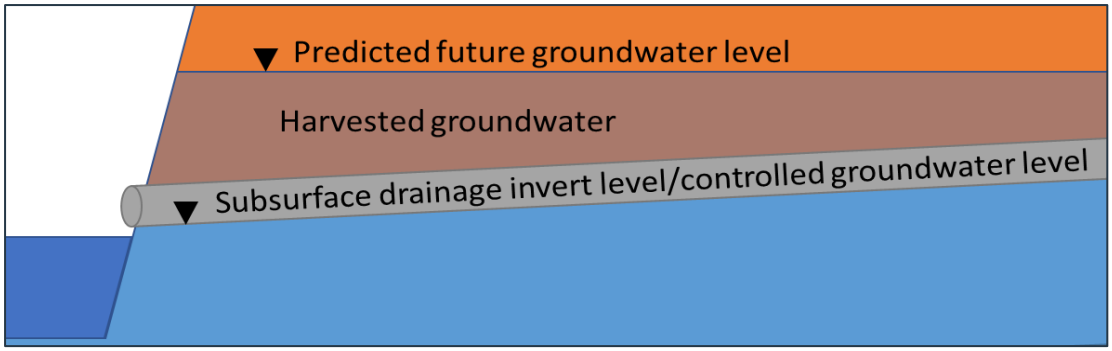

Figure 29: Schematic representation of estimated harvested groundwater

Assuming a specific yield of 0.2, with the controlled groundwater level set at AAMGL (1986-95) the volume of groundwater harvested on full build-out (assumed to occur over a 50-year timeframe) is estimated at 3.4GL/year. With the controlled groundwater level set at MGL (1986-95) the volume of groundwater harvested is estimated at 2.1GL/year. The volume of fill that would be required to achieve a controlled groundwater level of MGL throughout the development would be significant and is likely to be prohibitively expensive. Therefore, the CGL recommended for use in the East Wanneroo DSP area is AAMGL (1986-95). Indicative areas where groundwater may potentially be harvested are shown in Figure 30.

To provide a preliminary estimate of system sizing requirements, flow rates from each precinct have been estimated assuming that groundwater is harvested at a continuous rate over 100 days of the year. Estimated yield volumes and flow rates for each precinct are provided in Table 29. It is noted that these volumes are estimated from the groundwater level predicted at full build-out of the entire East Wanneroo DSP area and are therefore not expected to be reached until after that has occurred.

Table 29: Preliminary groundwater yields from subsoil drainage set at AAMGL 1986-95)

Stage	Precinct	Potential harvesting area (Ha)	Potential groundwater yield (ML)	Estimated flow rate (L/s)
1	1	17.17	75.6	8.8
	6	27.23	3.2	0.4
	10	11.41	231.1	26.7
	18	68.1	18.5	2.1
Stage 1 subtotals			328.4	38.0
2	17*	8.56	26.9	3.1
	25	30.11	59.0	6.8
	24	48.63	28.8	3.3
	8	3.133	131.0	15.2
	12	8.44	1,118.4	129.4
	13	97.5	198.7	23.0
	15	259.3	293.5	34.0
	20	78	87.5	10.1

Stage	Precinct	Potential harvesting area (Ha)	Potential groundwater yield (ML)	Estimated flow rate (L/s)
Stage 2 subtotals			1,943.8	224.9
3	2	34.15	82.7	9.6
	11	151.1	318.4	36.9
	23	14.41	188.5	21.8
	16	42.97	542.0	62.7
	22	35.66	33.3	3.9
Stage 3 subtotals			1,164.9	134.9
Totals		**2,064 Ha**	**3,437 ML**	**397.8L/s**

Note: Precinct 17 is an existing industrial area. The harvested volumes in this precinct are relatively small and it is probable that management of groundwater in surrounding areas will prevent any need to retrofit groundwater management systems into the precinct.

The location of subsoil drains in the vicinity of wetlands will require further consideration in the local water management strategy for each precinct.

Treatment and transfer system design

Local hubs at the terminus of each subsoil drainage network will be required to provide pumping facilities and buffer storage. These are likely to be combined with stormwater detention storage and in some cases may be integrated with retained wetlands. In other cases, new constructed wetlands or detention basins may be constructed to incorporate discharge pumps as shown in Figure 31.

Individual hubs will need to be sized to provide space for a pump station and an appropriate volume of storage in the event of a 24-hour pump shut-down event although it is likely that this could be accommodated within storage provided for management of major storm events.

Assuming that, a small amount of storage, targeted at sediment removal prior to pumping, is provided at each precinct hub, it would also be necessary to provide a more substantial treatment site at a central location prior to the final transfer for use. Based on the estimated harvesting areas and flow rates presented in Table 29, to provide for treatment using a constructed wetland it is likely that a site of up to 30 hectares would be needed to accommodate the facility.

As a comparison, the recently completed Eric Singleton Bird Sanctuary treatment wetland is approximately 2.5 hectares and manages an inflow rate of 50L/s. Similarly, the Wharf Street and Cannington Civic Gardens treatment wetland is approximately 4 hectares and manages approximately 60L/s.

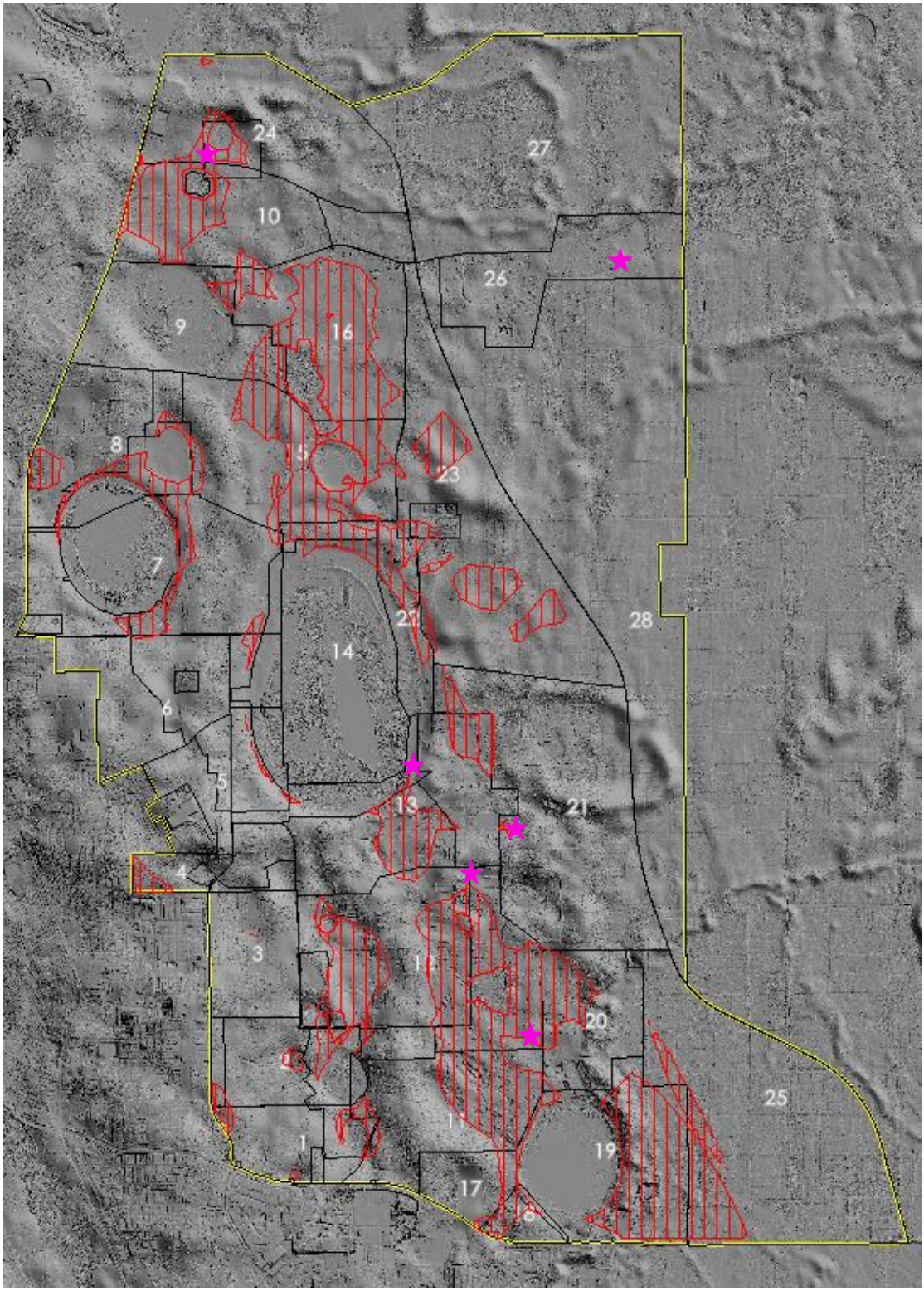

Figure 30: Development areas at risk from rising groundwater levels where subsoil drains should be installed and later utilised to harvest water for reuse (pink stars indicate potential contamination sources (DWER, 1991)

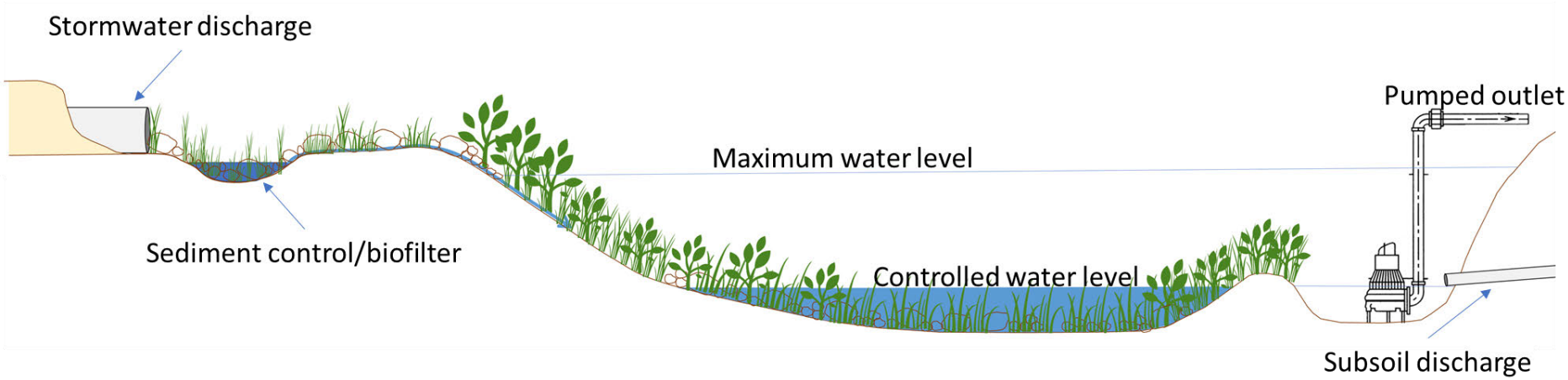

Figure 31: Schematic representation of detention storage and discharge pump system at a local hub

Note: Subsoil drainage infrastructure is to be located outside wetland buffers. Adequate space needs to be provided at the local structure plan stage to accommodate this infrastructure outside wetland buffers.

5.4 Fit-for-purpose water supply and wastewater servicing

As noted in the East Wanneroo DSP, development of the area is expected to proceed through the extension and sequential roll-out of existing water and wastewater services from the western edge of the structure plan area, pushing east from the existing suburbs, consistent with the Staging Plan. This is likely to provide the most efficient and cost-effective way of infrastructure provision.

Local structure plans must outline the strategy for the provision of drinking water, wastewater and irrigation of public open space.

5.4.1 Drinking water

All development is required to connect to scheme water for drinking water purposes. Consultation with the Water Corporation will be necessary to identify the infrastructure requirements, costs and timeframes associated with connection to the Integrated Water Supply System (IWSS). Conventional headworks charges will be payable at time of connection.

5.4.2 Wastewater servicing

Development within the East Wanneroo DSP area should comply with the requirements of the Government Sewerage Policy (2017).

Consultation with the Water Corporation will be necessary to identify the infrastructure requirements, costs and timeframes associated with connection to sewerage. This should include the consideration of any opportunity for sewer mining or access to treated wastewater to supply the non-potable needs of the urban development if there is limited access to groundwater.

5.4.3 Irrigation requirements for public open space and schools

There is a requirement for fit-for-purpose water supply for efficient irrigation of public open spaces throughout the development. As discussed in Section 3.2.1 the change in land uses proposed by the East Wanneroo DSP will result in significantly reduced demands for groundwater allocations for horticultural and agricultural purposes. Additionally, the assessment of future groundwater demands for irrigation of public open spaces and schools indicates that there will be sufficient groundwater to fully cover the likely demands. Therefore, the proposed water source for irrigation of public open spaces and schools throughout the East Wanneroo DSP area is groundwater.

Measures should be implemented to minimise the water use (efficient irrigation of public open space) within the East Wanneroo DSP area including:

- Prioritisation of turf in sport/active public open spaces areas, minimising turf in recreation/passive public open spaces;
- Limiting the use of irrigation to turfed areas of public open spaces only (with all other areas to be irrigated for establishment only, including garden beds, streetscapes, verges and street trees); and,
- Incorporation of non-irrigated landscaping including retention of native vegetation, soft landscaping, and nature play areas.

6 IMPLEMENTATION FRAMEWORK

This water management strategy will be implemented through incorporation of its requirements into local structure planning through the preparation of local water management strategies. Other elements that are critical to the implementation of this strategy include the creation of a developer contributions plan, district monitoring program and district groundwater model.

6.1 Local water management strategy preparation

The information and recommendations presented in this strategy should guide development of Local Water Management Strategies for individual precincts in the East Wanneroo DSP area.

The requirements for local water management strategies are outlined in Department of Water and Environmental Regulation's *Interim: Developing a local water management strategy* (2008a). The local water management strategy is prepared by the developer and should demonstrate to the satisfaction of the WAPC on the advice of DWER in accordance with this DWMS:

- How the key principles and strategies of this plan have been addressed;
- How the urban structure will address water use and management;
- Existing and required water management infrastructure; and
- Detailed land requirements for water management.

The local water management strategy must demonstrate proof of concept including how the water management strategy addresses the issues identified in this district water management strategy and will achieve the criteria in Section 3.

A single local water management strategy is required to be prepared to accompany a local structure plan for each precinct. This will increase the ability to optimise the efficiency of the stormwater management strategy and address any risks from areas that may be identified as having high levels of nutrients or contamination in the soil.

Detailed surface water modelling will be required to support future local structure plans and presented in local water management strategies. This modelling will need to include consideration of the risks associated with surface and groundwater interaction both now and in the future. The establishment of appropriate antecedent conditions in drainage infiltration basins and wetlands functioning as part of the surface water management system will need to consider changing groundwater levels and the performance of subsurface drainage systems under flood conditions.

Technical investigations that will be necessary to support the local water management strategy include, but are not limited to:

- Geotechnical testing of infiltration rates;
- Site investigation for contamination and/or nutrient risks from past land use activities;
- Assessment of the pre-development hydrology, including monitoring of groundwater levels and quality, to determine implications of groundwater recharge and the proposed stormwater management strategy;
- Flora and fauna assessment of any remaining areas of native vegetation;

Stakeholder consultations that will be required include:

- Department of Conservation, Biodiversity and Attractions – regarding wetland delineation and evaluation, and the protection and management of wetlands in Bush forever areas.
- Water Corporation – to understand the potential for relocation of drinking water bores and associated infrastructure, determine the present capacity of water and wastewater services, consider opportunities for sewer mining or treated wastewater for non-potable needs as well as to discuss timescales and costs for any necessary upgrades and/or modifications.
- Department of Water and Environmental Regulation – regarding the potential for future groundwater allocations; if any contaminated material is found on site; and for management of any acid sulfate soils.
- Department of Water and Environmental Regulation (EPA Services) and City of Wanneroo regarding the protection and management of wetlands.
- Department of Water and Environmental Regulation Department of Health and Water Corporation – regarding Public Drinking Water Source Area protection issues.
- Department of Water and Environmental Regulation and City of Wanneroo – to obtain support for the proposed local water management strategy.

The local water management strategy and any subsequent urban water management plan(s) will be referred to DWER for consultation in recognition that it is a sensitive site for water resources, particularly in terms of drinking water supply.

6.2 Considerations for investigation areas

The East Wanneroo DSP area contains a number of Urban Investigation, Industrial Investigation and Planning Investigation areas as identified in the draft Perth-Peel Subregional Planning Frameworks (WAPC, 2018), and presented in Figure 32. Key considerations for these areas that have been addressed in part by the East Wanneroo DSP and this DWMS are presented in Table 30 with their current status in the DSP. Many of these key considerations will require further investigation during development of local structure plans and local water management strategies.

Table 30: Considerations for investigation areas

Investigation area name	Key considerations	Precinct number	Current status
Urban investigation			
South Pinjar (See location 1 in Figure 32)	Impacts, risks and management of groundwater resources (existing Priority 1 Source Protection Area) Protection of Bush Forever areas and Conservation Category Wetlands Basic raw materials – sequential land use allowing for extraction of sand resources Bushfire risk	10	Confirmed suitable for suburban neighbourhood development. Should rezoning under the MRS be approved, DWER will then change the priority of this P1 area to P3* . Land uses are to be consistent with the requirements of Appendix C, WQPN 25 and WQPN 38 and extraction of sand resources.

Investigation area name	Key considerations	Precinct number	Current status
South Gnangara (See location 2 in Figure 32)	Impacts, risks and management of groundwater resources (existing Priority 1 Source Protection Area) Land use transition/interface with Parks and Recreation reserve (Lake Gnangara) and Bush Forever areas Bushfire risk	18	Confirmed suitable for service commercial development. Should rezoning under the MRS be approved, DWER will then change the priority of the small area of P1 to P3*. Land uses are to be consistent with the requirements of Appendix C, WQPN 25 and WQPN 38.
West Jandabup (See location 3 in Figure 32)	Impacts, risks and management of groundwater resources (existing Priority 2 Source Protection Area) Land use transition/interface with Parks and Recreation reserve (Jandabup Lake) and Bush Forever areas Bushfire risk	22	Confirmed unsuitable for urban development. Area is to remain rural with tourism opportunities.
Industrial Investigation			
South Pinjar (See location 4 in Figure 32)	Impacts, risks and management of groundwater resources (existing Priority 1 Source Protection Area) Basic raw materials – sequential land use allowing for extraction of sand resources Protection of Bush Forever areas and Conservation Category Wetlands Bushfire risk	24	Confirmed suitable for employment development. Should rezoning occur in the future under the MRS, DWER will then change the priority of these areas to P3*. Land uses are to be consistent with the requirements of Appendix C, WQPN 25 and WQPN 38.
Jandabup (See location 5 in Figure 32)	Impacts, risks and management of groundwater resources (existing Priority 1 Source Protection Area) Basic raw materials – sequential land use allowing for extraction of sand resources Protection of Conservation Category Wetlands Bushfire risk	23	Confirmed suitable for employment development. Should rezoning occur in the future under the MRS, DWER will then change the priority of these areas to P3*. Land uses are to be consistent with the requirements of Appendix C, WQPN 25 and WQPN 38.
Planning Investigation			
Wanneroo (Bebich Drive precinct) (See location 6 in Figure 32)	Land use transition/interface with Parks and Recreation Reserve (Bagerup Lake) and Bush Forever areas Protection of significant environmental values including high value Carnaby's Black Cockatoo and Redtail Cockatoo feeding habitats, vegetation with between 10%-30% remaining in Perth and Peel regions and threatened ecological communities Bushfire risk	2	Confirmed suitable for special residential development (lots 2000m^2 or larger). Area will be identified as Urban Expansion following completion of the Subregional frameworks review.

Investigation area name	Key considerations	Precinct number	Current status
Jandabup/East Gnangara (See location 7, 7a and 7b in Figure 32)	Land use transition/interface with Parks and Recreation reserve, Bush Forever areas and Conservation Category Wetland Impacts, risks and management associated with groundwater resources (existing Priority 1 and 2 Source Protection Area) Protection of significant environmental values including high value Carnaby's Black Cockatoo and Redtail Cockatoo feeding habitats, vegetation with 10-30% remaining in Perth and Peel regions, resource enhancement wetlands and threatened ecological communities Potential East Wanneroo Rail Link (to be investigated as part of METRONET Stage 2) Proposed Whiteman-Yanchep Highway Bushfire risk	13/21/25	Majority area (Precinct 21/ Location 7) confirmed unsuitable for further development and will identified as Rural and State Forest following completion of the Subregional frameworks review. Small area in Precinct 13 (Location 7a) will be identified as Urban Expansion following completion of the Subregional frameworks review. Small area in Precinct 25 (Location 7b) may be suitable for long term urban development following completion of further investigations and will be identified as Urban Investigation following completion of the Subregional frameworks review. Should rezoning occur in the future under the MRS, DWER will then change the priority of this small area of P2 to P3*. Land uses are to be consistent with the requirements of Appendix C, WQPN 25 and WQPN 38.
East Gnangara (Gnangara Road) (See location 8 in Figure 32)	Impacts, risks and management associated with groundwater resources (existing Priority 1 Source Protection Area) Protection of significant environmental values including high value Carnaby's Black Cockatoo and Redtail Cockatoo feeding habitats, vegetation with 10-30% remaining in Perth and Peel regions, resource enhancement wetlands and threatened ecological communities No land use change is proposed.	19	Confirmed unsuitable for further development. Area is to remain rural.
East Gnangara (See location 9 in Figure 32)	Land use transition/interface with Parks and Recreation reserve and Bush Forever areas Impacts, risks and management associated with groundwater resources (existing Priority 1 Source Protection Area) Protection of significant environmental values including high value Carnaby's Black Cockatoo and Redtail Cockatoo feeding habitats, vegetation with 10-30% remaining in Perth and Peel regions, resource enhancement wetlands and threatened ecological communities Potential East Wanneroo Rail Link (to be investigated as part of METRONET Stage 2) Proposed Whiteman-Yanchep Highway	25	May be suitable for long term urban development following completion of further investigations and will be identified as Urban Investigation following completion of the Subregional frameworks review. Should rezoning occur in the future under the MRS, DWER will then change the priority of this area to P3*. Land uses are to be consistent with the requirements of Appendix C, WQPN 25 and WQPN 38.

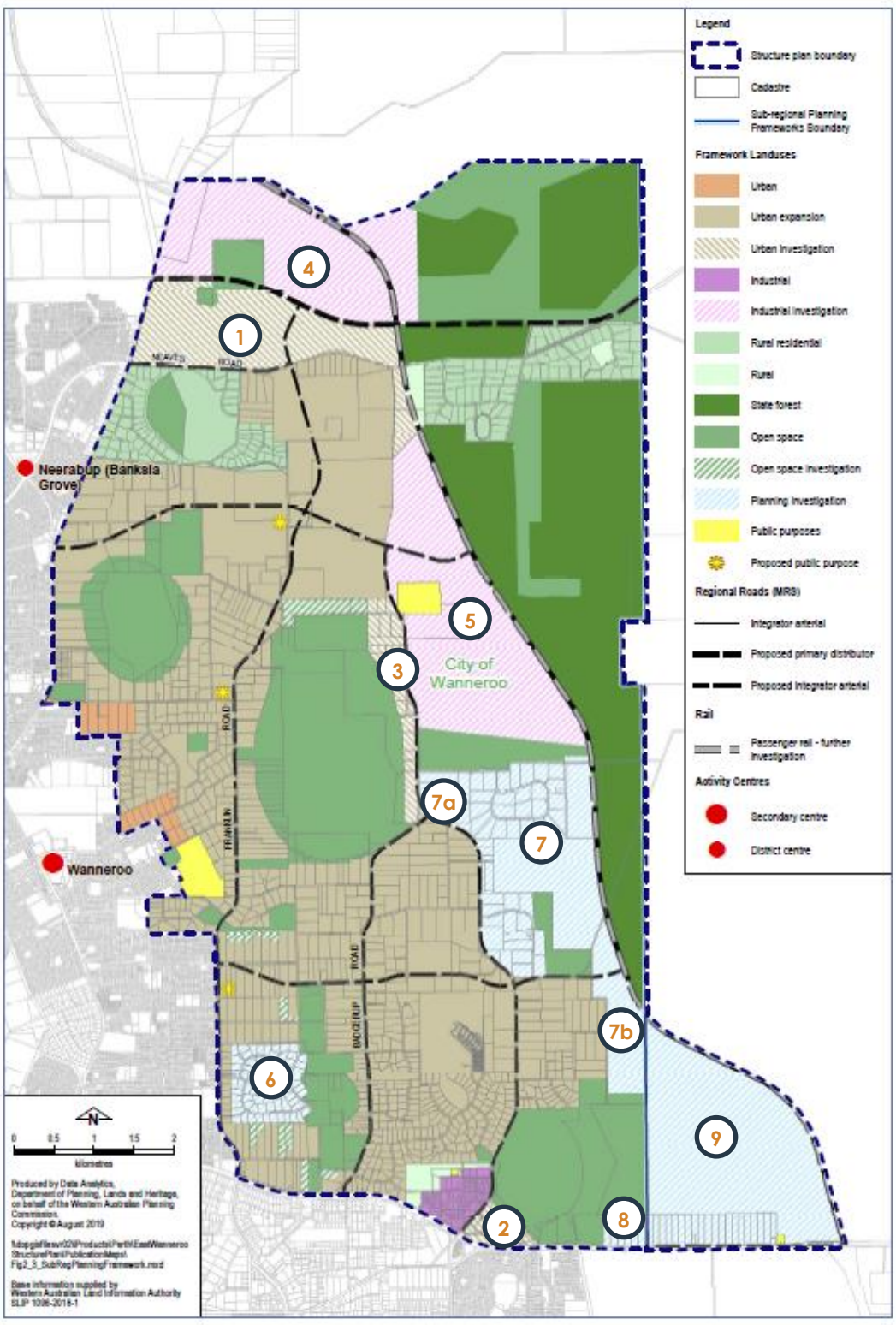

Figure 32: Extract from draft Perth-Peel Sub-regional Frameworks (North West and North East)

Numbered locations relating to Table 30:

1. South Pinjar
2. South Gnangara
3. West Jandabup
4. South Pinjar
5. Jandabup
6. Wanneroo (Bebich Drive precinct)
7. Jandabup/East Gnangara
   7a – small area in precinct 13
   7b – small area in precinct 25
8. East Gnangara (Gnangara Road)
9. East Gnangara

6.3 Developer contributions plan requirements

There are a number of water management actions and requirements that have been proposed that will require work to be undertaken at a district scale and in many cases commencing prior to local structure planning. The actions and requirements outlined below will need to be initiated by DPLH or other agencies with funding provided through the district wide developer contributions plan in accordance with draft State Planning Policy 3.6 – Infrastructure Contributions:

- Implementation of the proposed district monitoring program
- Ongoing planning and design works associated with the district groundwater management strategy.
- Development of wetland management plans for key sites including:
    - Jandabup Lake
    - Mariginiup Lake
    - Lake Adams
    - Gnangara Lake

6.4 District monitoring program

In addition to the implementation of strategies presented in section 6, it will be critical to undertake a more extensive pre- and post-development monitoring program throughout the DSP with the following objectives:

Pre-development

- Provide baseline water quality and level information for district scale design purposes.
- Establish more accurate assessments of the existing health of surface and groundwater systems (including wetlands and native vegetation) in East Wanneroo.

During and post development

- Provide ongoing assessments of surface and groundwater system (including wetlands and native vegetation) health.
- Provide early warning for arising issues enabling adaptive management of surface and groundwater management systems.
- Review the performance of water quality and quantity management systems and propose design adjustments where necessary.

The following sections provide a summary of district scale monitoring programs proposed for the East Wanneroo DSP area. It is anticipated that these programs will be funded through the East Wanneroo developer contributions scheme so that they can be undertaken in a coordinated manner throughout the DSP area rather than in a piecemeal precinct-by-precinct approach.

It is noted that precinct scale monitoring to provide detailed local scale information for design purposes is likely be required in addition to this district scale monitoring in accordance with the usual requirements for developments.

6.4.1 Proposed pre-development monitoring program

District scale predevelopment monitoring should commence as soon as reasonably practical and continue seamlessly throughout development. Local Water Management Strategies

supporting Local Structure Plans for each precinct will be required to report on pre-development monitoring data relevant to their site recorded over a period not less than 18 months (2 winters). Additional site-specific monitoring may be required and should be confirmed with DWER prior to commencement.

Ecological health assessment

Flora and fauna surveys, vegetation condition assessments and weed mapping will need to be undertaken to establish a baseline for the ecological health of all retained wetlands and areas of terrestrial native vegetation.

Groundwater monitoring

District scale groundwater monitoring should be undertaken at a minimum of 3 sites per development precinct with an average distribution throughout the East Wanneroo DSP area of no less than 1 site per 80 hectares.

An assessment/review of the bore network should occur, including consideration of existing bores and new bores to be established, to determine if there are enough bores and appropriate data available. The outcomes of this would need to be discussed and confirmed with DWER before commencement.

Groundwater level monitoring should include installation of loggers to provide continuous recording for at least 18 months (2 winters) at a minimum of 10 sites distributed through the DSP area. Other groundwater monitoring sites should record levels at least once per month.

It is noted that the indicative groundwater monitoring bore network discussed above is unlikely to be sufficient to provide detailed local scale information for subdivision design purposes and that individual precinct-scale monitoring programs will need to be established in addition to district scale monitoring in accordance with the usual requirements for developments.

Table 31 summarises the recommended groundwater quality monitoring parameters and the frequency at which they should be sampled.

Table 31: Groundwater quality monitoring parameters

Analyte group	Parameters	Frequency
In situ measurements	Dissolved Oxygen (DO), Redox potential (Eh), Electrical Conductivity (EC), temperature, pH.	Quarterly
Anions & nutrients	TKN, NH_4, NO_3, DON, TN, TP, PO_4, Cl, SO_4.	Quarterly
Metals (dissolved)	Al, As, Cd, Cr, Cu, Fe, Pb, Ni, Zn and Hg	Annually
Pathogens	E. coli	Quarterly

Surface water monitoring

Surface water monitoring should be undertaken at a 3 sites per major wetland (Badgerup, Gnangara, Jandabup, and Mariginiup) and 1 site per minor retained wetland. Lake Adams, although it has a relatively large catchment, has limited development proposed and will therefore require only one monitoring site.

Table 32 summarises the recommended surface water quality monitoring parameters and the frequency at which they should be sampled.

Table 32: Surface water quality monitoring parameters

Analyte group	Parameters	Frequency
In situ measurements	Depth, Dissolved Oxygen (DO), Redox potential (Eh), Electrical Conductivity (EC), temperature, pH, Turbidity.	Monthly when water is present above ground level
Physio-chemical	Total Alkalinity, Total Acidity, Chlorophyll-a, Gilvin (g440).	Monthly when water is present above ground level
Anions & nutrients	TKN, NH_4, NO_2, NO_3, DON, TN, TP, PO_4, Cl, SO_4.	Monthly when water is present above ground level
Metals	Al, Ca, Fe, K, Mg, Na, S, As, Cd, Cr, Cu, Ni, Pb, Hg, Zn	Bi-annually (winter and summer)
Pathogens	E. coli	Bi-annually (winter and summer)

Establishing baseline water quality and suitable trigger levels for contingency action

As development in the DSP area commences, pre-development data should be reviewed to derive baseline water quality levels and determine appropriate trigger levels for contingency action. This analysis will require a minimum of 18 months (2 winters) of continuous data and a longer duration of record is preferred.

6.4.2 *Proposed development phase and post-development monitoring program and adaptive management*

In general, it is preferred to continue monitoring throughout and following development in a manner that is consistent with the pre-development program including ongoing monitoring of ecological health in retained wetlands and terrestrial vegetation areas. However, it is recommended that an adaptive management approach to monitoring is taken and that annual reporting should consider the relevance of the monitoring program and recommend revisions where necessary to improve understanding of surface water and groundwater systems. Changes to the post-development monitoring program may include:

- The frequency of monitoring may be reduced over time where systems are observed to be reasonably stable or increased to consider specific issues arising.
- The range of analytes may be reduced where systems are observed to be reasonably stable or adjusted to consider specific issues arising.

As development commences in the East Wanneroo DSP area, monitoring sites will need to be adjusted as necessary to deal with landform, land use and hydrological changes. However, where possible, all pre-development monitoring sites should be retained or reinstated in their pre-development locations to maintain continuity.

Additional surface water monitoring sites should be established at all significant discharge points into wetlands including subsoil drainage outlets. Wherever possible, these sites should include both flow and quality monitoring to provide for estimation of annual nutrient loads entering wetlands.

6.5 Future water management reports

Water Management reports are required to be prepared to demonstrate that designs achieve the objectives, strategies and design criteria outlined in this DWMS and any future local water management strategy. They are required to be prepared in support of applications for

subdivision. Where an endorsed local water management strategy exists, the final water management report is able to be prepared as a condition of subdivision (or development). Any water management report should be prepared in consultation with the City of Wanneroo and DWER and submitted to these agencies for approval.

Water Management reports are based on local site investigations appropriate to the proposal and level of risk to water resources. The Water Management report should be consistent with the requirements of the Department of Water and Environmental Regulation's *Urban water management plans: Guidelines for preparing plans and for complying with subdivision conditions* (DoW, 2008b).

Specifically, the Water Management report should include detailed engineering designs (drainage and wastewater) and any landscaping designs relating to water quality improvement or water efficiency improvement. The Water Management report will also include a framework for implementing the water management strategies and plans through the construction and post-development phases of the project.

6.6 Roles and responsibilities

A summary of roles and responsibilities for implementation is provided in Table 33.

Table 33: Summary of roles and responsibilities

Implementation Item	Responsibility	Planning Stage
Prepare and implement developer contributions plan	WAPC/City of Wanneroo	Prior to local structure planning
Prepare and implement district monitoring program	WAPC/City of Wanneroo	Prior to local structure planning
Develop District groundwater management model and implementation strategy	WAPC/City of Wanneroo	Prior to local structure planning
Development of district stormwater drainage and groundwater management concepts	WAPC/City of Wanneroo	Prior to local structure planning
Development of local stormwater drainage and groundwater management concepts	Landowner/ developer	Local structure plan (local water management strategy)
Development of conceptual Landscaping plan incorporating wetland protection and WSUD	Landowner/ developer	Local structure plan (local water management strategy)
Development of refined water balance and confirmation of fit-for-purpose water sources	Landowner/ developer	Local structure plan (local water management strategy)
Identification of water source for irrigation of public open space	Landowner/ developer	Local structure plan (local water management strategy)
Acid sulfate soils investigations/ potential acid sulfate soils management plan	Landowner/ developer	Local structure plan (local water management strategy)
Geotechnical investigations	Landowner/ developer	Local structure plan (local water management strategy)
Flora and fauna investigations	Landowner/ developer	Local structure plan (local water management strategy)
Potable water supply planning and connection to main distribution network	Water Corporation	Local structure plan (local water management strategy)

Implementation Item	Responsibility	Planning Stage
Wastewater planning and connection to main distribution network	Water Corporation	Local structure plan (local water management strategy)
Confirmation of a water supply for POS irrigation	Landowner/ developer	Local structure plan (local water management strategy)
Implementation of pre-development monitoring program	Landowner/ developer	Local structure plan (local water management strategy)
Confirmation of post-development monitoring program	Landowner/ developer	Local structure plan (local water management strategy)
Referral to the EPA of specific mechanisms and provisions to adequately secure, protect and manage the environmental values within the East Wanneroo area	Landowner/ developer	Prior to local scheme amendment
Design of water distribution networks	Landowner/ developer	Subdivision (urban water management plan)
Design of wastewater reticulation networks	Landowner/ developer	Subdivision (urban water management plan)
Design of drainage networks	Landowner/ developer	Subdivision (urban water management plan)
Aboriginal consultation	Landowner/ developer	Subdivision (urban water management plan)
Stormwater and contamination management plan	Landowner/ developer	Development Application

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APPENDIX A – GEOMORPHIC WETLANDS IN THE EAST WANNEROO DSP AREA (DBCA, 2020)

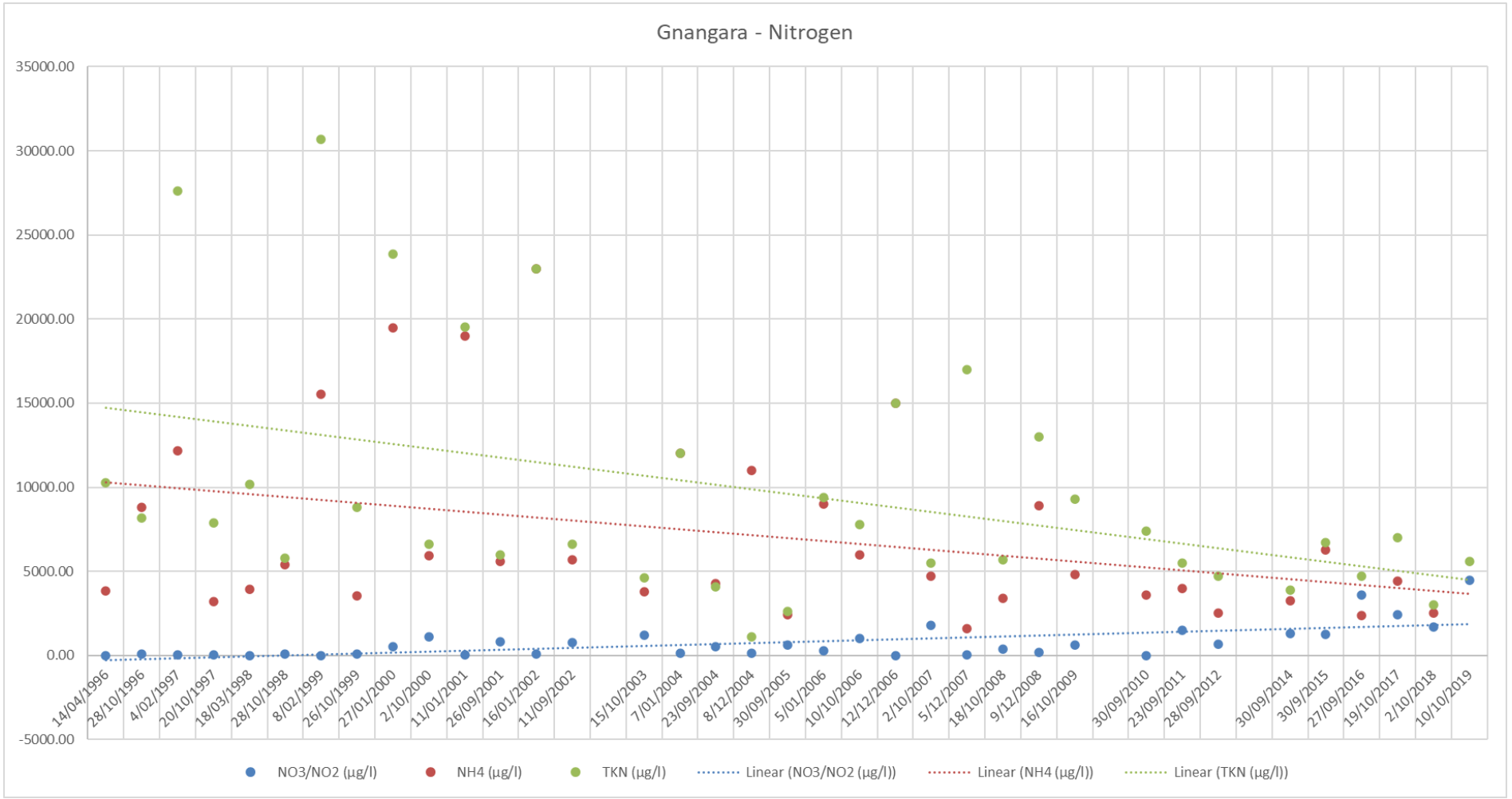
Table 34: Geomorphic wetlands listing

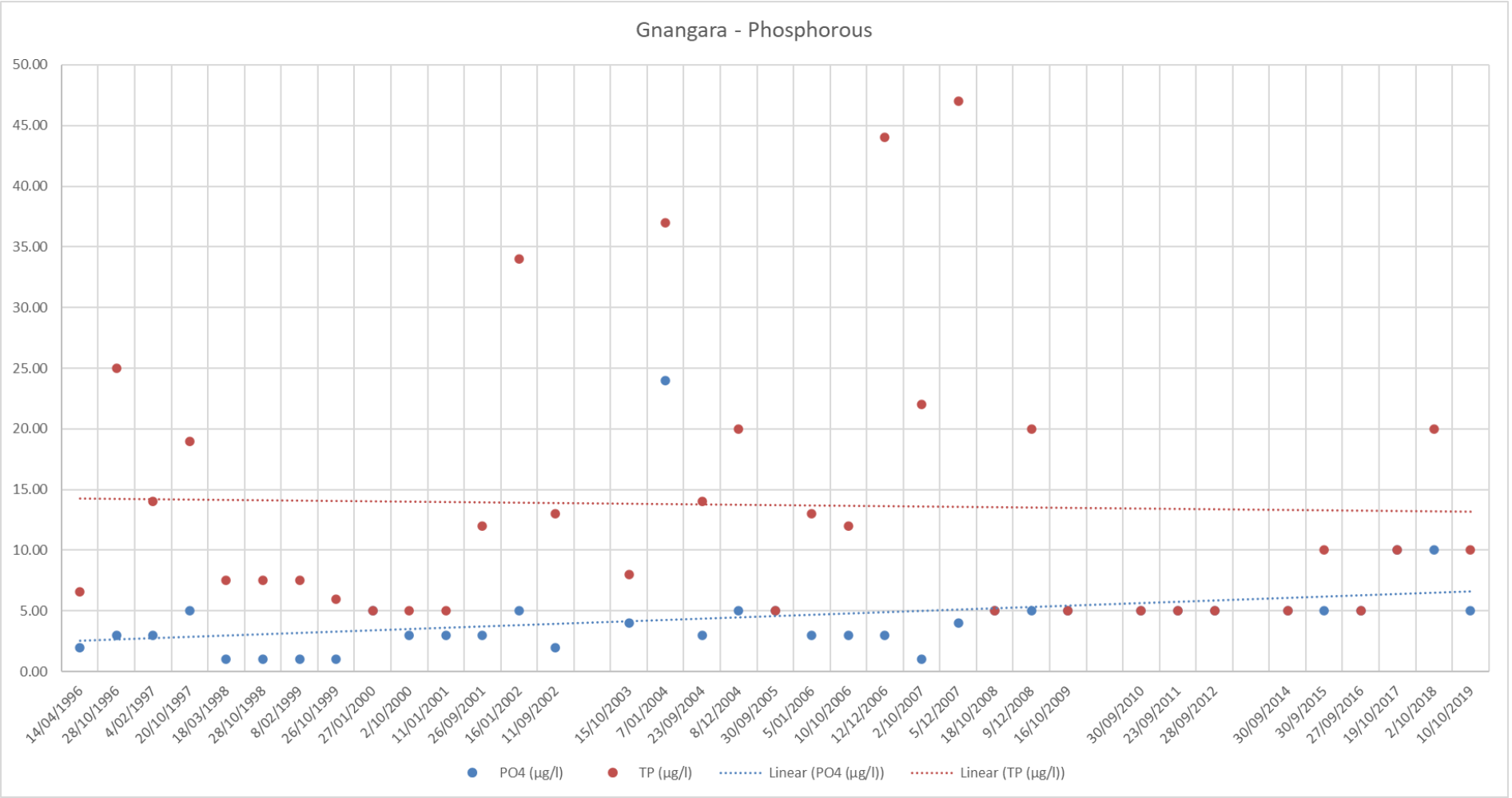
UFI	Management category	Wetland type	Landform	Name	Area (ha)
7944	Conservation	Sumpland	Basin	unknown	2.4
7945	Conservation	Dampland	Basin	Little Coogee Flat	5.4
7946	Conservation	Dampland	Basin	unknown	1.2
7953	Conservation	Lake	Basin	Mariginup Lake	145.2
7959	Conservation	Dampland	Basin	Lake Adams	56.7
7960	Conservation	Dampland	Basin	Lake Adams	33.2
8077	Conservation	Sumpland	Basin	unknown	4.9
8079	Conservation	Dampland	Basin	unknown	1.1
8088	Conservation	Dampland	Basin	unknown	27.3
8093	Conservation	Sumpland	Basin	Hawkins Road Swamp	6.2
8098	Conservation	Dampland	Basin	Bustard Landing	1.0
8099	Conservation	Dampland	Basin	Bustard Swamp	2.4
8102	Conservation	Dampland	Basin	unknown	9.9
8119	Conservation	Dampland	Basin	Bustard North	1.3
8122	Conservation	Dampland	Basin	unknown	0.8
8130	Conservation	Lake	Basin	Gnangara lake	117.4
8132	Conservation	Sumpland	Basin	Little Badgerup Lake	5.4
8154	Conservation	Sumpland	Basin	unknown	4.4
8161	Conservation	Sumpland	Basin	Little Mariginup	17.5
8165	Conservation	Sumpland	Basin	Badgerup Lake	23.7
14241	Conservation	Sumpland	Basin	unknown	12.8
15006	Conservation	Lake	Basin	Jandabup Lake	313.9
15901	Conservation	Dampland	Basin	unknown	10.5
7940	Resource Enhancement	Dampland	Basin	unknown	1.8
7941	Resource Enhancement	Dampland	Basin	Little Coogee Swamp	5.1
7942	Resource Enhancement	Dampland	Basin	unknown	1.6
7943	Resource Enhancement	Dampland	Basin	unknown	1.9
8078	Resource Enhancement	Dampland	Basin	unknown	4.4
8081	Resource Enhancement	Dampland	Basin	unknown	0.8
8092	Resource Enhancement	Dampland	Basin	unknown	32.9
8094	Resource Enhancement	Dampland	Basin	unknown	6.4

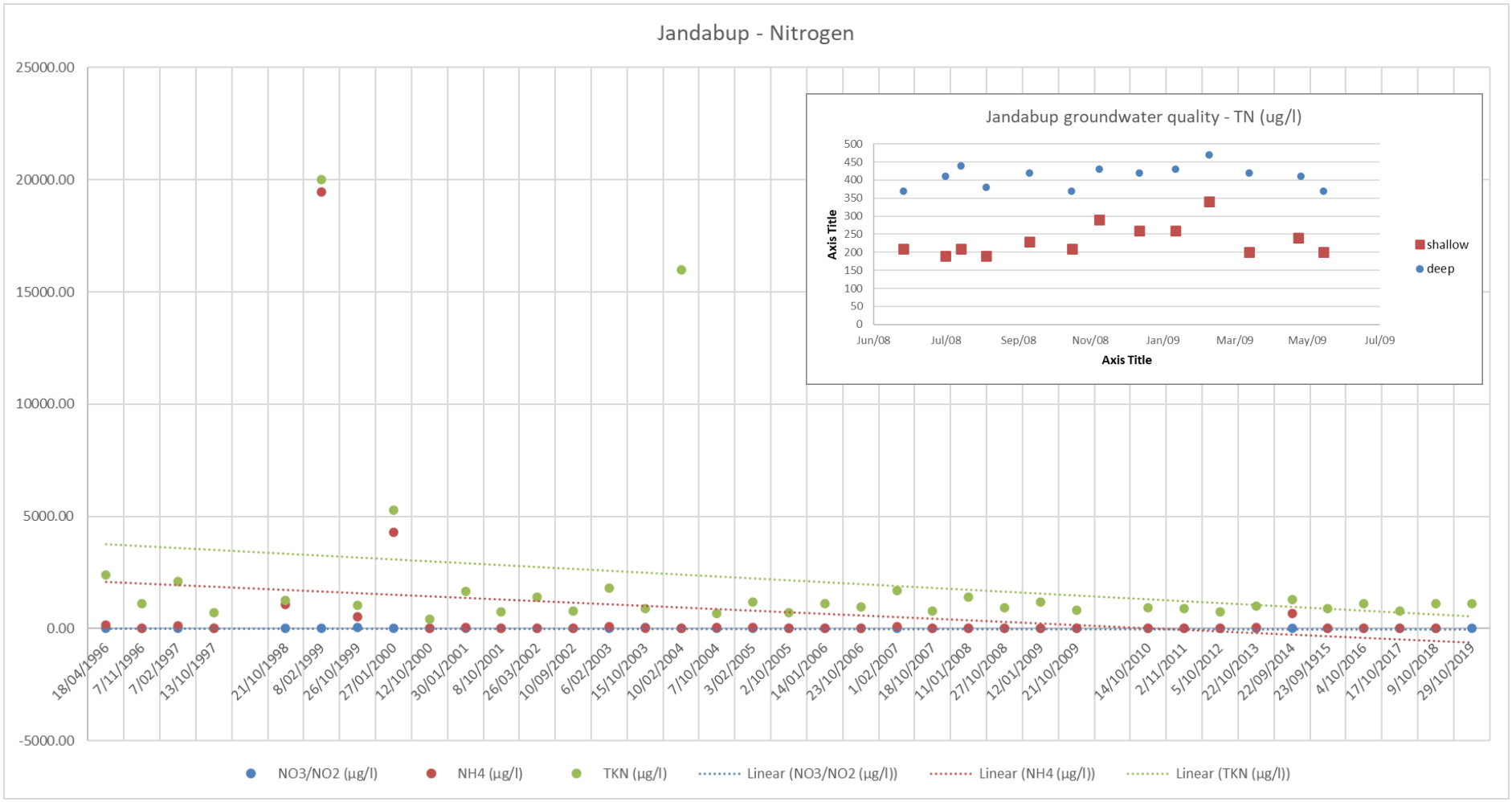
UFI	Management category	Wetland type	Landform	Name	Area (ha)
8095	Resource Enhancement	Dampland	Basin	unknown	27.0
8101	Resource Enhancement	Dampland	Basin	unknown	1.1
8105	Resource Enhancement	Sumpland	Basin	unknown	1.5
8114	Resource Enhancement	Lake	Basin	Jandabup Lake	17.5
8120	Resource Enhancement	Sumpland	Basin	unknown	0.9
8121	Resource Enhancement	Dampland	Basin	unknown	5.5
8123	Resource Enhancement	Dampland	Basin	unknown	9.0
8127	Resource Enhancement	Dampland	Basin	unknown	7.3
8258	Resource Enhancement	Dampland	Basin	unknown	2.3
8338	Resource Enhancement	Dampland	Basin	unknown	1.2
14244	Resource Enhancement	Dampland	Basin	unknown	1.2
14245	Resource Enhancement	Dampland	Basin	unknown	2.9
14247	Resource Enhancement	Dampland	Basin	unknown	5.3
14253	Resource Enhancement	Sumpland	Basin	unknown	2.6
14254	Resource Enhancement	Dampland	Basin	unknown	1.6
14261	Resource Enhancement	Dampland	Basin	unknown	1.4
15443	Resource Enhancement	Dampland	Basin	unknown	17.3
7957	Multiple Use	Lake	Basin	Jandabup Lake	99.2
8096	Multiple Use	Dampland	Basin	unknown	2.9
8100	Multiple Use	Dampland	Basin	unknown	1.2
8103	Multiple Use	Sumpland	Basin	unknown	5.9
8104	Multiple Use	Dampland	Basin	unknown	0.7
8106	Multiple Use	Dampland	Basin	unknown	3.0
8107	Multiple Use	Sumpland	Basin	unknown	2.0
8108	Multiple Use	Dampland	Basin	unknown	17.1
8110	Multiple Use	Sumpland	Basin	unknown	4.9
8111	Multiple Use	Dampland	Basin	unknown	4.7
8112	Multiple Use	Dampland	Basin	unknown	5.5
8113	Multiple Use	Sumpland	Basin	unknown	1.5
8116	Multiple Use	Dampland	Basin	Snake Swamp	14.4
8117	Multiple Use	Sumpland	Basin	Little Dundarbar Swamp	11.2
8118	Multiple Use	Dampland	Basin	unknown	22.4
8128	Multiple Use	Sumpland	Basin	unknown	5.4
8129	Multiple Use	Dampland	Basin	unknown	4.8
8131	Multiple Use	Dampland	Basin	unknown	4.4

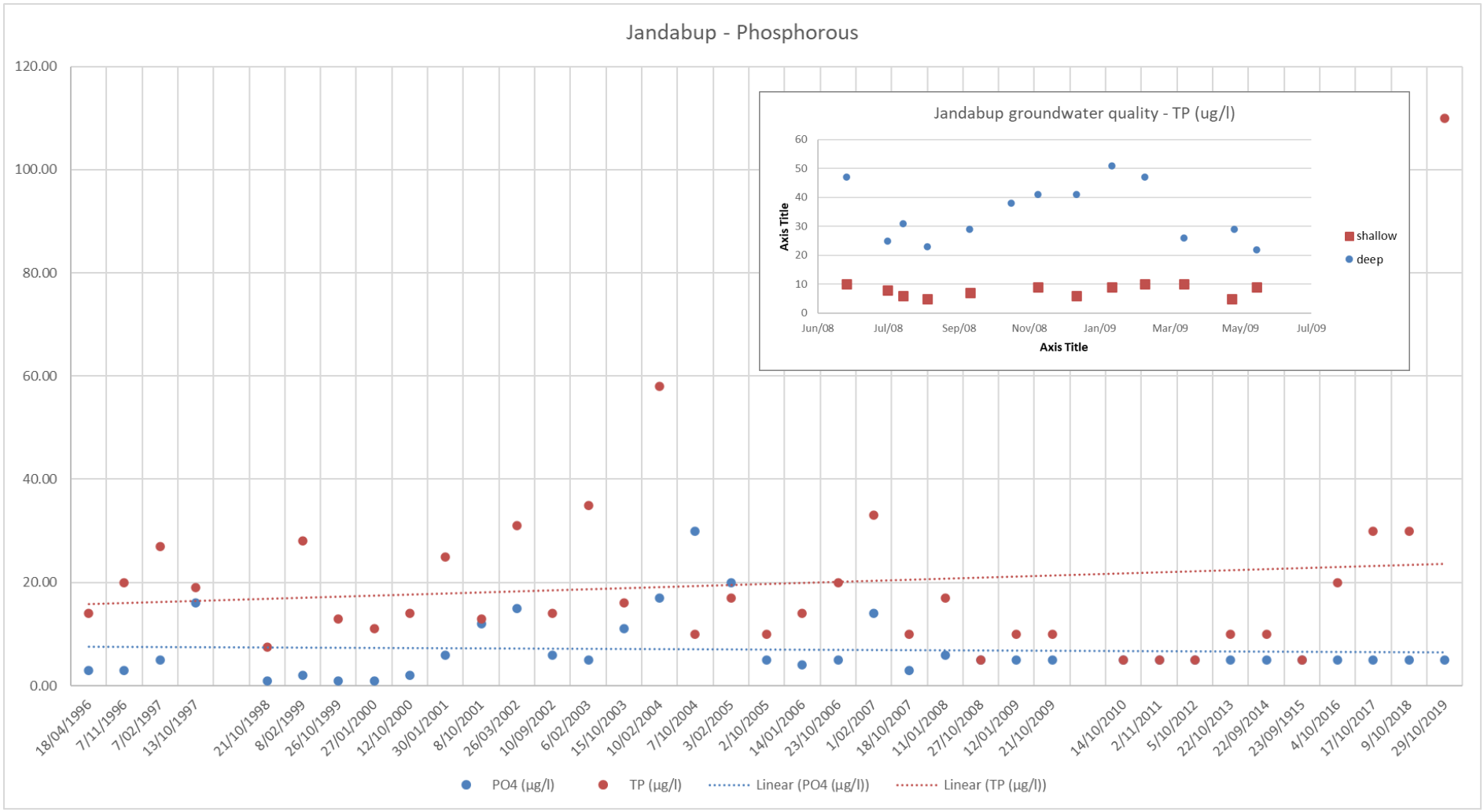
UFI	Management category	Wetland type	Landform	Name	Area (ha)
8134	Multiple Use	Sumpland	Basin	unknown	1.7
8138	Multiple Use	Dampland	Basin	unknown	1.0
8153	Multiple Use	Dampland	Basin	Pinesend Farm Swamp	47.5
8155	Multiple Use	Sumpland	Basin	unknown	7.6
8164	Multiple Use	Dampland	Basin	unknown	9.7
8259	Multiple Use	Dampland	Basin	unknown	3.3
8269	Multiple Use	Dampland	Basin	unknown	1.6
8340	Multiple Use	Dampland	Basin	unknown	1.3
8341	Multiple Use	Dampland	Basin	unknown	0.5
13920	Multiple Use	Dampland	Basin	unknown	22.0
14242	Multiple Use	Sumpland	Basin	unknown	1.6
14248	Multiple Use	Dampland	Basin	unknown	1.8
14252	Multiple Use	Sumpland	Basin	unknown	8.7
15022	Multiple Use	Dampland	Basin	unknown	38.3
15442	Multiple Use	Dampland	Basin	unknown	6.4
15900	Multiple Use	Dampland	Basin	unknown	12.1
15902	Multiple Use	Dampland	Basin	unknown	12.1

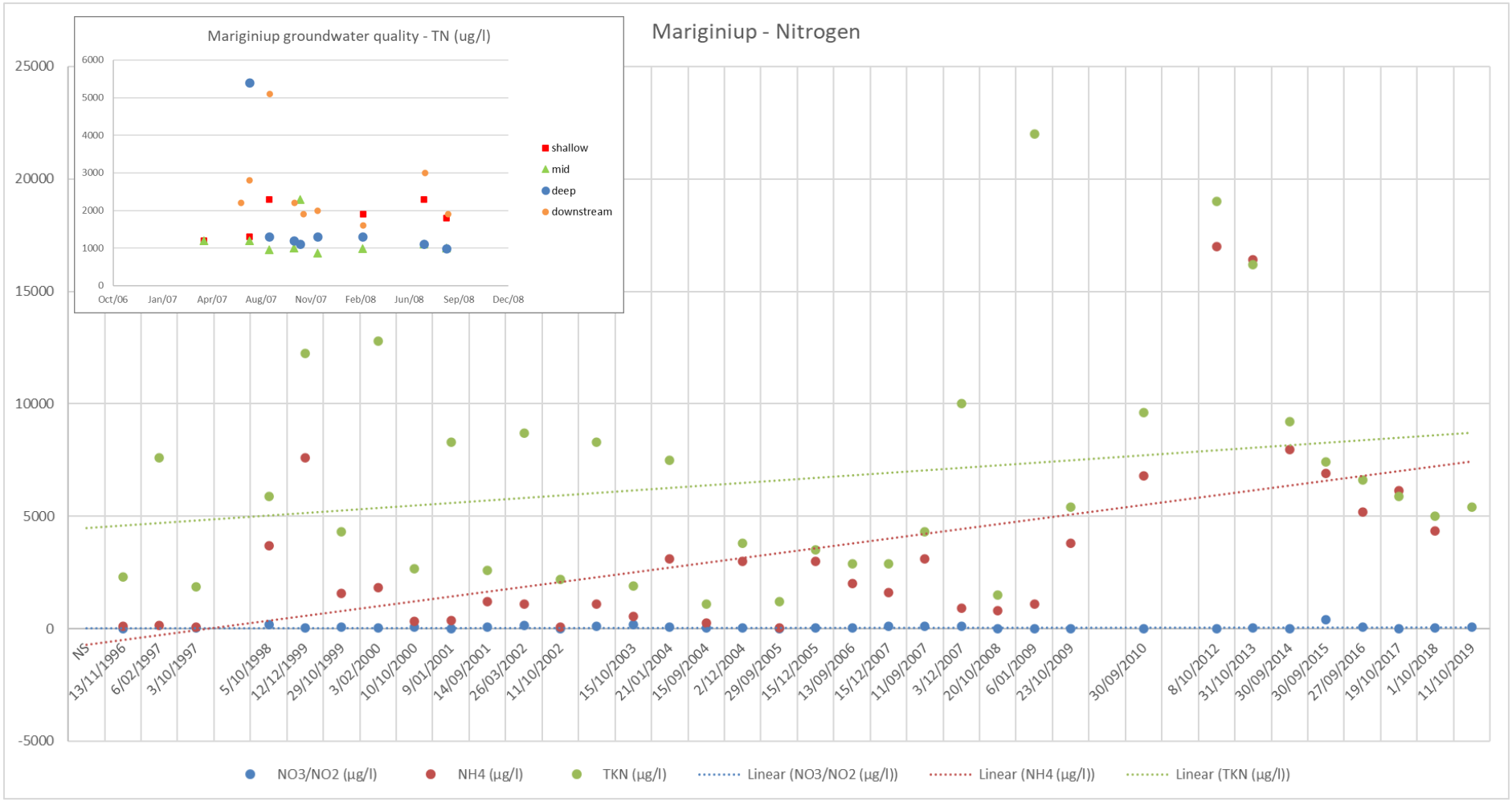
APPENDIX B – WATER QUALITY DATA FOR MAJOR LAKES AND ADJACENT GROUNDWATER (WHERE AVAILABLE)

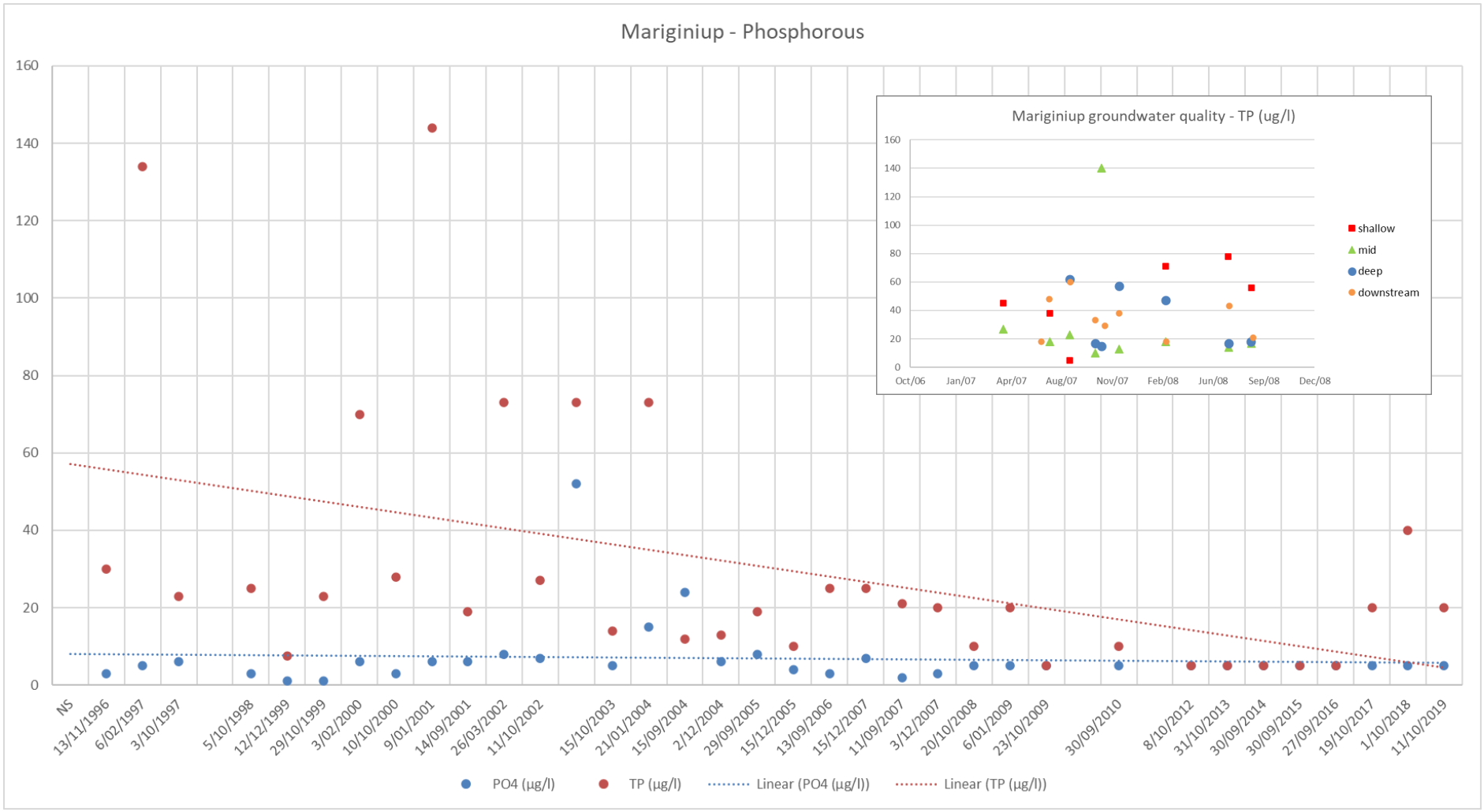

Gnangara - Nitrogen
35000.00
30000.00
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
-5000.00
14/04/1996
28/10/1996
4/02/1997
20/10/1997
18/03/1998
28/10/1998
8/02/1999
26/10/1999
27/01/2000
2/10/2000
11/01/2001
26/09/2001
16/01/2002
11/09/2002
15/10/2003
7/01/2004
23/09/2004
8/12/2004
30/09/2005
5/01/2006
10/10/2006
12/12/2006
2/10/2007
5/12/2007
18/10/2008
9/12/2008
16/10/2009
30/09/2010
23/09/2011
28/09/2012
30/09/2014
30/9/2015
27/09/2016
19/10/2017
2/10/2018
10/10/2019
NO3/NO2 (µg/l)
NH4 (µg/l)
TKN (µg/l)
Linear (NO3/NO2 (µg/l))
Linear (NH4 (µg/l))
Linear (TKN (µg/l))


Gnangara - Phosphorous
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
14/04/1996
28/10/1996
4/02/1997
20/10/1997
18/03/1998
28/10/1998
8/02/1999
26/10/1999
27/01/2000
2/10/2000
11/01/2001
26/09/2001
16/01/2002
11/09/2002
15/10/2003
7/01/2004
23/09/2004
8/12/2004
30/09/2005
5/01/2006
10/10/2006
12/12/2006
2/10/2007
5/12/2007
18/10/2008
9/12/2008
16/10/2009
30/09/2010
23/09/2011
28/09/2012
30/09/2014
30/9/2015
27/09/2016
19/10/2017
2/10/2018
10/10/2019
PO4 (µg/l)
TP (µg/l)
Linear (PO4 (µg/l))
Linear (TP (µg/l))


Jandabup - Nitrogen
25000.00
20000.00
15000.00
10000.00
5000.00
0.00
-5000.00
18/04/1996
7/11/1996
7/02/1997
13/10/1997
21/10/1998
8/02/1999
26/10/1999
27/01/2000
12/10/2000
30/01/2001
8/10/2001
26/03/2002
10/09/2002
6/02/2003
15/10/2003
10/02/2004
7/10/2004
3/02/2005
2/10/2005
14/01/2006
23/10/2006
1/02/2007
18/10/2007
11/01/2008
27/10/2008
12/01/2009
21/10/2009
14/10/2010
2/11/2011
5/10/2012
22/10/2013
22/09/2014
23/09/1915
4/10/2016
17/10/2017
9/10/2018
29/10/2019
NO3/NO2 (µg/l)
NH4 (µg/l)
TKN (µg/l)
Linear (NO3/NO2 (µg/l))
Linear (NH4 (µg/l))
Linear (TKN (µg/l))
Jandabup groundwater quality - TN (ug/l)
500
450
400
350
300
250
200
150
100
50
0
Axis Title
Jun/08
Jul/08
Sep/08
Nov/08
Jan/09
Mar/09
May/09
Jul/09
Axis Title
shallow
deep


Jandabup - Phosphorous
120.00
100.00
80.00
60.00
40.00
20.00
0.00
18/04/1996
7/11/1996
7/02/1997
13/10/1997
21/10/1998
8/02/1999
26/10/1999
27/01/2000
12/10/2000
30/01/2001
8/10/2001
26/03/2002
10/09/2002
6/02/2003
15/10/2003
10/02/2004
7/10/2004
3/02/2005
2/10/2005
14/01/2006
23/10/2006
1/02/2007
18/10/2007
11/01/2008
27/10/2008
12/01/2009
21/10/2009
14/10/2010
2/11/2011
5/10/2012
22/10/2013
22/09/2014
23/09/1915
4/10/2016
17/10/2017
9/10/2018
29/10/2019
PO4 (µg/l)
TP (µg/l)
Linear (PO4 (µg/l))
Linear (TP (µg/l))
Jandabup groundwater quality - TP (ug/l)
60
50
40
30
20
10
0
Axis Title
Jun/08
Jul/08
Sep/08
Nov/08
Jan/09
Mar/09
May/09
Jul/09
Axis Title
shallow
deep


Mariginiup - Nitrogen
Mariginiup groundwater quality - TN (ug/l)
shallow
mid
deep
downstream
NO3/NO2 (µg/l)
NH4 (µg/l)
TKN (µg/l)
Linear (NO3/NO2 (µg/l))
Linear (NH4 (µg/l))
Linear (TKN (µg/l))


Mariginiup - Phosphorous
160
140
120
100
80
60
40
20
0
NS
13/11/1996
6/02/1997
3/10/1997
5/10/1998
12/12/1999
29/10/1999
3/02/2000
10/10/2000
9/01/2001
14/09/2001
26/03/2002
11/10/2002
15/10/2003
21/01/2004
15/09/2004
2/12/2004
29/09/2005
15/12/2005
13/09/2006
15/12/2007
11/09/2007
3/12/2007
20/10/2008
6/01/2009
23/10/2009
30/09/2010
8/10/2012
31/10/2013
30/09/2014
30/09/2015
27/09/2016
19/10/2017
1/10/2018
11/10/2019
PO4 (µg/l)
TP (µg/l)
Linear (PO4 (µg/l))
Linear (TP (µg/l))
Mariginiup groundwater quality - TP (ug/l)
160
140
120
100
80
60
40
20
0
Oct/06
Jan/07
Apr/07
Aug/07
Nov/07
Feb/08
Jun/08
Sep/08
Dec/08
shallow
mid
deep
downstream

APPENDIX C – APPROPRIATE LAND USES FOR FUTURE P3* AREAS

The table below shows land uses that would be considered appropriate within areas that will become P3* PDWSAs should rezoning be approved under the MRS. Subsequent stages of planning and their associated water management plans should include increasing level of detail of land use zonings and specific land uses as appropriate. The local scheme should include suitable acknowledgement of all PDWSAs, including P3* areas, ideally via special control area, outlining the appropriate land uses within the zone, and requirement for referral to DWER for advice on protecting drinking water quality and public health.

It is important to refer to DWER's WQPN 25 and WQPN 38 for further advice on requirements in P3* areas.

EMPLOYMENT AREAS

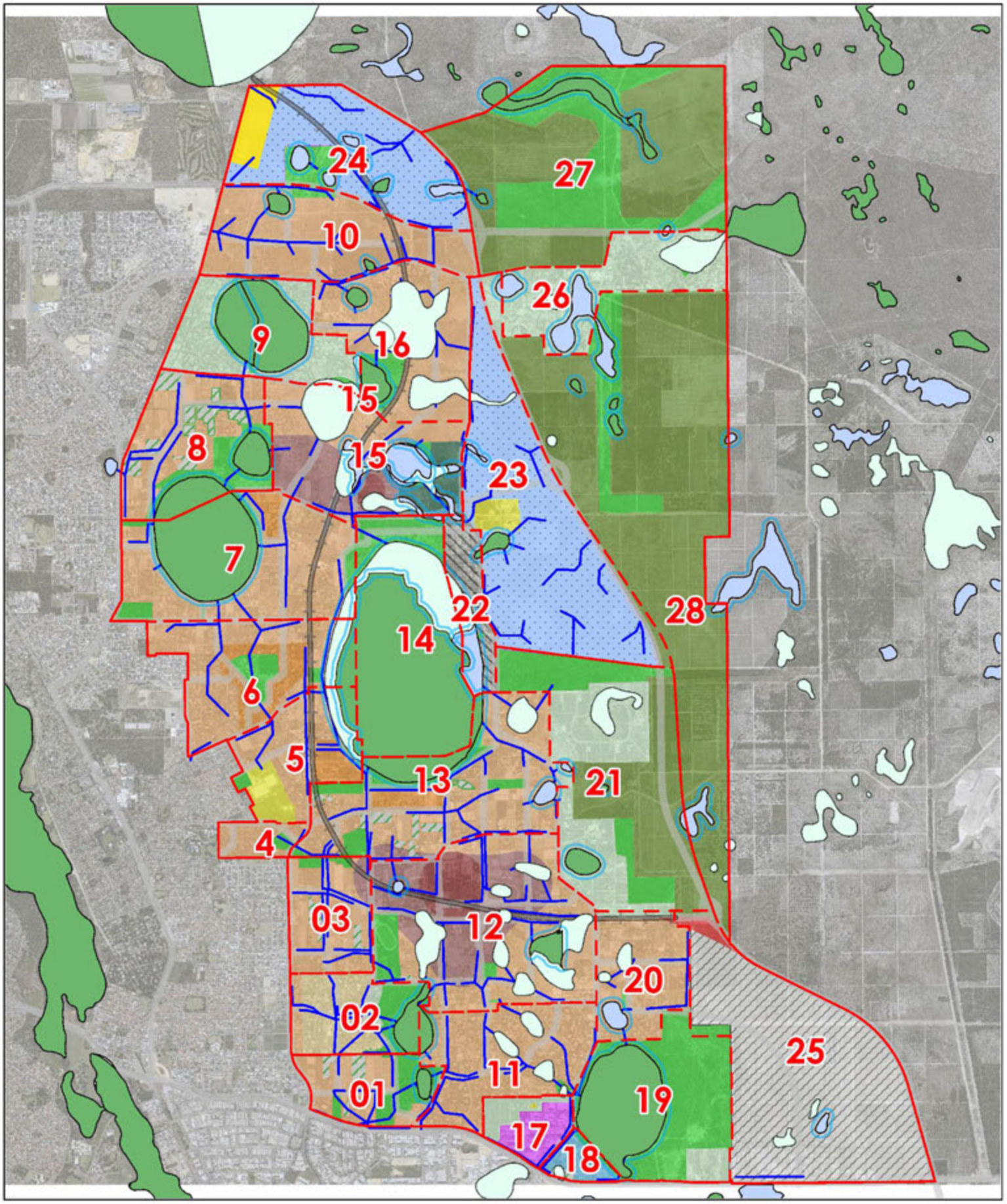
- Amusement parlour
- Betting agency
- Child care premises
- Cinema/theatre
- Convenience store
- Exhibition centre
- Funeral parlour
- Garden centre (but no nursery)
- Market (i.e. markets not market gardens)
- Night club
- Office
- Restricted premises
- Shop
- Showroom
- Trade display
- Primary school, secondary school (but not tertiary or scientific research institution)
- Fast food outlet
- Lunch bar
- Reception centre
- Restaurant/café
- Tavern
- Winery (but not viticulture), distillery and cidery
- Railway station
- Consulting rooms
- Medical centre (but not hospital)
- Caravan Park / Park home park - ONLY if connected to reticulated sewerage and no discharge to ground permitted
- Circus/fair
- Club premises (but not public swimming pools/aquatic centres – unless backwash is disposed to reticulated sewerage, which requires a trade waste agreement with the wastewater service provider)
- Community hall
- Recreation park/oval
- Hotel
- Motel
- Place of worship

URBAN AREAS • Childcare premises • Home business • Recreation park/oval • Dwellings (types to be specified at later planning stages)
SERVICE COMMERCIAL AREAS • Showroom • Trade display • Lunch bar

**Land uses are defined in Schedule 1, Division 2 of the Planning and Development (Local Planning Scheme) Regulations 2015*

APPENDIX D – PRELIMINARY PRECINCT DRAINAGE LAYOUTS AND SUBCATCHMENT MODELLING DETAILS

Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 33: Layout plan for Figures 34 - 51 Precinct drainage assessment



Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

@ A4

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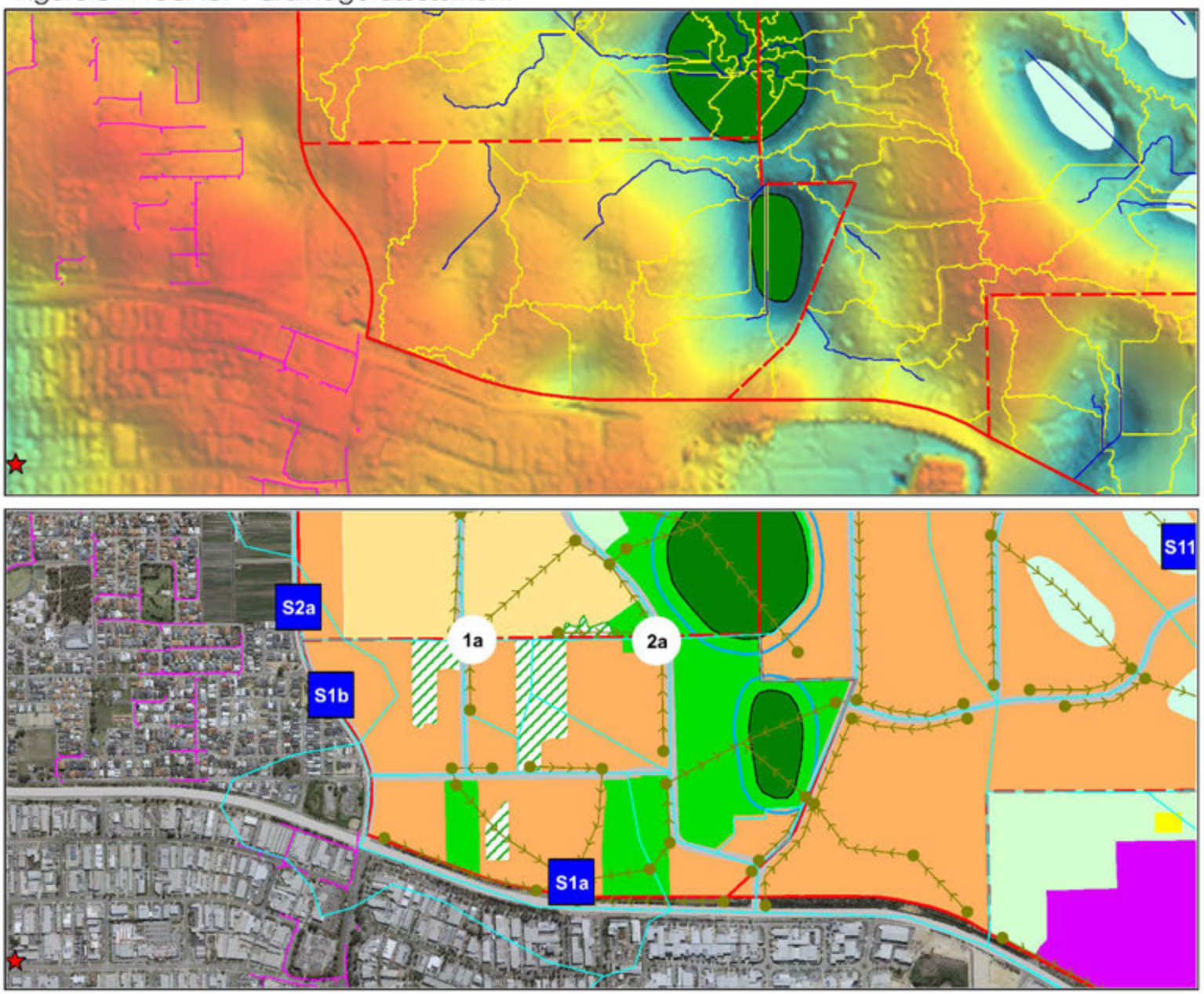
Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 34 Precinct 1 drainage assessment



LEGEND:

- Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use
- Indicative 50m wetland buffers
- Potential contaminated sites
- Indicative flowpaths
- Topographic subcatchments
- Modelled subcatchments
- Modelled drainage
- Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area
- Precinct boundaries
- Rail transit corridor
- Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

- S1a — Modelled storages
- 1a — Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

0 500
metres
Scale 1:20,000 @ A4

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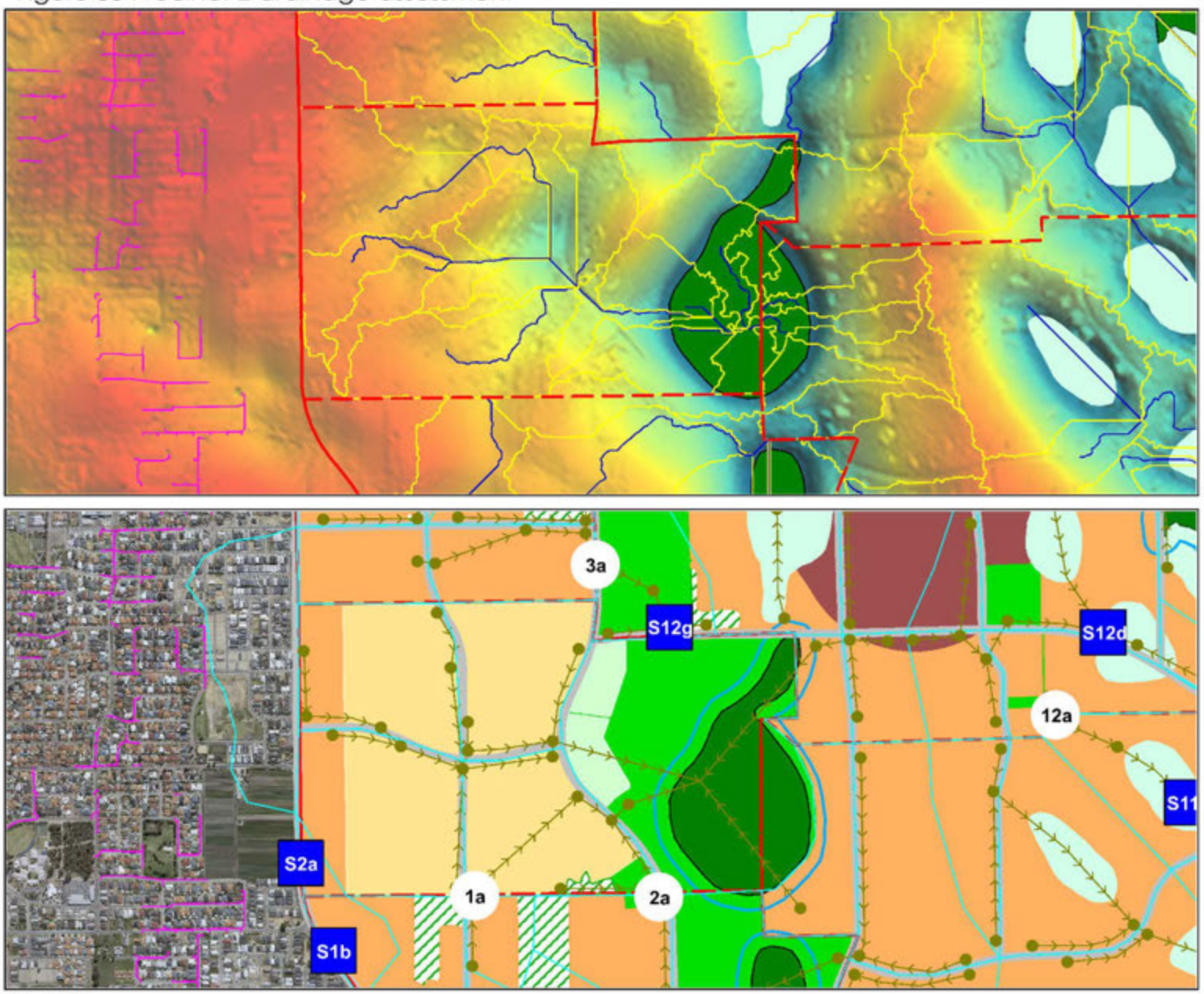
Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 35 Precinct 2 drainage assessment



LEGEND:

Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use

Indicative 50m wetland buffers

Potential contaminated sites

Indicative flowpaths

Topographic subcatchments

Modelled subcatchments

Modelled drainage

Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area

Precinct boundaries

Rail transit corridor

Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

S1a Modelled storages

1a Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

0 500
metres
Scale 1:20,000 @ A4

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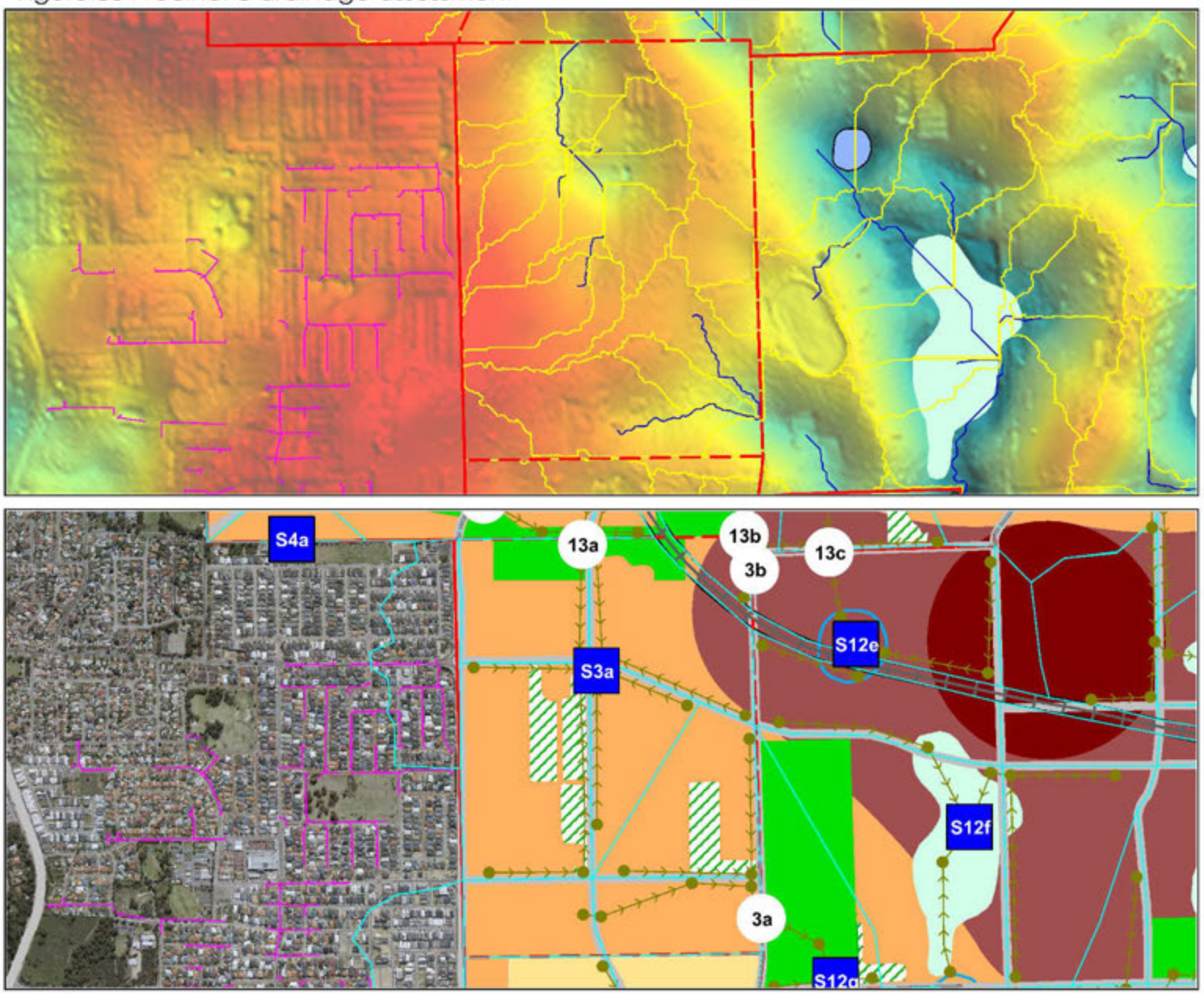
Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 36 Precinct 3 drainage assessment



LEGEND:

Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use

Indicative 50m wetland buffers

Potential contaminated sites

Indicative flowpaths

Topographic subcatchments

Modelled subcatchments

Modelled drainage

Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area

Precinct boundaries

Rail transit corridor

Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

S1a Modelled storages

1a Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

N

0 500
metres

Scale 1:20,000 @ A4

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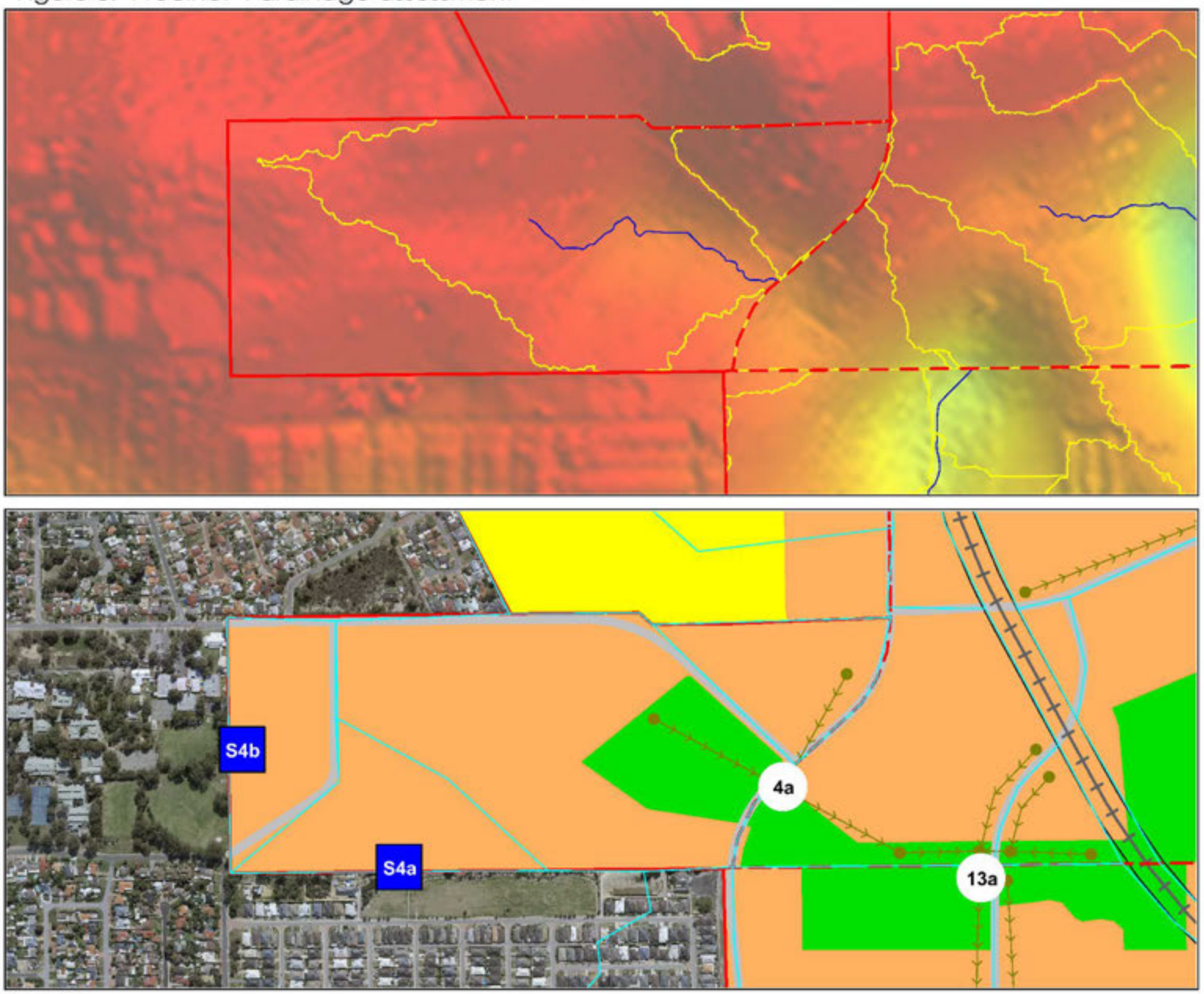
Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 37 Precinct 4 drainage assessment



LEGEND:

- Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use
- Indicative 50m wetland buffers
- Potential contaminated sites
- Indicative flowpaths
- Topographic subcatchments
- Modelled subcatchments
- Modelled drainage
- Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area
- Precinct boundaries
- Rail transit corridor
- Road alignments
- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

- S1a — Modelled storages
- 1a — Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

N
0 250
metres
Scale 1:10,000 @ A4

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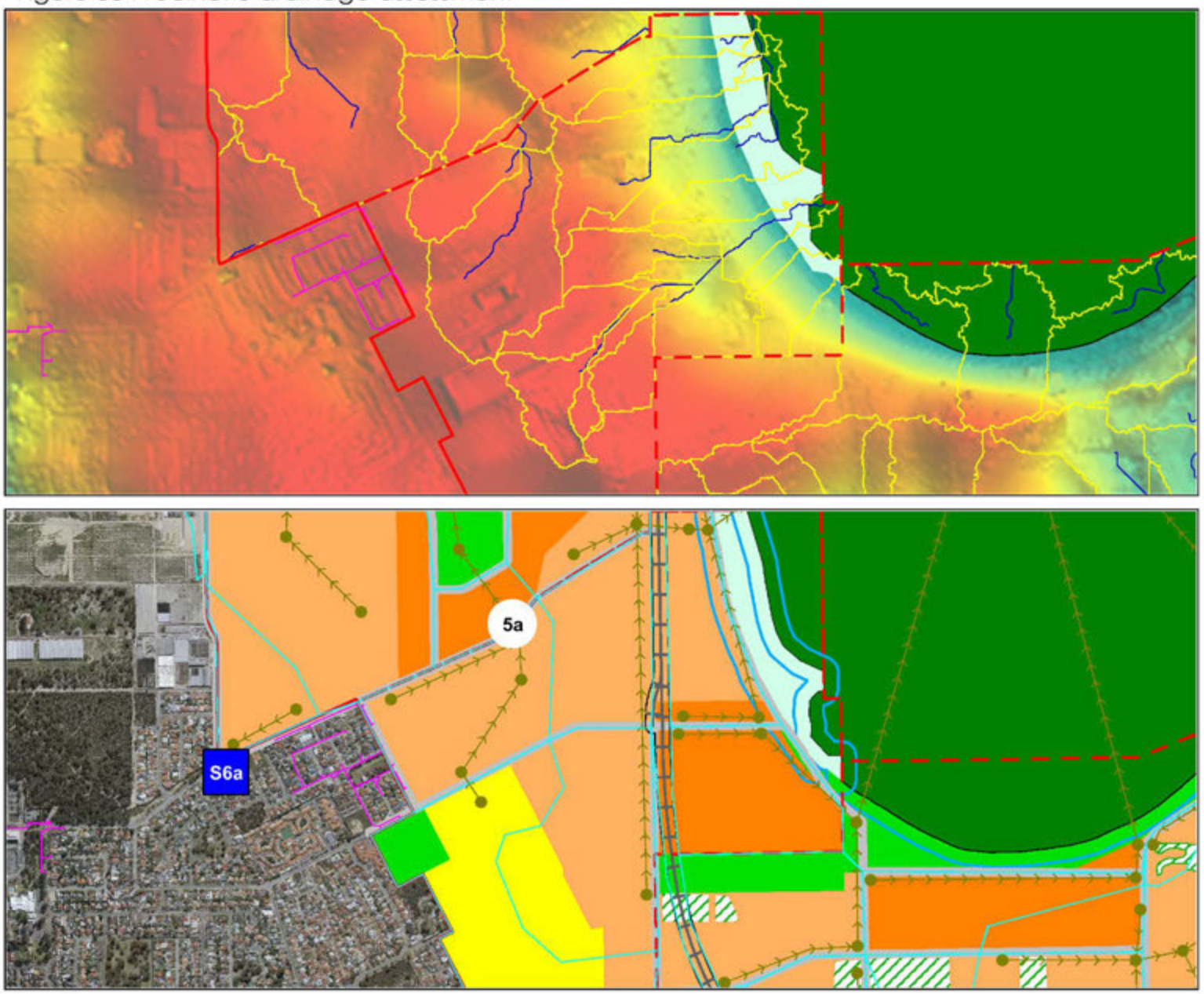
Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 38 Precinct 5 drainage assessment



LEGEND:

Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use

Indicative 50m wetland buffers

Potential contaminated sites

Indicative flowpaths

Topographic subcatchments

Modelled subcatchments

Modelled drainage

Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area

Precinct boundaries

Rail transit corridor

Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

S1a Modelled storages

1a Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

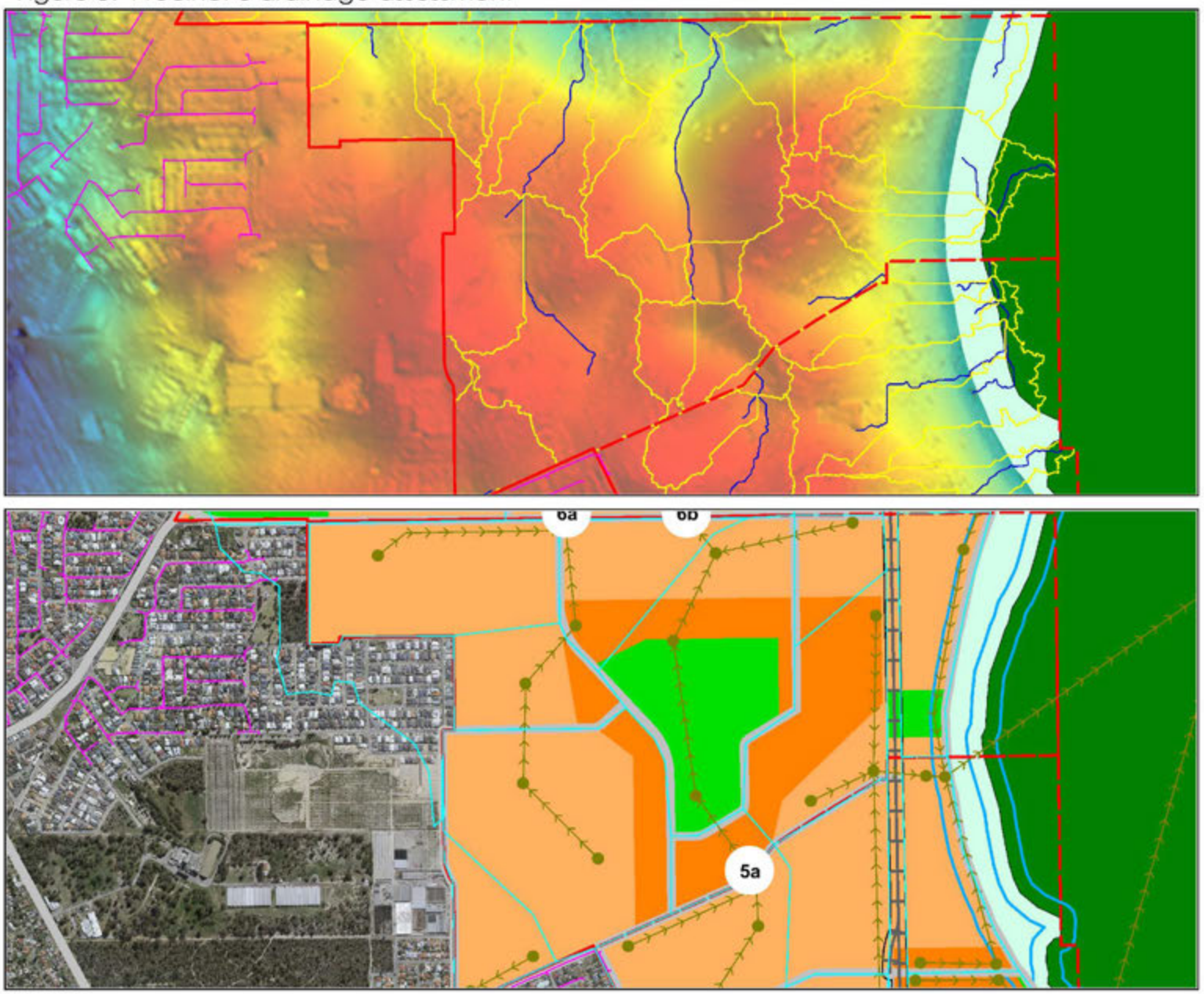
N

0 500
metres

Scale 1:20,000 @ A4

urbaqua
land and water solutions

Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 39 Precinct 6 drainage assessment



LEGEND:

Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use

Indicative 50m wetland buffers

Potential contaminated sites

Indicative flowpaths

Topographic subcatchments

Modelled subcatchments

Modelled drainage

Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area

Precinct boundaries

Rail transit corridor

Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

S1a Modelled storages

1a Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

N

0 500
metres

Scale 1:20,000 @ A4

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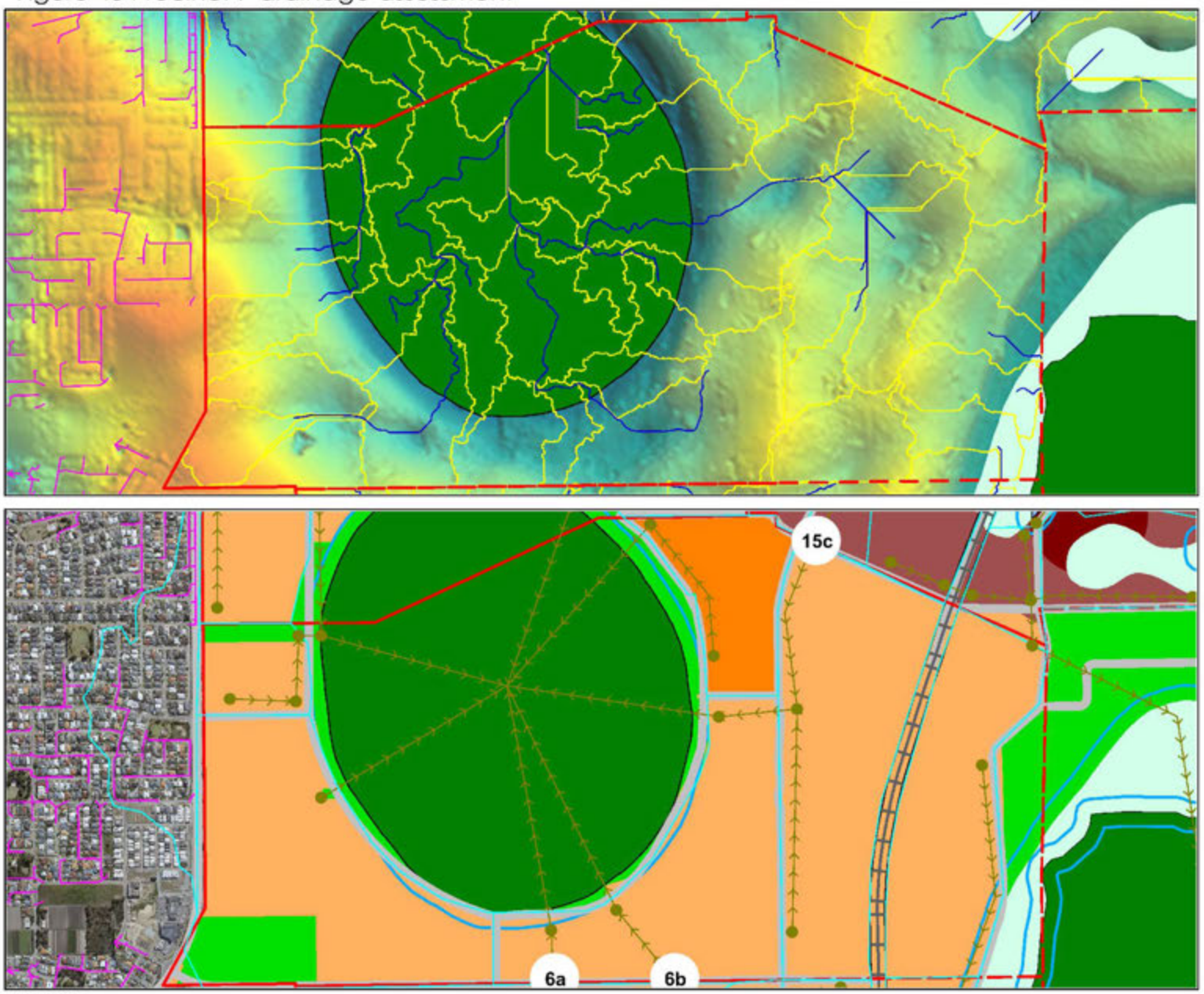
Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 40 Precinct 7 drainage assessment



LEGEND:

Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use

Indicative 50m wetland buffers

Potential contaminated sites

Indicative flowpaths

Topographic subcatchments

Modelled subcatchments

Modelled drainage

Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area

Precinct boundaries

Rail transit corridor

Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

S1a Modelled storages

1a Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

N

0 500
metres

Scale 1:20,000 @ A4

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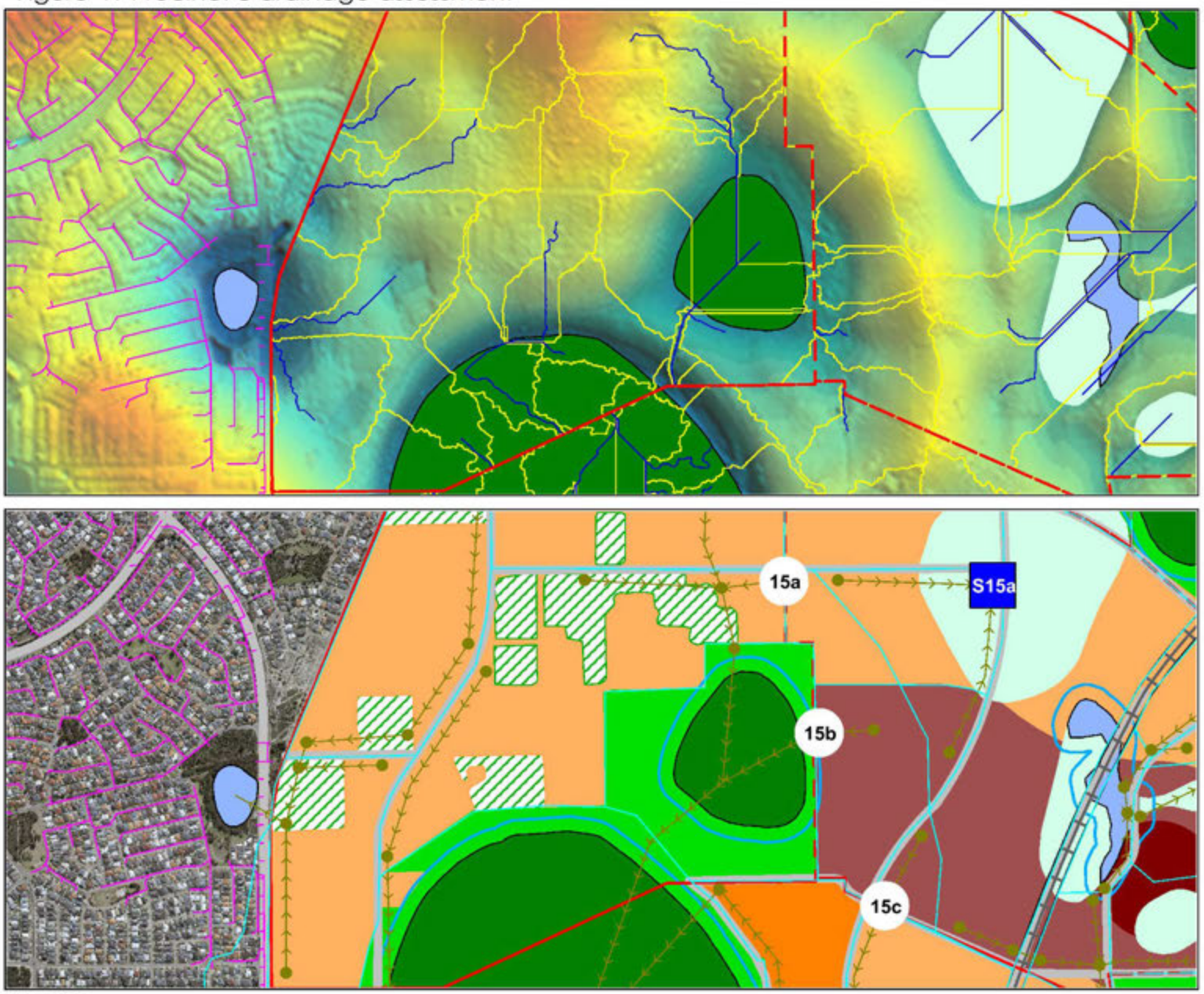
Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 41 Precinct 8 drainage assessment



LEGEND:

- Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use
- Indicative 50m wetland buffers
- Potential contaminated sites
- Indicative flowpaths
- Topographic subcatchments
- Modelled subcatchments
- Modelled drainage
- Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area
- Precinct boundaries
- Rail transit corridor
- Road alignments
- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning
- S1a Modelled storages
- 1a Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

0 500
metres
Scale 1:20,000 @ A4

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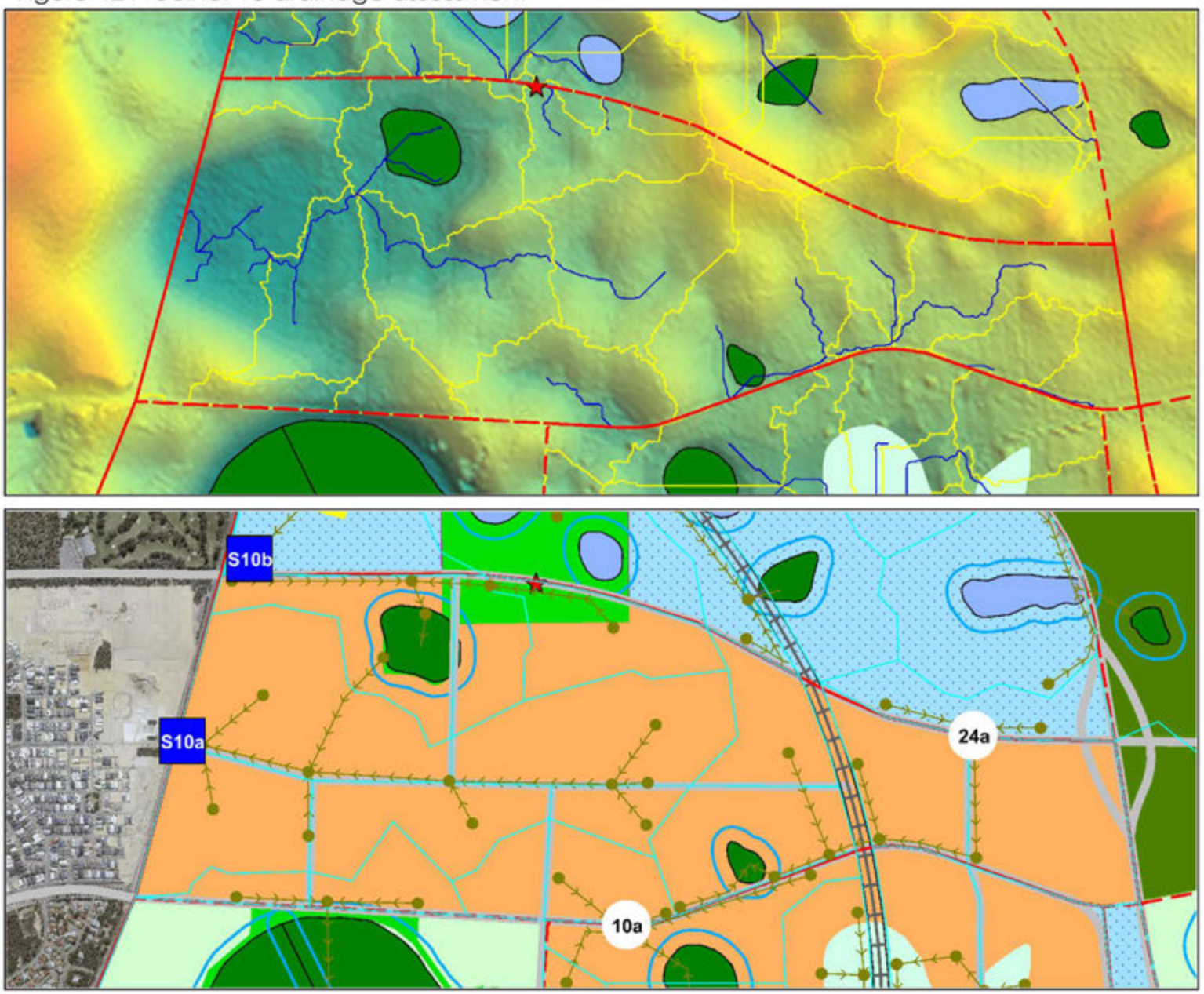
District Water Management Strategy
Figure 42 Precinct 10 drainage assessment



LEGEND:

- Structure Plan Boundary
- Geomorphic Wetlands
  - Conservation
  - Resource Enhancement
  - Multiple Use
- Indicative 50m wetland buffers
- Potential contaminated sites
- Indicative flowpaths
- Topographic subcatchments
- Modelled subcatchments
- Modelled drainage
- Modelled node

EWDSP Land uses

- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area
- Precinct boundaries
- Rail transit corridor
- Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

- S1a Modelled storages
- 1a Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

0 500
metres
Scale 1:20,000 @ A4

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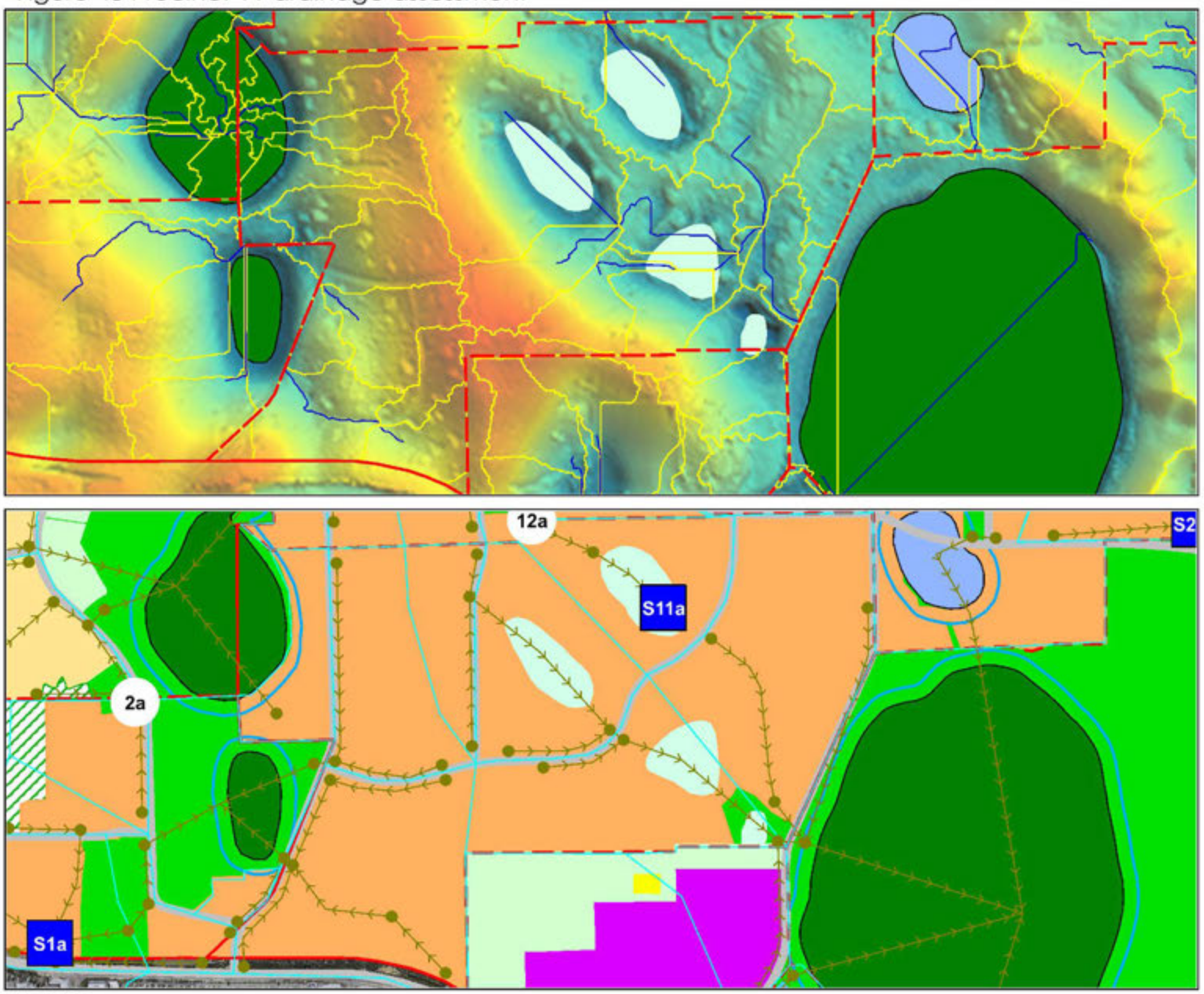
District Water Management Strategy
Figure 43 Precinct 11 drainage assessment



LEGEND:

Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use

Indicative 50m wetland buffers

Potential contaminated sites

Indicative flowpaths

Topographic subcatchments

Modelled subcatchments

Modelled drainage

Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area

Precinct boundaries

Rail transit corridor

Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

S1a Modelled storages

1a Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

0 500
metres
Scale 1:20,000 @ A4

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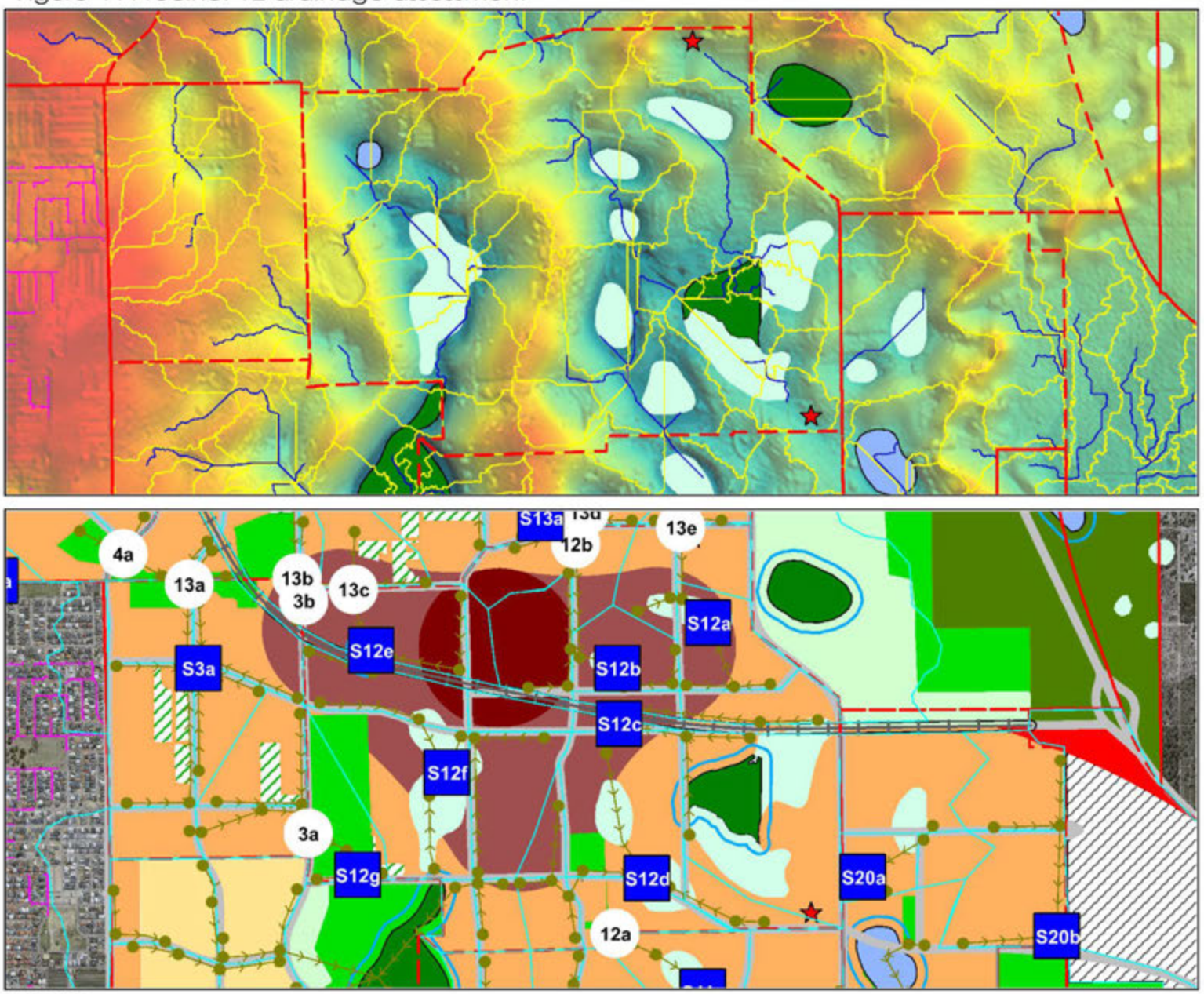
District Water Management Strategy
Figure 44 Precinct 12 drainage assessment



LEGEND:

Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use

Indicative 50m wetland buffers

Potential contaminated sites

Indicative flowpaths

Topographic subcatchments

Modelled subcatchments

Modelled drainage

Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area

Precinct boundaries

Rail transit corridor

Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

S1a Modelled storages

1a Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

0 750
metres
Scale 1:30,000 @ A4

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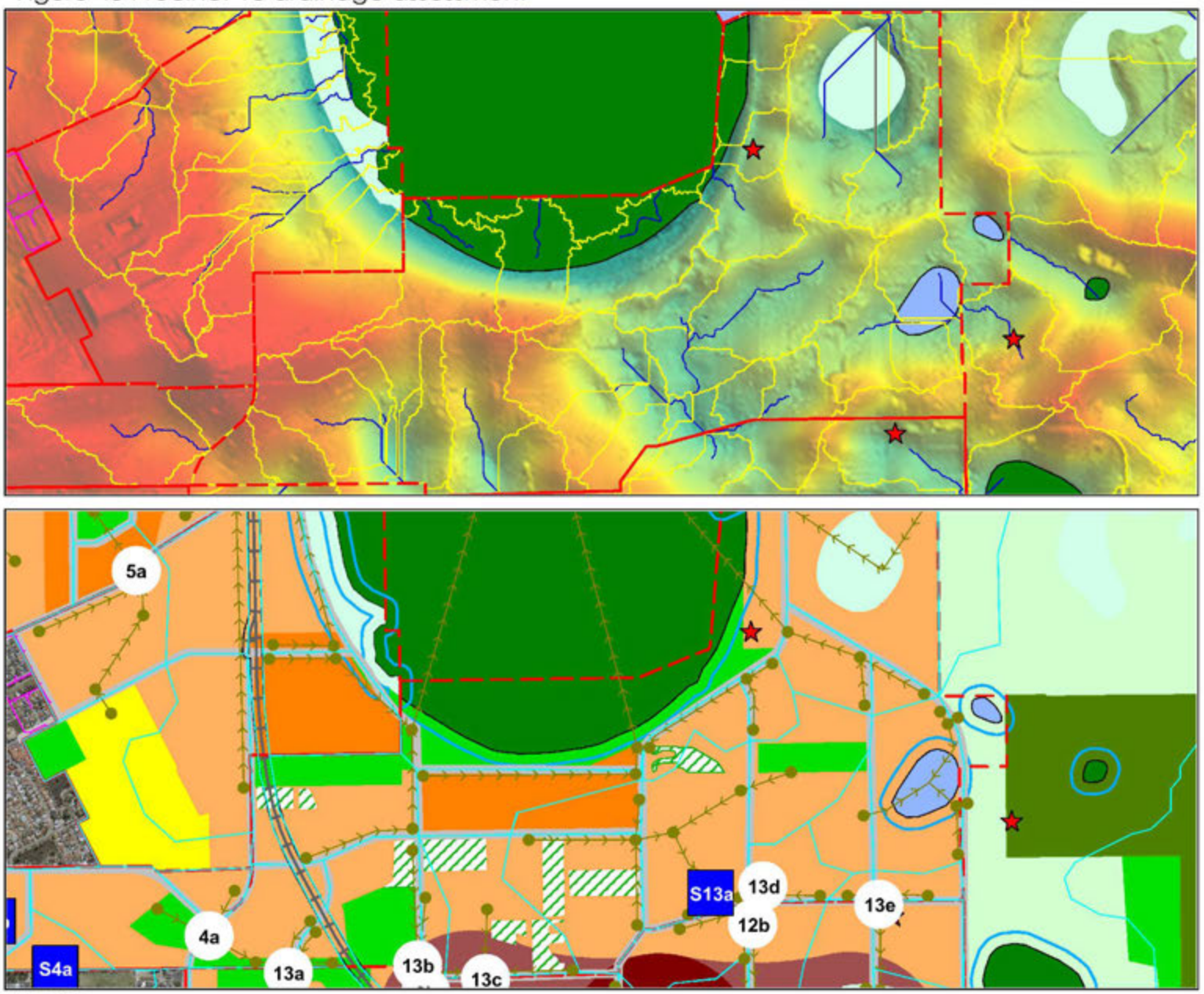
District Water Management Strategy
Figure 45 Precinct 13 drainage assessment



LEGEND:

Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use

Indicative 50m wetland buffers

Potential contaminated sites

Indicative flowpaths

Topographic subcatchments

Modelled subcatchments

Modelled drainage

Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area

Precinct boundaries

Rail transit corridor

Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

S1a Modelled storages

1a Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

0 624.4
metres
Scale 1:24,980@ A4

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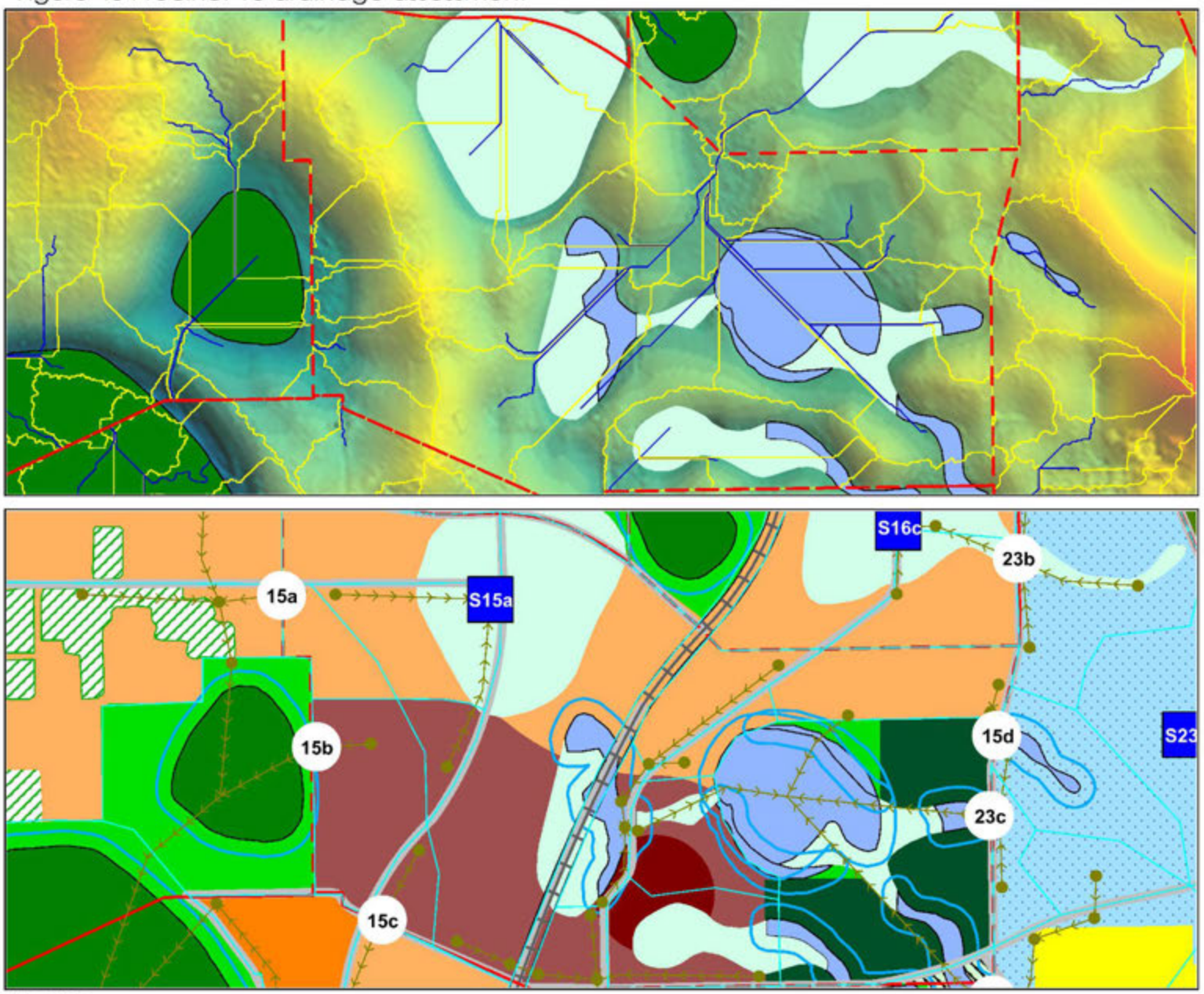
Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 46 Precinct 15 drainage assessment



LEGEND:

Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use

Indicative 50m wetland buffers

Potential contaminated sites

Indicative flowpaths

Topographic subcatchments

Modelled subcatchments

Modelled drainage

Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area

Precinct boundaries

Rail transit corridor

Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

S1a Modelled storages

1a Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

0 500
metres
Scale 1:20,000 @ A4

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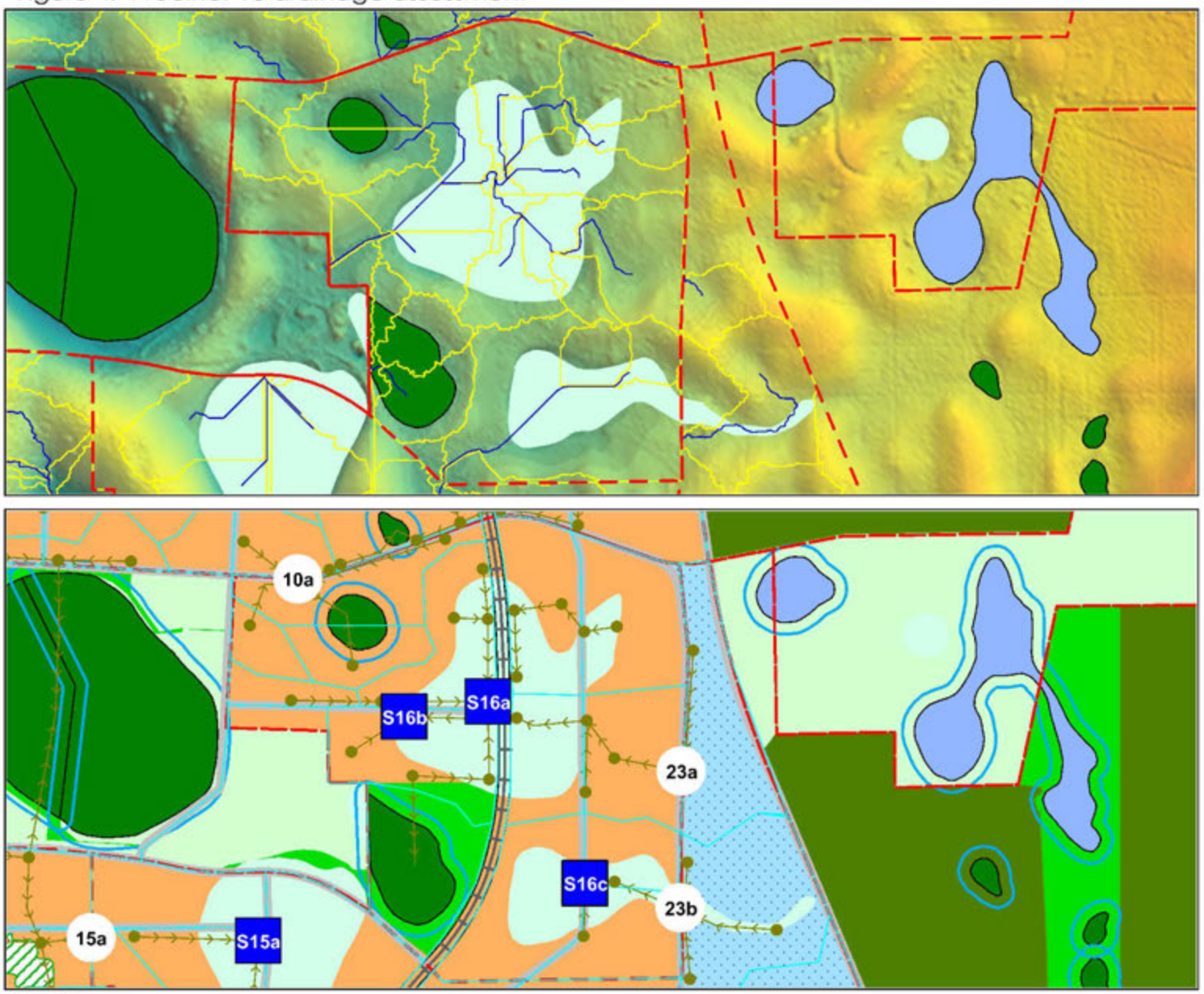
Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 47 Precinct 16 drainage assessment



LEGEND:

Structure Plan Boundary

Geomorphic Wetlands
- Conservation
- Resource Enhancement
- Multiple Use

Indicative 50m wetland buffers

Potential contaminated sites

Indicative flowpaths

Topographic subcatchments

Modelled subcatchments

Modelled drainage

Modelled node

EWDSP Land uses
- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area

Precinct boundaries

Rail transit corridor

Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

S1a Modelled storages

1a Precinct boundary crossings

Elevation
85 mAHD
1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

0 624.4
metres
Scale 1:24,980@ A4

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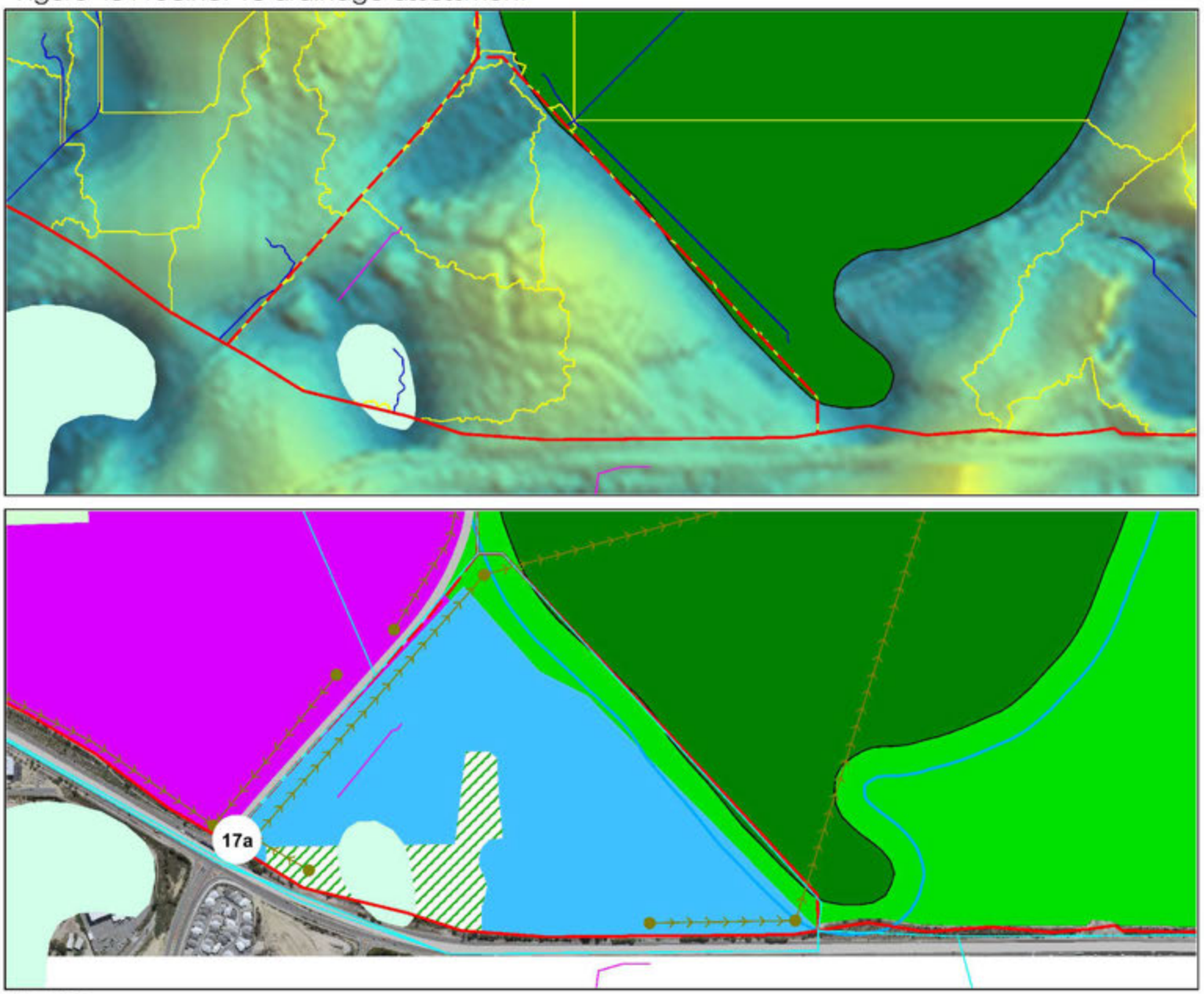
District Water Management Strategy
Figure 48 Precinct 18 drainage assessment



LEGEND:

- Structure Plan Boundary

Geomorphic Wetlands

- Conservation
- Resource Enhancement
- Multiple Use
- Indicative 50m wetland buffers
- Potential contaminated sites
- Indicative flowpaths
- Topographic subcatchments
- Modelled subcatchments
- Modelled drainage
- Modelled node

EWDSP Land uses

- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area
- Precinct boundaries
- Rail transit corridor
- Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

- S1a — Modelled storages
- 1a — Precinct boundary crossings

Elevation

85 mAHD

1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

N

0 250

metres

Scale 1:10,000 @ A4

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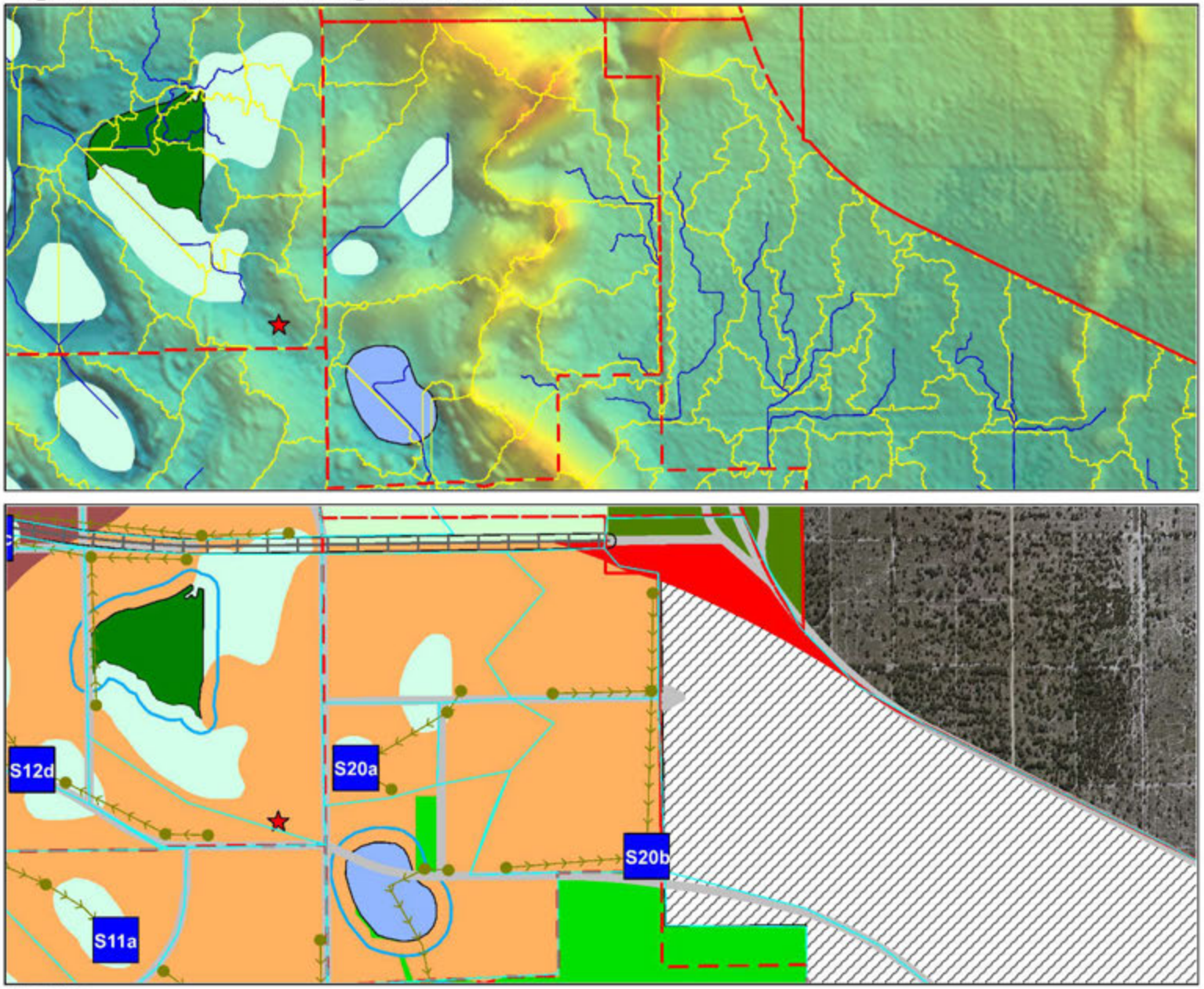
Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 49 Precinct 20 drainage assessment



LEGEND:

- Structure Plan Boundary

Geomorphic Wetlands

- Conservation
- Resource Enhancement
- Multiple Use
- Indicative 50m wetland buffers
- Potential contaminated sites
- Indicative flowpaths
- Topographic subcatchments
- Modelled subcatchments
- Modelled drainage
- Modelled node

EWDSP Land uses

- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area
- Precinct boundaries
- Rail transit corridor
- Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

- S1a — Modelled storages
- 1a — Precinct boundary crossings

Elevation

85 mAHD

1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

0 500
metres
Scale 1:20,000 @ A4

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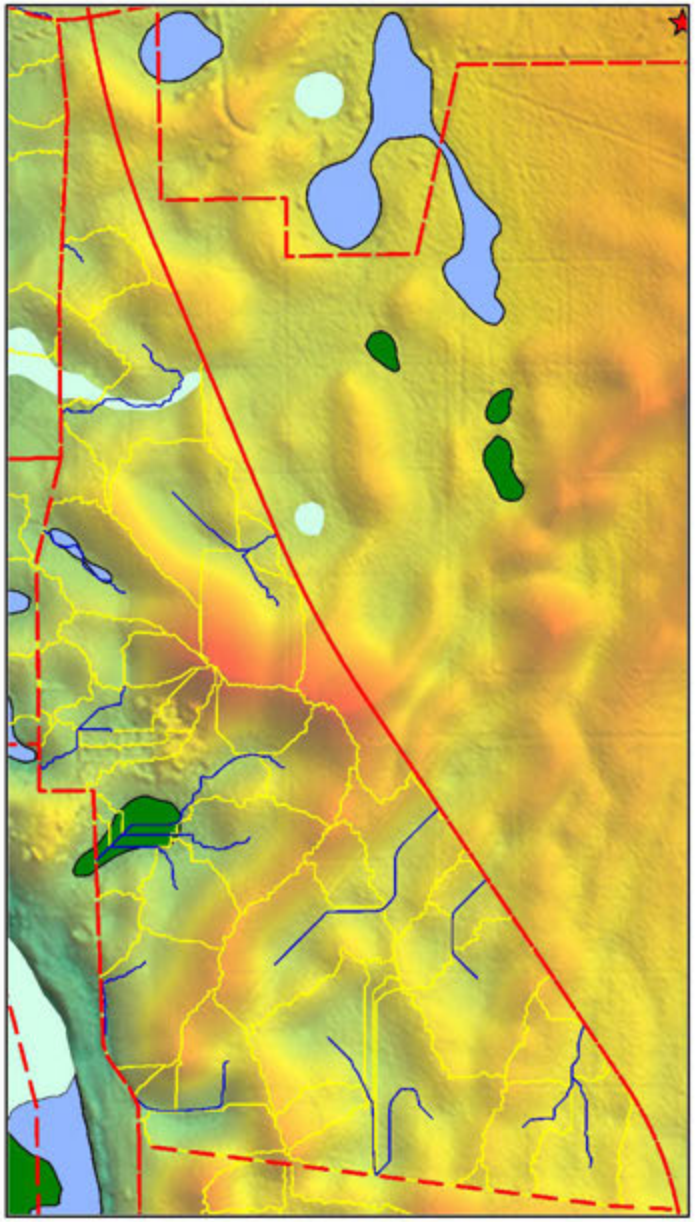
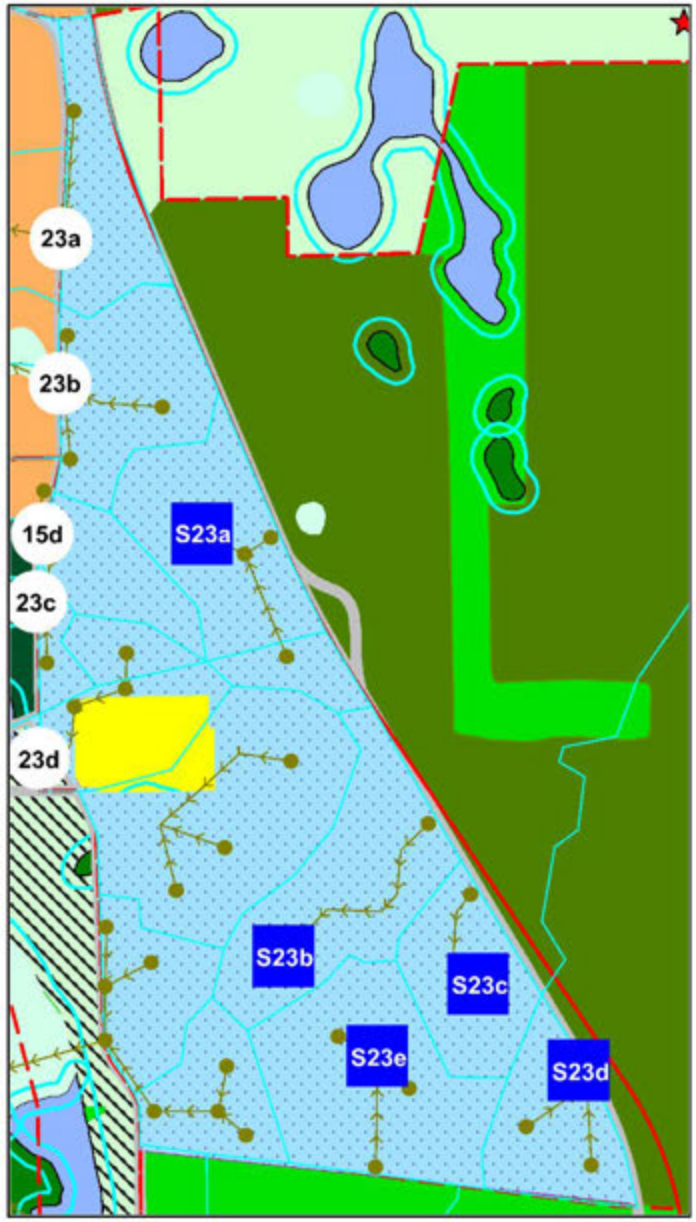
Figure 50 Precinct 23 drainage assessment





LEGEND

- Structure Plan Boundary
- Potential contaminated sites
- Geomorphic Wetlands
- Indicative flowpaths
- Conservation
- Topographic subcatchments
- Multiple Use
- Modelled subcatchments
- Not Applicable
- Modelled drainage
- Resource Enhancement
- Modelled node
- Indicative 50m wetland buffers
- S1a Modelled storages
- 1a Precinct boundary crossings

EWDSP Land uses

- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area
- Precinct boundaries
- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning
- Rail transit corridor
- Road alignments

Elevation

85 mAHD — 1 mAHD

0 600

metres

Scale 1:30,000 @ A4

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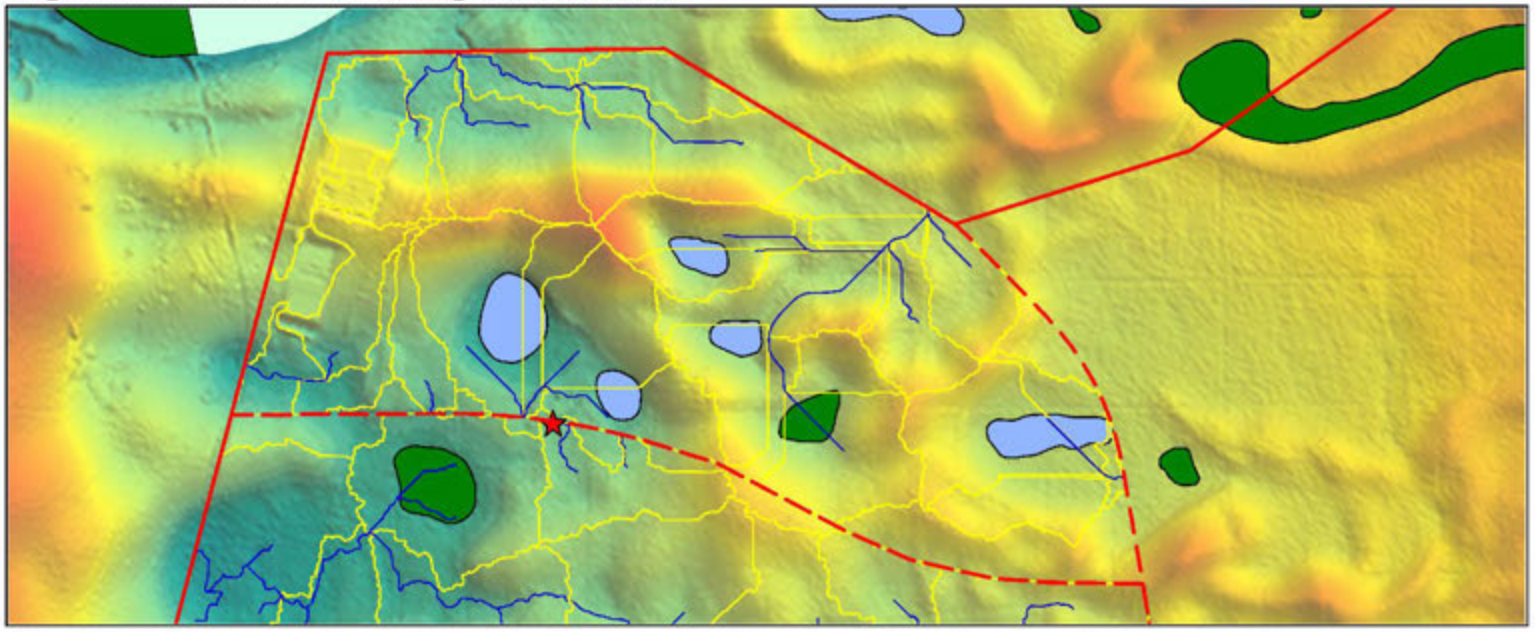
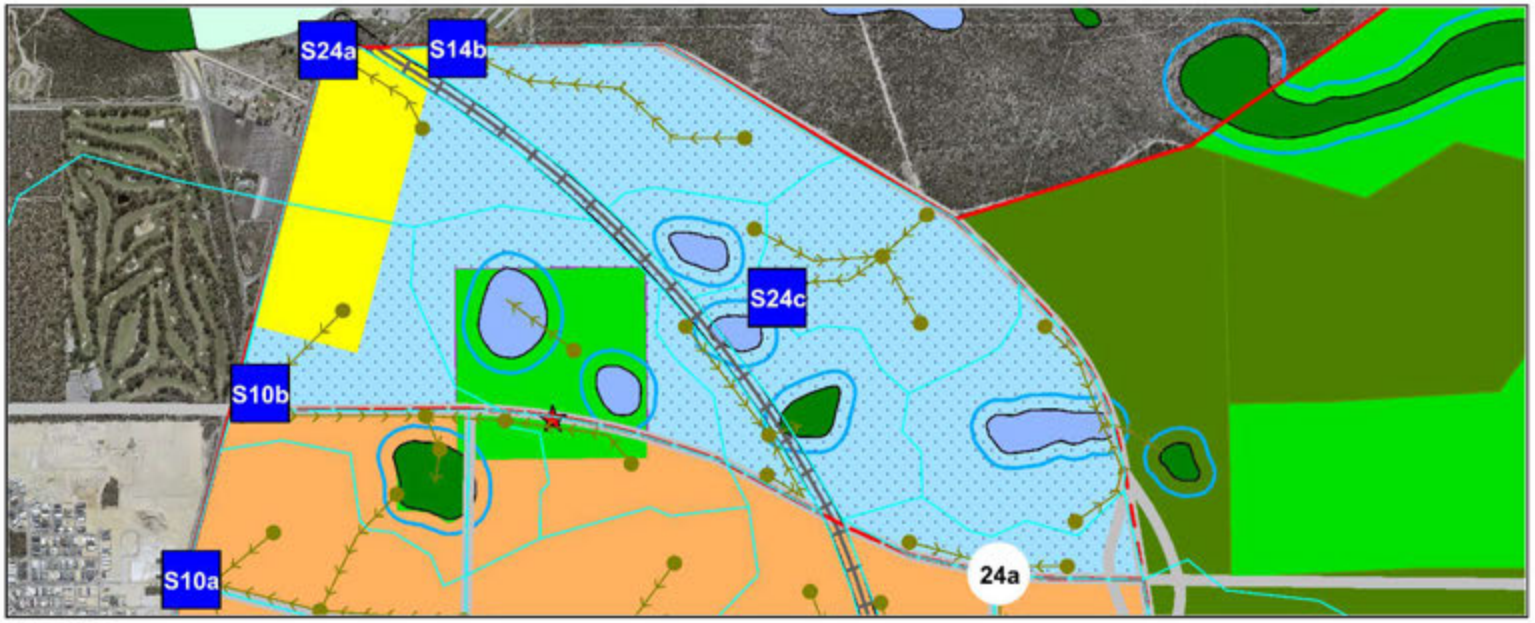
Department of Planning, Lands and Heritage - East Wanneroo District Structure Plan:
District Water Management Strategy
Figure 51 Precinct 24 drainage assessment





LEGEND:

- Structure Plan Boundary

Geomorphic Wetlands

- Conservation
- Resource Enhancement
- Multiple Use
- Indicative 50m wetland buffers
- Potential contaminated sites
- Indicative flowpaths
- Topographic subcatchments
- Modelled subcatchments
- Modelled drainage
- Modelled node

EWDSP Land uses

- Centre
- Urban neighbourhood
- Character areas
- Suburban neighbourhood
- Special residential area
- Industrial
- Public purpose
- Regional open space
- Employment area
- Precinct boundaries
- Rail transit corridor
- Road alignments

- High priority vegetation area
- Regional sporting fields
- Rural
- Service commercial
- State forest
- Tourism oppertunities
- Intersection area
- Subject to further planning

- S1a — Modelled storages
- 1a — Precinct boundary crossings

Elevation

85 mAHD

1 mAHD

Data sourceLandcate. DPLH Created by: HBrookes Projection: MGA: zone 50.

0 624.4
metres
Scale 1:24,980@ A4

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Table 35: Pre-development subcatchment surface type breakdown

Subcatchment id	Total area (ha)	ICA (ha)	EIA (ha)	Total FI	Rural pervious (ha)	Urban pervious (ha)
Adams	647	28	28	0.1	591	0
Badgerup	798	86	43	0.2	670	0
Gnangara	1352	109	73	0.1	1152	19
Jandabup	2785	80	44	0.0	2660	2
Mariginiup	760	59	30	0.1	671	1
Outside major wetland catchments	2197	27	54	0.0	2116	1
Totals	***8540***	***387***	***271***	***0.1***	***7859***	***22***

Table 36: Post-development subcatchment surface type breakdown

Subcatchment id	Total area (ha)	ICA (ha)	EIA (ha)	Total FI	Rural pervious (ha)	Urban pervious (ha)
10_1	4.5	1.3	0.8	0.5	0.5	2.0
10_4	11.2	3.4	2.2	0.5	0.0	5.6
10_5	20.7	5.8	3.9	0.5	1.2	9.7
10_6	14.0	4.2	2.8	0.5	0.0	7.0
10_7	22.3	4.8	3.3	0.4	6.2	8.0
10_8	17.9	4.0	2.7	0.4	4.7	6.6
10_9	11.1	2.3	1.5	0.3	3.5	3.8
10_10	20.9	6.3	4.2	0.5	0.0	10.4
10_11	35.5	10.7	7.1	0.5	0.0	17.8
10_12	29.4	8.8	5.9	0.5	0.0	14.7
10_13	19.4	5.8	3.9	0.5	0.0	9.7
10_14	7.2	2.2	1.4	0.5	0.0	3.6
16_55	21.1	5.6	3.7	0.4	2.6	9.3
16_56	12.3	3.1	2.1	0.4	1.8	5.2
16_57	23.5	7.0	4.7	0.5	0.0	11.7
16_60	6.4	1.9	1.3	0.5	0.0	3.2
Brozwing	26.6	0.1	0.1	0.0	26.2	0.2
16_69	26.4	6.7	4.5	0.4	4.2	11.1
16_72	6.9	2.1	1.4	0.5	0.1	3.4
16_73	22.7	6.8	4.5	0.5	0.0	11.4
16_74	25.7	7.7	5.3	0.5	0.0	12.8
16_75	23.3	7.0	4.7	0.5	0.0	11.6
16_76	16.2	4.9	3.2	0.5	0.0	8.1
16_82	11.5	3.5	2.3	0.5	0.0	5.8
16_83	17.9	5.4	3.6	0.5	0.0	9.0
16_84	28.4	8.5	5.7	0.5	0.0	14.2
24_86	15.1	3.1	6.0	0.6	0.0	6.1
24_87	37.6	7.5	15.1	0.6	0.0	15.1
24_88	41.8	8.4	16.7	0.6	0.0	16.7

Subcatchment id	Total area (ha)	ICA (ha)	EIA (ha)	Total FI	Rural pervious (ha)	Urban pervious (ha)
24_90	44.7	8.9	17.9	0.6	0.0	17.9
24_91	12.5	2.5	5.0	0.6	0.0	5.0
24_92	27.0	5.4	10.8	0.6	0.0	10.8
24_93	9.5	1.9	3.8	0.6	0.0	3.8
24_94	53.4	4.4	8.9	0.2	31.3	8.9
24_95	37.1	7.3	14.6	0.6	0.6	14.6
24_96	32.7	6.6	13.1	0.6	0.0	13.1
10_104	27.4	8.2	5.5	0.5	0.0	13.7
10_105	17.5	5.2	3.6	0.5	0.0	8.8
23_108	29.1	5.8	11.1	0.6	1.2	11.1
23_109	39.2	7.9	15.6	0.6	0.0	15.7
23_114	44.0	8.8	17.6	0.6	0.1	17.6
23_115	21.1	4.2	8.4	0.6	0.0	8.5
23_116	9.7	1.9	3.9	0.6	0.0	3.9
23_117	6.9	1.4	2.8	0.6	0.0	2.8
15_118	18.4	5.5	3.7	0.5	0.0	9.2
15_121	4.7	1.4	0.9	0.5	0.1	2.3
15_122	13.9	4.1	4.0	0.6	0.2	5.6
15_123	18.7	5.5	5.2	0.6	0.0	8.1
15_127	11.0	3.3	2.2	0.5	0.0	5.5
23_131	25.8	6.8	3.3	0.4	1.4	14.4
23_132	69.3	14.4	25.8	0.6	0.0	29.2
23_133	10.7	2.1	4.3	0.6	0.0	4.3
23_134	24.0	4.8	9.6	0.6	0.0	9.6
23_135	53.2	10.6	21.3	0.6	0.0	21.3
23_136	30.1	6.0	12.0	0.6	0.0	12.0
23_137	29.7	5.8	11.7	0.6	0.6	11.7
23_138	59.2	11.9	23.7	0.6	0.0	23.7
23_139	23.6	4.7	9.5	0.6	0.0	9.5
13_158	41.9	12.6	8.4	0.5	0.0	21.0
13_159	26.1	7.8	5.2	0.5	0.1	13.0
13_160	4.7	1.4	0.9	0.5	0.0	2.4
13_161	3.7	1.1	0.7	0.5	0.0	1.9
13_162	11.6	3.5	2.3	0.5	0.0	5.8
13_163	21.0	4.6	3.0	0.4	5.8	7.6
13_164	1.6	0.5	0.3	0.5	0.0	0.8
13_165	8.3	2.4	1.6	0.5	0.3	4.0
13_166	9.3	2.8	1.9	0.5	0.0	4.7
13_167	8.8	2.4	1.6	0.5	0.6	4.1
13_168	6.0	1.8	1.2	0.5	0.0	3.0
13_169	30.9	8.9	5.9	0.5	1.3	14.8
12_170	13.4	4.0	3.2	0.5	0.0	6.2
12_171	21.1	6.3	6.3	0.6	0.0	8.5
12_172	12.8	3.8	2.6	0.5	0.0	6.3
12_173	23.1	7.0	6.0	0.6	0.0	10.2

Subcatchment id	Total area (ha)	ICA (ha)	EIA (ha)	Total FI	Rural pervious (ha)	Urban pervious (ha)
12_174	19.0	5.7	5.7	0.6	0.0	7.6
12_175	12.0	3.6	2.9	0.5	0.0	5.5
12_176	13.8	4.1	3.6	0.6	0.0	6.1
12_177	5.6	1.7	1.7	0.6	0.0	2.2
12_178	5.3	1.6	1.6	0.6	0.0	2.1
12_179	14.7	4.4	3.1	0.5	0.2	7.1
12_180	30.3	9.1	9.1	0.6	0.0	12.1
13_181	23.8	4.9	3.9	0.4	7.4	7.6
13_182	25.4	5.5	3.8	0.4	7.0	9.1
13_183	17.5	5.2	5.2	0.6	0.0	7.0
13_184	5.1	1.4	1.1	0.5	0.3	2.2
13_185	22.5	3.2	2.4	0.2	11.9	5.0
13_186	22.5	4.2	2.8	0.3	8.5	7.0
13_187	1.1	0.3	0.2	0.5	0.0	0.6
03_188	23.0	6.1	4.6	0.5	2.7	9.6
13_189	2.6	0.5	0.3	0.3	0.8	0.9
13_190	14.7	3.6	2.4	0.4	2.9	5.9
03_191	18.3	4.1	2.7	0.4	4.7	6.8
04_192	5.5	1.7	1.1	0.5	0.0	2.8
04_193	23.7	5.6	3.7	0.4	4.9	9.4
05_194	32.0	8.4	1.1	0.3	4.0	18.4
04_195	6.5	1.9	1.3	0.5	0.0	3.2
04_196	6.5	2.0	1.3	0.5	0.0	3.3
05_197	32.0	9.6	4.6	0.4	0.0	17.8
05_198	19.8	5.9	4.0	0.5	0.0	9.9
05_199	25.3	7.6	5.1	0.5	0.0	12.7
06_201	11.3	3.4	2.3	0.5	0.0	5.7
06_202	47.5	14.3	10.4	0.5	0.0	22.9
06_203	16.4	4.9	3.6	0.5	0.0	7.9
06_204	7.2	2.2	2.2	0.6	0.0	2.9
06_205	43.4	5.9	4.9	0.2	23.9	8.7
06_206	26.5	8.0	7.2	0.6	0.0	11.4
05_207	17.1	5.1	3.7	0.5	0.2	8.1
06_208	17.5	4.5	3.0	0.4	2.6	7.5
06_209	9.7	2.9	2.1	0.5	0.0	4.7
06_210	17.2	5.1	3.9	0.5	0.1	8.1
01_233	36.8	6.5	7.7	0.4	10.4	12.3
01_234	13.7	3.1	2.0	0.4	3.4	5.1
01_235	14.9	3.5	2.3	0.4	3.3	5.8
02_236	27.6	6.1	1.3	0.3	16.6	3.3
02_237	24.6	4.4	0.0	0.2	20.0	0.1
02_238	24.0	5.5	1.3	0.3	13.9	3.3
02_239	21.4	4.3	0.1	0.2	16.8	0.2
Little_Badgerup	30.6	0.2	0.2	0.0	29.9	0.4
Badgerup	59.6	1.8	0.1	0.0	57.4	0.2

Subcatchment id	Total area (ha)	ICA (ha)	EIA (ha)	Total FI	Rural pervious (ha)	Urban pervious (ha)
11_242	13.2	3.9	2.6	0.5	0.3	6.5
12_243	7.0	2.1	1.4	0.5	0.0	3.5
11_244	46.2	12.5	11.6	0.5	0.0	22.2
11_245	25.4	7.6	5.1	0.5	0.0	12.7
11_246	12.4	3.7	2.5	0.5	0.0	6.2
12_247	8.6	2.6	1.8	0.5	0.0	4.2
12_248	10.1	3.0	2.1	0.5	0.0	5.0
12_249	27.6	8.3	8.3	0.6	0.0	11.0
12_250	7.5	2.3	2.3	0.6	0.0	3.0
12_251	8.6	2.6	2.6	0.6	0.0	3.4
12_252	3.0	0.9	0.9	0.6	0.0	1.2
12_253	46.1	12.6	9.8	0.5	4.2	19.5
12_254	16.9	4.9	3.2	0.5	0.8	8.1
11_255	29.9	9.0	6.0	0.5	0.0	15.0
11_256	25.4	7.6	5.1	0.5	0.0	12.7
12_257	47.5	11.7	10.1	0.5	8.6	17.2
12_258	21.2	0.6	0.3	0.0	19.5	0.9
03_259	14.6	4.4	2.9	0.5	0.0	7.3
03_260	21.5	5.2	3.5	0.4	4.1	8.7
03_261	13.9	4.2	2.8	0.5	0.0	7.0
03_262	11.7	3.5	2.4	0.5	0.0	5.9
03_263	31.9	6.9	4.6	0.4	8.9	11.5
05_264	21.8	6.4	6.4	0.6	0.5	8.5
13_265	4.2	1.0	0.7	0.4	0.8	1.7
12_266	20.3	6.1	6.1	0.6	0.0	8.1
12_267	66.7	16.9	11.3	0.4	10.5	28.1
20_269	23.5	6.9	5.0	0.5	0.0	11.7
20_270	30.7	9.2	6.1	0.5	0.0	15.4
20_271	8.2	2.5	1.6	0.5	0.0	4.1
20_272	12.4	3.7	2.5	0.5	0.0	6.2
11_273	50.4	14.9	9.9	0.5	1.0	24.8
11_274	35.2	9.9	6.5	0.5	2.6	16.3
17_275	57.2	10.8	15.5	0.5	16.4	14.5
17_276	17.3	3.4	5.2	0.5	3.5	5.3
18_277	38.8	15.3	2.4	0.5	9.8	11.3
01_333	7.1	1.3	0.9	0.3	2.8	2.2
01_334	2.9	0.9	0.6	0.5	0.1	1.4
01_337	6.4	1.5	1.0	0.4	1.5	2.5
13_357	8.5	2.5	2.5	0.6	0.0	3.4
10_358	8.8	2.6	1.7	0.5	0.4	4.1
10_359	7.3	2.2	1.4	0.5	0.2	3.5
Jandabup	589.2	17.3	3.9	0.0	560.7	8.6
Boundary	71.0	8.9	0.0	0.1	26.7	35.5
Adams	185.5	17.3	0.0	0.1	168.3	0.1
Mariginiup	174.9	1.2	0.8	0.0	171.2	1.9

Subcatchment id	Total area (ha)	ICA (ha)	EIA (ha)	Total FI	Rural pervious (ha)	Urban pervious (ha)
Little Mariginiup	47.2	0.2	0.1	0.0	46.8	0.2
Gnangara	318.9	4.3	0.8	0.0	313.2	0.6
20_366	43.4	11.7	7.8	0.4	4.4	19.5
21_367	60.8	4.1	0.4	0.1	55.7	0.6
06_368	32.2	9.7	6.4	0.5	0.0	16.1
07_369	63.4	15.4	10.3	0.4	9.9	25.7
07_370	11.5	2.7	1.8	0.4	1.9	4.5
08_371	29.0	6.9	4.6	0.4	5.7	11.4
07_372	49.4	14.7	9.8	0.5	0.5	24.5
07_373	20.4	6.1	6.1	0.6	0.2	8.1
07_374	55.0	16.5	11.0	0.5	0.0	27.5
15_375	22.5	6.8	6.8	0.6	0.0	9.0
15_376	6.0	1.8	1.8	0.6	0.0	2.4
15_377	5.6	1.7	1.7	0.6	0.0	2.3
15_378	68.9	20.7	16.9	0.5	0.0	31.4
15_379	18.8	5.6	3.8	0.5	0.0	9.4
15_380	8.5	2.5	1.7	0.5	0.5	4.2
15_381	19.3	5.8	3.9	0.5	0.0	9.6
08_382	34.6	9.8	6.4	0.5	2.5	16.0
08_383	66.2	13.6	9.1	0.3	23.8	22.7
08_384	44.2	9.8	6.5	0.4	11.8	16.2
07_385	40.7	12.7	8.5	0.5	0.0	21.2
15_386	7.4	2.2	2.2	0.6	0.0	3.0
09_387	46.6	8.6	0.9	0.2	34.8	2.3
01_393	6.3	1.9	1.2	0.5	0.0	3.1
02_394	2.0	0.6	0.4	0.5	0.0	1.0
01_399	3.2	0.9	0.6	0.5	0.0	1.6
25_400	140.8	28.2	28.2	0.4	0.1	84.5
25_401	417.2	80.3	87.7	0.4	4.6	243.7
15_10	8.2	1.9	1.9	0.5	0.0	2.6
01_09	10.0	1.3	1.9	0.3	4.2	2.6
12_57	10.6	3.1	2.1	0.5	0.0	5.2
20_268	32.6	9.8	6.5	0.5	0.0	16.3
Gnangara_ext	319.0	35.7	0.1	0.1	283.2	0.3
Jandabup_ext	1727.3	44.4	0.2	0.0	1682.5	0.2
Other undeveloped	322.7	35.0	54.0	0.0	233.7	0.0
Totals	***8540***	***1310***	***1091***	***0.3***	***4092***	***2053***

APPENDIX E – SUPPORTING TECHNICAL DETAILS FOR STORMWATER MODELLING

7.1 Model selection and definition

The hydraulic and hydrologic modelling presented in this DWMS has been undertaken at a relatively high level, in keeping with the high-level strategic planning that it supports. The modelling addresses three key questions that are critical at this level of planning:

1. How much land is required to be set aside for flood storage in developing precincts?
2. What is the quantum of peak flows to and from adjacent precincts that needs to be accommodated in local arterial drainage systems?
3. What is the impact (volume and top water level) of directing flood flows from the proposed development into key wetlands?

To respond to these key questions, two models needed to be developed as follows:

- **Post-development model**, to define and test an arterial drainage system that can adequately manage stormwater from developing precincts. This model is used for all three questions above.
- **Predevelopment model**, to provide a baseline of storage volumes and levels in key wetlands for question three above and to assess the acceptability of the drainage system proposed to address questions one and two.

The selection of an appropriate modelling methodology to address these key questions must consider the key processes that need to be modelled, the available data and the level of information that is required.

The findings of hydraulic and hydrologic modelling in relation to questions one and two are presented in Section 5.3.3 and Appendix D. The findings in relation to question 3 are presented in Section 3.1.4.

7.1.1 Predevelopment model selection

In this case, as described in Section 2, Natural surface water expressions in East Wanneroo are limited to wetlands which are principally fed by groundwater. Therefore, predevelopment surface water modelling, even for very large events, would be expected to generate very short-lived overland flowpaths and quite a small short-term storage response in wetlands despite relatively large topographic catchments.

Also, in this case, there is no available data that can be used to assess the natural wetland response to major storm events in East Wanneroo.

Because the required pre-development information is limited to storage volumes and top water levels and extensive overland flood routing is not expected, a 1-dimensional representation of each major wetland and its catchment was considered to be an acceptable predevelopment modelling methodology.

Integrated 1-dimensional hydraulic and hydrological modelling with InfoWorks ICM provides the capability to model large catchments and wetlands using a broad range of runoff volume and routing methodologies. The modelling system is supported by a GIS interface and a range

of post-processing tools which allows rapid graphical and statistical representation of modelling inputs and outputs.

7.1.2 Post-development model selection

Modelling of the post-development drainage system needs to consider all three of the questions presented above. This means that is was necessary to provide a model that included constructed storages and retained wetlands in addition to the key wetlands considered in question three. To support urban development, it is preferable to limit overland flooding and provide an arterial drainage system that is capable of managing minor and major storm events.

Integrated 1-dimensional hydraulic and hydrological modelling with InfoWorks ICM provides the capability to develop and test an arterial system formed by open channels, storages and wetlands that will contain the major flood event without overland flooding.

7.2 Selection and definition of antecedent conditions

The modelled East Wanneroo arterial drainage system has been defined with the following assumptions and criteria:

- Modelling assumes that subsoil drainage has been installed at controlled groundwater level (AAMGL 1986-95) and is functioning effectively.
- The invert levels of all drains and storages have been set at a minimum of 300m above the controlled groundwater level (AAMGL 1986-95). This ensures that the system should generally function without groundwater ingress.
- Open drains have been designed with a minimum grade of 1:1000.

The invert levels of wetlands in East Wanneroo are typically low enough that there will be open water present seasonally. Where the constructed drainage system is proposed to interface with retained wetlands it is therefore necessary to set an antecedent water level condition to ensure that the designed system will function appropriately during winter.

As discussed in Section 3.2 and Section 5.2 of this report there is a need for establishment of a district scale groundwater management system in East Wanneroo to prevent significant groundwater level rise in future.

A preliminary conceptual system has been described in this DWMS and includes the establishment of subsoil drains throughout developing areas set at a proposed controlled groundwater level (AAMGL 1986-95). The objective of this system is to manage and prevent the potential impacts of groundwater level rise to retained wetlands and developed lots and infrastructure.

For surface water modelling, it has been assumed that subsoil drains, and the district scale management system have been installed and are functioning effectively. Therefore, it is assumed that future water levels in wetlands will be consistent with those recorded from 1986 to 1995 and the average winter maximum water level for this period has been selected as the antecedent water level condition in retained wetlands.

Detailed surface water modelling will be required to support future local structure plans and presented in local water management strategies. This modelling will need to include consideration of the risks associated with surface and groundwater interaction both now and in the future. The establishment of appropriate antecedent conditions in drainage infiltration

basins and wetlands functioning as part of the surface water management system will need to consider changing groundwater levels and the performance of subsurface drainage systems under flood conditions.

7.3 Selection and definition of modelling parameters

InfoWorks ICM enables definition of subcatchment hydrology using up to 12 different surface types, each with individually defined runoff volume generation and routing characteristics. This provides flexibility to assess both land uses and site conditions to assign parameters.

In East Wanneroo, there are seven distinct predevelopment land uses and fifteen post-development land uses. Aerial imagery has been used to develop an estimate of the typical proportion of pervious and impervious surfaces present in each land use. Proportions of four different surface types have been allocated to each land use. The surface types used in this assessment are:

Effective impervious areas (EIA) – these areas are directly connected to a drainage system and may include areas such as roads, driveways and carparking areas.

Indirectly connected areas (ICA) – these areas are indirectly connected to a drainage system and may include some connected pervious areas. Typically, the connection to the drainage system will be via overland flow from a soakwell, raingarden, buffer-strip, or other form of pervious infiltration system.

Rural pervious areas – these are undeveloped pervious areas.

Urban pervious areas – these are developed pervious areas such as public open spaces and private gardens.

The runoff characteristics for each surface type have been defined with an initial and continuing loss model as recommended by Australian Rainfall and Runoff 2019. The applied loss model is presented in Table 37.

Runoff volumes are generated using a constant infiltration model which applies an initial loss followed by a constant infiltration rate and a fixed runoff rate which is applied when the surface becomes saturated. The fixed runoff coefficient applied to all surfaces in this model is 1.

Table 37: Surface type loss model

Surface type	Initial loss (mm)	Continuing loss (mm/hr)
Indirectly Connected Areas	15	3.0
Effective Impervious Areas	2	0.0
Rural pervious areas	42	3.1
Urban pervious areas	21	3.1

Runoff generated in the hydrological model is routed to the hydraulic model using the SWMM routing model which uses a single non-linear reservoir, whose routing coefficient depends on surface area, ground slope, catchment width and user defined parameters for surface roughness. The roughness (Manning's N) parameters selected for use in this model are 0.015 for impervious areas (ICA and EIA), 0.04 for rural pervious areas and 0.025 for urban pervious areas.

The proportions of each surface type applied to existing land uses and each of the land uses defined in the East Wanneroo District Structure Plan are presented in Table 38 along with the total estimated Fraction Impervious (FI) for each land use. The resulting surface type breakdown for each pre- and post-development subcatchment in the East Wanneroo DSP area are presented in Appendix D.

Table 38: Surface type breakdown for existing and DSP land uses

Land use category	ICA	EIA	Total FI	Rural pervious	Urban pervious
DSP land uses					
Centre	0.3	0.3	0.6	0.0	0.4
Character areas	0.3	0.3	0.6	0.0	0.4
High priority vegetation area	0.0	0.0	0.0	1.0	0.0
Industrial	0.2	0.4	0.6	0.0	0.4
Intersection area	0.0	0.7	0.7	0.0	0.3
Public purpose	0.3	0.0	0.3	0.0	0.7
Regional open space	0.0	0.0	0.0	1.0	0.0
Regional sporting fields	0.2	0.0	0.2	0.0	0.8
Rural	0.2	0.0	0.2	0.8	0.0
Service commercial	0.6	0.0	0.6	0.0	0.4
Special residential area	0.2	0.0	0.2	0.8	0.0
State forest	0.0	0.0	0.0	1.0	0.0
Subject to further planning	0.2	0.2	0.4	0.0	0.6
Suburban neighbourhood	0.3	0.2	0.5	0.0	0.5
Urban neighbourhood	0.3	0.3	0.6	0.0	0.4
Existing land uses					
Roads	0.7	0.0	0.7	0.3	0.0
Urban land uses (incl. aged care and industrial)	0.6	0.3	0.3	0.0	0.4
Suburban land uses (lots 600-1,500m2)	0.4	0.3	0.1	0.0	0.5
Suburban land uses (lots 450-600m2)	0.5	0.3	0.2	0.0	0.5
Rural land uses (lots >2ha)	0.1	0.1	0.0	0.9	0.0
Rural land uses (lots <2ha)	0.2	0.2	0.0	0.8	0.0
POS, conservation areas and state forest	0.0	0.0	0.0	1.0	0.0

7.4 Representation of the conveyance system

Predevelopment modelling does not include a conveyance system. Modelling of catchment flows into key wetlands is represented through the runoff volume generation and routing model selected for each modelled surface type.

Post development modelling includes representation of an arterial drainage system which is formed as a network of open vegetated swales integrated with road reserves and linear public open spaces. The actual dimensions of swales will vary but preliminary modelling applies swales with 1:6 side slopes that are 1m wide at the base and up to 1m deep as shown in Figure 52.

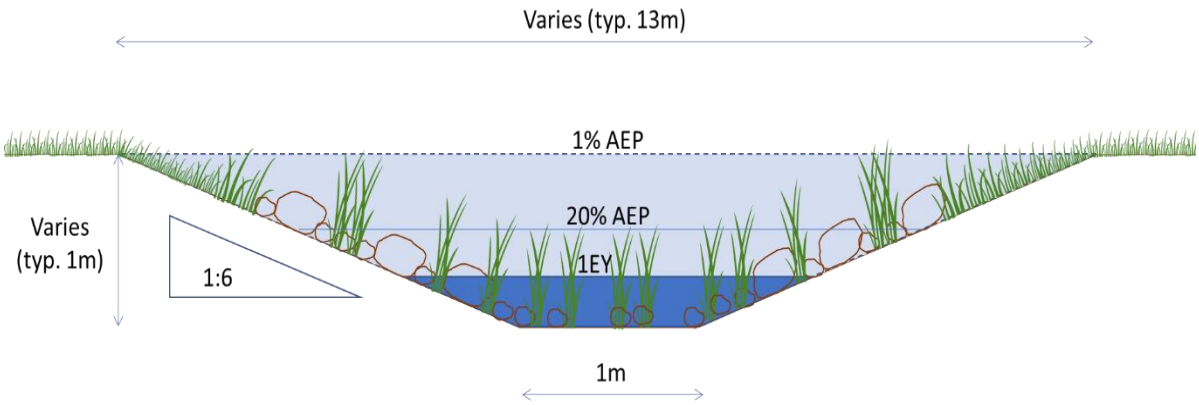

Figure 52: Modelled arterial drainage swale

Although the conceptual drainage system proposed is formed with open drainage swales and these are intended to be vegetated, it is likely that at least some parts of the ultimate system will be piped. Therefore, because the primary purpose of this modelling is to consider storage and land take implications, the roughness (Manning's N) of the conveyance system has been set at 0.015. This is lower than expected for vegetated open drains, which typically have roughness (Manning's N) in the range 0.025-0.05, and this conservative approach is likely to generate larger storage requirements than may be ultimately required.

7.5 Representation of wetlands and constructed storages

InfoWorks ICM allows for representation of storages in two ways:

Storage nodes – are defined by a simple stage/area table and may have a single infiltration rate specified which is applied to the base area and can also be applied to wetted portions of the sides if a perimeter is defined. In this case, the infiltration rate at storage nodes has been set to 10m/day which is consistent with the in-situ sandy soils prevalent in East Wanneroo and the design criteria setting invert levels at least 300mm above the local controlled groundwater level that has been applied. However, to provide a reasonably conservative assessment of the required storage volume, infiltration is only accounted for from the base of constructed storages.

Pond nodes – are defined by a stage/area/perimeter table and may have up to three infiltration rates specified to different portions of the node as shown in Figure 53.

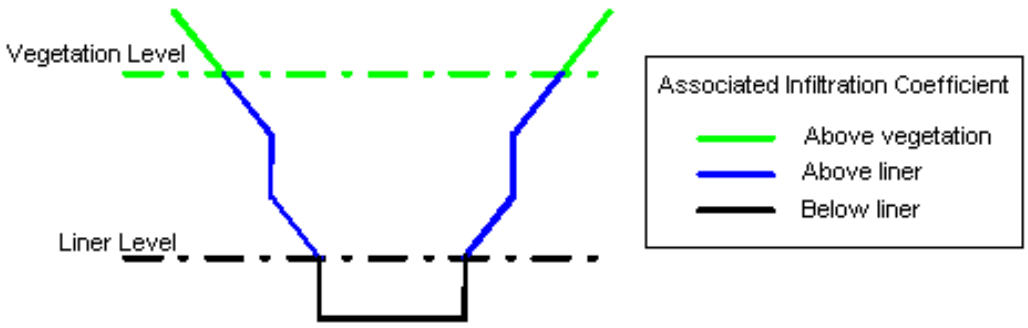

Figure 53: Model representation of wetlands

For modelled retained wetlands in East Wanneroo, the liner level has been set at the average winter water level (1986-95) which also forms the base of the modelled node. In effect, this sets the antecedent water level condition for modelling and no infiltration is allowed from wetlands at or below this level. Above the liner, infiltration has been modelled at a rate of 0.006m/day consistent with low permeability clay soils such as those found in the core of wetlands in East Wanneroo. The vegetation level for wetlands has been set at the level of the mapped wetland boundary and infiltration above this level has been modelled as 2m/day consistent with clogged, sandy/clay soils and shallow groundwater such as those found in wetlands of East Wanneroo.

7.6 Sensitivity testing of key parameters

Modelling presented in this DWMS provides a high-level assessment of storage volumes and peak flows between precincts to assist in preliminary local scale planning but does not replace detailed surface water modelling which will be required to support future local structure plans and presented in local water management strategies. This modelling will need to include consideration of the risks associated with surface and groundwater interaction both now and in the future.

To provide some consideration of the potential variability of storage volumes and peak flows in response to key parameters, sensitivity testing has been undertaken.

Sensitivity testing included running the predevelopment and post-development models with the following amended parameters and routing models:

- Base model parameters with non-linear (SWMM) routing
- Base model parameters with linear (SPRINT) routing
- Initial losses reduced by 50% with non-linear (SWMM) routing
- Continuing losses reduced by 50% non-linear (SWMM) routing
- Reduced initial and continuing losses with non-linear (SWMM) routing
- Reduced initial and continuing losses with linear (SPRINT) routing

In all cases, these scenarios resulted in increased peak flows and storage volumes and a summary of the increases at key locations are presented in the following tables.

It is observed in Table 39 that the pre-development model, particularly for the larger wetland catchments (Jandabup and Mariginiup), is highly sensitive to all considered parameter and routing model changes. It is important to note that the increases resulting from sensitivity testing are in many cases larger than the changes resulting from development that are also shown.

Table 39: Predevelopment volume changes in key wetlands resulting from sensitivity testing

Wetland	Base model	Post development change	Reduced initial loss	Reduced continuing loss	Reduced initial and continuing loss	Linear routing	Linear routing and reduced losses
Adams	635,800	+12%	+17%	+8%	+29%	+106%	+228%
Badgerup	32,100	+25%	+9%	+5%	+16%	+18%	+42%
Gnangara	31,400	-7%	+15%	+6%	+25%	+71%	+137%
Jandabup	49,300	-20%	+72%	+34%	+128%	+255%	+497%
Mariginiup	286,300	+132%	+60%	+38%	+122%	+167%	+381%

Post-development model sensitivity testing reveals that the wetland volumes predicted are less sensitive than in the predevelopment model for all considered parameter and routing model changes. In this case, the increases resulting from sensitivity testing are generally smaller than the changes resulting from development that are also shown.

Table 40: Post-development volume increases in key wetlands resulting from sensitivity testing

Wetland	Base model	Post development change	Reduced initial loss	Reduced continuing loss	Reduced initial and continuing loss	Linear routing	Linear routing and reduced losses
Adams	713,600	+12%	+6%	+4%	+10%	+12%	+27%
Badgerup	916,900	+25%	+4%	+4%	+9%	+2%	+12%
Gnangara	214,200	-7%	+5%	+2%	+8%	+10%	+22%
Jandabup	39,200	-20%	+35%	+26%	+62%	+41%	+105%
Mariginiup	663,100	+132%	+15%	+16%	+34%	+24%	+57%

The results of post-development model sensitivity testing at constructed storages are presented in Table 41. It is observed that modelled storage volumes are generally most sensitive to initial and continuing losses and that those with large external (undeveloped) catchments such as S10a and S23a are significantly more sensitive than catchments that will be fully developed.

Table 41: Post-development volume increases in storages resulting from sensitivity testing

Location	Base model	Reduced initial loss	Reduced continuing loss	Reduced initial and continuing loss	Linear routing	Linear routing and reduced losses
S1a	13,300	+12%	+10%	+22%	+3%	+25%
S1b	5,400	+7%	+7%	+17%	+7%	+24%
S2a	4,600	+0%	+0%	+0%	+0%	+0%
S3a	22,800	+12%	+10%	+22%	+2%	+25%
S4a	5,600	+9%	+7%	+16%	+7%	+25%
S4b	5,500	+9%	+7%	+16%	+7%	+24%
S6a	4,100	+17%	+17%	+37%	+5%	+46%
S10a	46,800	+93%	+50%	+173%	+152%	+384%
S10b	13,600	+15%	+14%	+24%	+11%	+30%
S11a	43,800	+13%	+13%	+28%	+4%	+33%
S12a	61,300	+12%	+12%	+25%	+4%	+29%
S12b	10,500	+27%	+18%	+48%	+21%	+74%
S12c	54,100	+10%	+9%	+19%	+7%	+24%
S12d	34,200	+16%	+15%	+33%	+8%	+41%
S12e	57,600	+29%	+21%	+50%	+10%	+59%
S12f	41,600	+16%	+14%	+30%	+8%	+37%
S12g	16,700	+22%	+15%	+37%	+5%	+42%
S13a	15,900	+43%	+33%	+98%	+6%	+122%

Location	Base model	Reduced initial loss	Reduced continuing loss	Reduced initial and continuing loss	Linear routing	Linear routing and reduced losses
S14b	11,900	+26%	+24%	+42%	+28%	+61%
S15a	23,000	+13%	+13%	+27%	+6%	+34%
S16a	39,800	+12%	+12%	+26%	+4%	+32%
S16b	48,000	+21%	+16%	+39%	+11%	+50%
S16c	49,400	+13%	+14%	+26%	+9%	+33%
S20a	14,200	+16%	+15%	+35%	+12%	+49%
S20b	13,200	+11%	+11%	+26%	+5%	+40%
S23a	92,100	+174%	+105%	+378%	+405%	+976%
S23b	10,700	+12%	+12%	+20%	+12%	+27%
S23c	8,700	+14%	+14%	+23%	+15%	+32%
S23d	6,900	+13%	+13%	+22%	+13%	+29%
S23e	12,400	+13%	+13%	+21%	+14%	+29%
S24a	11,400	+15%	+14%	+25%	+12%	+31%
S24c	15,800	+13%	+13%	+22%	+12%	+28%
S25a	145,700	+26%	+25%	+54%	+56%	+112%

The changes to peak flows at precinct boundaries resulting from sensitivity testing are presented in Table 42. It is observed that peak flows are generally most sensitive to the routing method and continuing losses. It is also observed that in some cases, the combined effect of changing the routing method and reducing losses results in an increase that is far greater than the individual increase from any one change alone.

Table 42: Post-development peak inter-precinct flow increases resulting from sensitivity testing

Location	Base model	Reduced initial loss	Reduced continuing loss	Reduced initial and continuing loss	Linear routing	Linear routing and reduced losses
1a	0.45	+6%	+10%	+11%	+11%	+40%
2a	1.02	+5%	+9%	+11%	+12%	+30%
3a	3.31	+3%	+8%	+9%	+12%	+53%
3b	1.52	+19%	+18%	+27%	+38%	+45%
4a	1.54	+5%	+9%	+11%	+18%	+52%
4a	0.42	+0%	+5%	+5%	+2%	+80%
5a	5.82	+0%	+6%	+6%	+11%	+20%
6a	8.92	+0%	+6%	+6%	+17%	+21%
6b	8.60	+7%	+10%	+14%	+22%	+28%
10a	1.26	+0%	+6%	+6%	+12%	+37%
12a	1.20	+0%	+6%	+6%	+10%	+84%
12b	1.35	+6%	+1%	+3%	+4%	+125%
13a	4.35	+5%	+9%	+10%	+14%	+19%
13b	1.18	+24%	+21%	+33%	+46%	+53%

13b	0.37	+0%	+5%	+5%	+4%	+52%
13c	3.04	+14%	+15%	+21%	+29%	+35%
13d	0.70	+0%	+5%	+5%	+5%	+76%
13e	0.47	+0%	+5%	+5%	+5%	+70%
15a	0.66	+0%	+5%	+5%	+4%	+61%
15b	1.67	+0%	+4%	+4%	+5%	+83%
15c	0.43	+0%	+4%	+4%	+3%	+73%
15d	1.27	+0%	+5%	+5%	+13%	+72%
17a	2.67	+1%	+3%	+2%	+9%	+9%
23a	2.04	+0%	+4%	+4%	+13%	+55%
23b	2.60	+0%	+5%	+5%	+19%	+64%
23c	2.63	+0%	+5%	+5%	+16%	+32%
23c	0.52	+0%	+4%	+4%	+5%	+60%
23d	2.06	+1%	+8%	+8%	+27%	+33%
24a	1.01	+0%	+5%	+4%	+19%	+50%

Sensitivity testing demonstrates that, particularly for sites with large undeveloped upstream catchments the selection of modelling parameters and methods can result in significantly varying results for both storage volumes and peak flows. This is a critical consideration for detailed surface water modelling which will be required to support future local structure plans and presented in local water management strategies. This modelling will therefore need to include further consideration of the risks associated with the selection of modelling parameters and methods. This should include detailed presentation of and justification for all modelling methods and parameters as well as appropriate sensitivity testing.

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