APPENDIX 3:

LOCAL WATER MANAGEMENT STRATEGY (INCLUDING MEMO FROM PENTIUM WATER)

Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

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Basis of Report

This report was originally prepared by 360 Environmental Pty Ltd, now part of SLR Consulting.

This report has been prepared by SLR Consulting Australia (SLR) with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with Hesperia Pty Ltd (the Client). Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of the Client. No warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

Executive Summary

This LWMS has been prepared in accordance with the Better Urban Water Management Guidelines (WAPC 2008) and demonstrates water is able to be appropriately managed to support the proposed Precinct 7 Local Structure Plan (LSP) for the site development. Table 1 below provide a summary of the environmental characteristics and proposed water management strategies for the site.

Table 1: Key LWMS Design Elements

Section	Description
Planning Background Section 1.2	The site is within the East Wanneroo District Structure Plan Area (EWDSP). The EWDSP guides the proposed future development of the area. The EWDSP will inform amendments to the Metropolitan Region Scheme (MRS) and provides a framework to guide future local structure plans, subdivision, and development. The site corresponds to Precinct 7. The LSP area is zoned: • "Urban Deferred" and "Parks and Recreation" under the Metropolitan Region Scheme (MRS) • "Rural Resource" and "Parks and Recreation" under the City of Wanneroo District Planning Scheme No. 2 • Urban Expansion Area as in the North-West Sub-regional Planning Framework (WAPC, 2018a). A District Water Management Strategy (DWMS) for the EWDSP was prepared by Urbaqua in 2021. This document guides the development of this LWMS.

Section	Description
Proposed Development Section 1.4	Precinct 7 covers an area of 394.74 ha. The proposed LSP includes residential housing, one high school, two primary schools, Water Corporation public purpose land, a railway reserve, public open space (POS) and road reserves.
Existing and Historical Land Use Section 3.1	The site is characterised by a mix of rural residential lots and rural land uses such as market gardens, equestrian activities, and rural lifestyle properties surrounding the wetlands.
Site Details Section 3.1	The site is located approximately 2 km east of the Wanneroo townsite, 6 km east of Joondalup and 25 km north of the Perth CBD. Pinjar Road bounds it to the west, Caporn Street to the south, Jandabup Lake Reserve and Rousset Road to the east and Mariginiup Lake and Lakeview Street to the north (Figure 1). The site is approximately 395 ha.
Topography Section 3.3	The site is undulating and generally slopes towards Mariginiup Lake in the centre of the site. Figure 2 indicates the topography ranges from approximately 65 m AHD in the south of the site to approximately 42 m AHD around the perimeter of Lake Mariginiup. The eastern side of the site contains several low-lying ridges, creating trapped low points. The southeast corner of the site slopes in a south easterly direction towards Lake Jandabup.
Soil Type Section 3.4	The Geotechnical Study undertaken by Douglas Partners (Douglas Partners 2021) details the ground conditions to comprise: • Topsoil – dark grey-brown sandy topsoil, with or trace silt and organics, generally 0.1 m thick at the majority of the locations • Fill – Sand, silty sand and sandy gravel fill encountered from the surface to depths of between 0.3 m and 1.3 m at locations 11, 12, 18 to 21 and 32 • Sand - fine to medium grained, generally pale grey or yellow-brown, trace or with silt, from surface or underlying the topsoil or fill, to termination depths of between 2 m and 10.2 m. The sand was generally in a loose or loose to medium dense condition near surface, increasing in density with depth.
Acid Sulphate Soils and contamination Section 3.5 and 3.6	Lake Mariginiup is mapped as having a high to moderate risk of acid sulphate soils (ASS) occurring within 3m of the natural soil surface. The northeast corner of the site is mapped as having a moderate to low risk of ASS beyond 3m of the natural soil surface. The remainder of the site is mapped as having no risk of containing ASS (Figure 6). A search in DWER's Contaminated Sites Database has identified that the site does not contain any registered sites under the Contaminated Sites Act 2003 (DWER, Contaminated sites database 2021b).
Surface Water Section 3.7	The site does not contain any rivers, creeks, or other significant waterways. It is characterised by highly conductive sandy soils which results in water predominantly infiltrating and evaporating. Surface water is generally confined to wetlands, such as Lake Mariginiup located in the site's centre.
Groundwater levels Section 3.8	A groundwater monitoring program was conducted by 360 Environmental between July 2019 and October 2020. A total of two winters were monitored with levels recorded at four (4) bores. Groundwater was found between 2.3 m below ground level (m bgl) near Lake Jandabup (Sept 2019) and 6.3 m bgl on the western edge of Lake Mariginiup (May 2020). This is generally consistent with the regional groundwater level data reported in DWER's Groundwater Map (DWER 2021c).

Section	Description
	The controlled groundwater level for the wider EWDSP area including the site, as stipulated in the DWMS, should be the Average Annual Maximum Groundwater Level (AAMGL). The AAMGL at the site ranges from 45 m AHD to the east to approximately 38.6 m AHD on the west. Groundwater flows from east to the wet towards Lake Mariginiup and from Lake Mariginiup to the southwest.
Groundwater quality Section 3.8.4	360 Environmental undertook groundwater quality monitoring at the four (4) bore location sites (GW01-GW04) between October 2019 and May 2020. The results were compared to the ANZECC & ARMCANZ Fresh Water Guidelines (ANZG 2018). The results of the groundwater quality monitoring can be summarised as: • pH was acidic during all monitoring occasions at all wells and below the adopted ANZECC trigger value • Salinity (determined from electrical conductivity (EC) results) varied from fresh to brackish and exceeded the trigger value at GW01 and GW02 • NH4-N exceeded the trigger value at GW01 on both monitoring occasions and GW02 in May 2020 • NO2 was consistent across all locations and rounds • NO3 is generally consistent except for the October 2019 measurement at GW01 • TN was elevated at all locations.
Groundwater allocation Section 3.8.6	Groundwater at the site is currently used for various purposes, including horticulture and agriculture. The number of existing licences and allocation limits are provided in Appendix E. The total licenced groundwater allocation for the site is 1,356.63 ML from the Perth- Superficial Swan Aquifer.
Wetland Mapping Section 3.9	Lake Mariginiup located in the centre of the site is mapped as a Conservation Category Wetland (UFI 7953) (DBCA, 2017). The Lake is 145.22 ha in size. Lake Jandabup is located approximately 430m east of the site and is the largest wetland located in the EWDSP. The section of Lake Jandabup closest to the site is categorised as Resource Enhancement Wetland.
Ministerial Wetland Criteria Section 3.9.1	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. Lake Mariginiup and Lake Jandabup have water level criteria set in Ministerial Statement No. 819. At Lake Mariginiup, water levels should not fall between 42.1 m AHD (spring minimum peak) and 41.5 m AHD at a rate of more than two in six years, with the absolute minimum criteria being 41.5 m AHD (summer minimum) (DoW, 2010). Lake Jandabup's water levels should not fall between 44.7 m AHD (preferred spring minimum peak) and 44.2 m AHD (absolute spring minimum peak) - 44.3 m AHD (absolute summer minimum) at a rate of more than two in six years.

Section	Description
Wetlands water levels Section 3.9.4	While the DWMS established a suitable baseline period (a ten-year period from 1986 to 1995) where, on average, water levels were compliant with criteria set in Ministerial Statement No. 819, it was observed that Lake Mariginiup was non-compliant with its preferred minimum peak criterion (42.1m) 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 but fully compliant with peak criteria (44.2-44.7m). Since the late 1960s, groundwater and Lake levels have declined such that Lake Mariginiup is now dry for more than six months a year and maximum water levels in winter have been reduced. Groundwater flow is now in weak connection with the Lake and interacts with less than one-third of the Superficial aquifer (DoW, Perth Shallow Groundwater Systems Investigations: Lake Mariginiup 2010).
Wetland water quality Section 3.9.5	DWER wetland water quality sampling locations 6164637 and 6162577 are located at Lake Mariginiup. The Lake presents acidic pH values, high nitrogen, and moderate phosphorus concentrations (Urbaqua 2021). Existing land uses, the regional decline of the water table and the changes in the interaction between surface water and groundwater at Lake Mariginiup have affected the chemistry of both groundwater and Lake water. Poor water quality is a threat to the system. In order to improve the ecological condition at Lake Mariginiup, water levels would need to increase (DoW, Perth Shallow Groundwater Systems Investigations: Lake Mariginiup 2010). Decreased groundwater abstraction may improve the ecological conditions of the Lake, however, urbanisation may pose a risk to the Lake’s water quality that can result from the mobilisation of legacy nutrients.
Fauna and Flora Section 3.11 and 3.12	A desktop assessment and outcomes from the Flora and Vegetation Survey completed by 360 Environmental details that there are no Threatened flora species pursuant to the EPBC Act 1999 and/or gazetted as Threatened/Declared Rare Flora pursuant to the BC Act 2016 in the site. Vegetation condition within the survey area ranged from Very Good to Completely Degraded. A total of 32.58ha of black cockatoo foraging habitat was recorded by 360 Environmental, of which 18.9ha was very high quality, 12.05ha was high quality, 0.65ha of Medium Quality 0.51ha was of low quality.
Water Servicing Section 4	The East Wanneroo – Precinct 7 Engineering Infrastructure Report (Tabec, 2021) states that the site can be serviced by the Water Corporation integrated water supply scheme (IWSS). The development will be connected to the Water Corporation deep sewer network. A new wastewater pumping station will be provided for the development at the southern end of the site between Mariginiup Lake and Caporn Street.
Water Conservation Strategy Section 5	• The development of the site will incorporate the following water conservation strategies: • The use of WaterWise landscaping and efficient irrigation design. The site will also retain mature vegetation reducing the need to establish newly planted vegetation which require irrigation to become established. • Groundwater will be used as the water source for irrigation to reduce potable water consumption. The existing groundwater licences will be transferred for this use. • The use of water efficient fixtures and fittings within the site. • Subsoil drainage water as a fit for a purpose source should be investigated at the UWMP stage in line with district level subsoil drainage investigations.

Section	Description
Stormwater Management Strategy Section 6	A Conceptual Stormwater Management Strategy has been developed for the site which demonstrates that the site can effectively manage stormwater generated during the small, minor, and major rainfall events. The site proposes utilising soakwells, bio-retention areas (BRAs), flood storge areas (FSAs), and wetlands to retain all events up to the major rainfall event on-site. Catchments directly linked to the wetland will retain the first 15 mm of runoff within BRAs in POS with minor and major event flows discharging to the wetland. Catchments with no direct link to the wetland will fully retain up to the major event flows within BRAs and FSAs in POS.
Groundwater Management Strategy Section 7	The AAMGL for the period between 1986 and 1995 is considered the controlled groundwater level (CGL) as detailed in the DWMS (Urbaqua 2021). Groundwater modelling was undertaken by RPS to better understand the risk posed by groundwater level rise. The objectives of the groundwater modelling were twofold: • Estimate post-development groundwater level changes across the site, including at the key environmental locations of Lake Jandabup and Lake Mariginiup. This would be used to estimate areas of the site that would require subsoil drainage. • Estimate subsoil drainage volumes that require management. This would inform the design of the groundwater management system. (RPS, 2021) The modelling indicates that no subsoil drainage is required across the development area, except for a portion to the east of Lake Mariginiup. The model also suggests that a small area to the east of the railway line reserve may require subsoils. For the site groundwater modelling assessment, a conservative subsoil drainage plan was assumed as follows: • For areas where the CGL is within 3 m of the ground surface (post-development surface where available), subsoil drainage was assumed to be at the CGL. • For areas where groundwater is expected to rise to within 3 m of the ground surface, but the CGL is more than 3 m below ground level, subsoil drainage was assumed to be at a maximum practicable depth of 3 m below ground level (post-development ground surface where available). Two options were provided to manage subsoil water: • For water discharging to the EWDSP groundwater management system, it will need to consider the average monthly subsoil flow ranging from 1.5 L/s in March to 23 L/s in August. The average peak seasonal subsoil drainage is ~25 L/s. • For subsoil drainage water discharging to Lake Mariginiup, The Lake levels would raise the average monthly level to ~42.5 m AHD. A Lake elevation of 42.5 m AHD is below the absolute maximum Lake elevation of 42.6 m AHD recommended in the DWMS.
Receiving Environments Section 8	The proposed water management systems are designed to treat stormwater prior to releasing it back to the environment, ensuring stormwater quality design criteria and criteria relating to receiving environments are met. Protection of the receiving environments also involves managing the post-development use of nutrients. A treatment train approach, including structural and non-structural controls, will be implemented to achieve this protection. UNDO modelling was performed for the site that indicates a nutrient export for the site of 6.47 kg/ha/yr for nitrogen and 0.13 kg/ha/yr for phosphorus in predevelopment environment. Post-development results indicate a nutrient export for the site of 1.29 kg/ha/yr for nitrogen and 0.05 kg/ha/yr for phosphorus.

Section	Description
Monitoring and Maintenance Section 10	The continued functioning and performance of the stormwater structures implemented throughout the site will require maintenance to ensure their continued performance and monitoring of the downstream receiving environments to confirm their effectiveness. The maintenance and monitoring programs will be detailed at the UWMP stage, however they likely will comprise of: • Groundwater Monitoring • Wetland Monitoring. Post-development trigger values should be based on the pre-development monitoring results provided in Section 3.8.5. and in consideration of Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018).
Implementation Section 11	A number of actions have been proposed to be undertaken at the district scale. These actions are instigated by the Department of Planning, Lands and Heritage (DPLH) and other agencies. They are funded through the district developer contribution scheme in accordance with State Planning Policy 3.6: Infrastructure Contributions (DPLH, 2021) to include: • Development of a wetland management plan (WMP) for critical sites including Lake Mariginiup and Lake Jandabup • Planning and design of the district groundwater management strategy. This LWMS has provided details to assist with this planning (refer to Section 7). This LWMS provides a framework that the proponent can use to assist in implementing stormwater management methods that have been based on site-specific investigations, are consistent with relevant State policies and have been endorsed by the CoW. The responsibility for working within the framework established within the LWMS rests with the proponent and contractors. However, it is anticipated that future management actions beyond the proposed management timeframes will be the responsibility of the CoW.

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1.0 Introduction

1.1 Background

360 Environmental Pty Ltd (360 Environmental), a part of SLR Consulting, was commissioned by Hesperia Pty Ltd (the proponent) to prepare a Local Water Management Strategy (LWMS) to support a Local Structure Plan (LSP) application which extends over Precinct 7 of the East Wanneroo District Structure Plan (EWDSP) (the site).

The level of detail included in an LWMS follows a risk-based approach with greater emphasis on the aspects of water management that are higher risk or more complex. This LWMS has been prepared to detail how all forms of water, including groundwater, stormwater, and potable water, will be managed on-site in accordance with the Better Urban Water Management (BUWM) guidelines (WAPC, Better Urban Water Management 2008a).

The proposed development will predominantly influence the total water cycle because of an increase in impervious areas, although also through a limited cut to fill strategy for the site. The LWMS has been prepared to provide strategies and plans for total water cycle management across the site in accordance with the principles of Water Sensitive Urban Design (WSUD) and the guiding documents described in Section 1.4. It summarises local and regional environmental data that inform management strategies for stormwater, groundwater, protection of receiving environments, and water conservation. A strategy for implementing the total water cycle management during construction and post-development is also provided.

1.2 Planning Background

The site is within the EWDSP area. The EWDSP was released by the Western Australian Planning Commission (WAPC) (WAPC, East Waneroo District Structure Plan 2021) to guide future development of the area in response to the proposals set out in the North-West Sub-regional Planning Framework (WAPC, North-West Sub-regional Planning Framework 2018a). The EWDSP will inform amendments to the Metropolitan Region Scheme (MRS) and provide a framework to guide future local structure plans, subdivisions, and development.

The EWDSP and District Water Management Strategy (DWMS) (Urbaqua 2021) covers an area of approximately 8,300 hectares (ha) 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.

The East Wanneroo DSP incorporates outcomes from previous studies, including:

- East Wanneroo District Structure Plan (WAPC, East Waneroo District Structure Plan 2021)
- Perth and Peel @ 3.5 million (WAPC, Perth and Peel @3.5 million 2018b)
- Northwest Sub-Regional Planning Framework (WAPC, North-West Sub-regional Planning Framework 2018a).

The EWDSP has been divided into 28 precincts, as detailed in Appendix B. Precinct 7, also referred to as the Lake Mariginiup precinct, is one of the 28 precincts proposed to be developed for urban purposes. The LSP area is zoned as:

- “Urban Deferred” and “Parks and Recreation” under the Metropolitan Region Scheme (MRS)

- “Rural Resource” and “Parks and Recreation” under the City of Wanneroo District Planning Scheme No. 2
- Urban Expansion Area as in the North-West Sub-regional Planning Framework (WAPC, North-West Sub-regional Planning Framework 2018a).

1.3 Proposed Development

Precinct 7 covers an area of 394.74 ha. The proposed LSP is detailed in Appendix B and includes residential housing, one high school, two primary schools, Water Corporation public purpose land, a transit corridor, public open space (POS) and road reserves. Table 2 summarises the proposed land area for each type of land use.

Table 2: Proposed development breakdown (ha)

Proposed Land use	Area Covered (ha)
MRS P&R Reserve	149.30
Public Purposes- Primary School	8.51
Public Purposes -High School	9.07
Public Purposes -Water Corporation	2.14
MRS Other Regional Road Reserve	6.03
Non-Creditable open areas 1:1 drainage (H1)	2.46
Non-Creditable open areas: Wetland core (H2)	0.19

1.4 Guidance Documents and Previous Studies

This report has been prepared in accordance with State Planning Policy 2.9: Water Resources (Government of Western Australia, 2006) and has been developed with reference to the following guidance documents:

- Better Urban Water Management Guidelines (WAPC, Better Urban Water Management 2008a)
- Interim: Developing a Local Water Management Strategy (DoW, Interim: Developing a Local Water Management Strategy 2008)
- Western Australian State Water Plan (DPC 2007)
- Stormwater Management Manual for Western Australia (DoW, Stormwater Management Manual for Western Australia 2004-2007)
- Integrated Water Management Framework (RPS 2019)
- Engineering Servicing Report (Cosill & Webley 2019)
- State Planning Policy 2.9 Water Resources (WAPC, State Planning Policy 2.9: Water Resources 2008b)
- Water Resource Considerations when Controlling Groundwater Levels in Urban Development (DoW, Water Resource Considerations when Controlling Groundwater Levels in Urban Development 2013)
- Decision Process for Stormwater Management in WA (DWER, Decision Process for Stormwater Management in WA 2017)
- Stormwater Drainage Design: Development Design Specification WD5 (City of Wanneroo 2019)

- Local Planning Policy 4.4: Urban Water Management (City of Wanneroo 2020).

Environmental and technical studies completed for the site and relevant to this report include:

- East Wanneroo Environmental Assessment Report (360 Environmental 2021)
- East Wanneroo – Precinct 7 Engineering Infrastructure Report (Tabec 2021)
- Preliminary Geotechnical Investigation – East Wanneroo Precinct 7, Caporn Street, Marginiup, WA (Douglas Partners 2021)
- Groundwater report (RPS 2019).

1.4.1 East Wanneroo District Water Management Strategy

The East Wanneroo DWMS (Urbaqua 2021) provides high-level water management strategies to guide planning and development. In addition, the DWMS summarises existing water resources and environmental conditions within the EWDSP area to demonstrate that the land is capable of development.

The DWMS states that further detailed investigations, including preparing an LWMS and urban water management plans, will occur at later planning stages.

The DWMS was used as a guidance document to prepare this LWMS.

2.0 Design Objectives and Criteria

2.1 Total Water Cycle Management

Total water cycle management recognises the finite limit to a region's water resources and the inter-relationships between water uses and its role in the natural environment. The urban water cycle is to be managed as one system where all forms of water are recognised. Water Sensitive Urban Design (WSUD) principles assist in managing and using water efficiently. Water efficiency, reuse and recycling are integral components of total water cycle management (DoW, Stormwater Management Manual for Western Australia 2004-2007).

The fundamental principles of integrated water cycle management (WAPC, Better Urban Water Management 2008a) are:

- Consideration of all water resources, including wastewater, in water planning
- Integration of water and land use planning
- The sustainable and equitable use of all water sources, considering the needs of all water users, including the community, industry, and the environment.

The design criteria for the site are presented in Table 3. The development of the design criteria was guided by the City of Wanneroo Stormwater Design Specifications (City of Wanneroo 2019), Better Urban Water Management (WAPC, Better Urban Water Management 2008a), the Stormwater Management Manual for Western Australia (DoW, Stormwater Management Manual for Western Australia 2004-2007), and the DWMS (Urbaqua 2021).

Table 3: Development Design Criteria

Element	Design Criteria	
Water Conservation Strategy	SW1	Retain and treat the small event runoff as close to source as possible
	SW2	Minor event runoff to be managed within road reserves, POS, and wetlands to maintain serviceability, amenity, and safety
	SW3	Major event runoff to be fully retained on site
	SW4	Habitable floor levels to be constructed at least 500mm above the 1% AEP water level of adjacent storage areas and wetlands
	SWQ1	Provide stormwater quality treatment measures throughout the site to maintain the water quality of receiving environments
Stormwater Quantity	SWQ2	Treatment areas to be sized to a minimum of 2% of total connected impervious area
	SW1	Retain and treat the small event runoff as close to source as possible
	SW2	Minor event runoff to be managed within road reserves, POS, and wetlands to maintain serviceability, amenity, and safety
	SW3	Major event runoff to be fully retained on site
Stormwater Quality	SW4	Habitable floor levels to be constructed at least 500mm above the 1% AEP water level of adjacent storage areas and wetlands
	SWQ1	Provide stormwater quality treatment measures throughout the site to maintain the water quality of receiving environments
Groundwater Management	GW1	Maintain groundwater quality using landscaped stormwater features and the use of Waterwise and low nutrient demand landscaping
	GW2	Use subsoil drainage as required to manage groundwater separation distance
	GW3	Provide sufficient separation distance to controlled groundwater levels from the base of stormwater management structures
	GW4	Harvest and reuse groundwater collected from subsurface drainage systems
Receiving environments	EV1	Manage post-development hydrology to maintain hydrological, and ecological functions of receiving environments
	EV2	Integrate vegetated overland flow paths to wetlands
	EV3	Manage, protect, or restore wetlands
	EV4	Retain natural landforms and vegetation (wherever possible) to increase urban biodiversity and amenity
	EV5	Maintain or reduce pre-development exported phosphorus and nitrogen to wetlands

3.0 Existing Environment

3.1 Site Location and Land Use

The site is located approximately 2 km east of the Wanneroo townsite, 6 km east of Joondalup and 25 km north of the Perth CBD. Pinjar Road bounds it to the west, Caporn Street to the south, Jandabup Lake Reserve and Rousset Road to the east and Mariginiup Lake and Lakeview Street to the north (Figure 1).

The site is approximately 395 ha and is characterised by a mix of rural residential lots, and rural land uses such as market gardens, equestrian activities, and rural lifestyle properties surrounding the wetlands.

Precinct 7 is in the centre of the EWDS, within Stage 2 of EWDSP development.

3.2 Climate and Rainfall

The site experiences a Mediterranean climate, with cool, wet winters from June to August and hot, dry summers from December to February.

The closest weather station with a long-term rainfall record is Wanneroo (BOM Station Number: 009105), located approximately 2 km west of the site. Daily rainfall has been recorded for the period 1905 - present, with a gap period between 1930 and 1960 where no data was recorded. The average annual rainfall is approximately 789 mm for the period 1905 – 2021, with annual rainfall trending down since 1994, as detailed in Plate 1.

The closest weather station with a long-term temperature record is Perth (BOM Station Number: 009225). The mean monthly maximum temperature is 31.5 °C, and the mean monthly minimum temperature is 8°C.

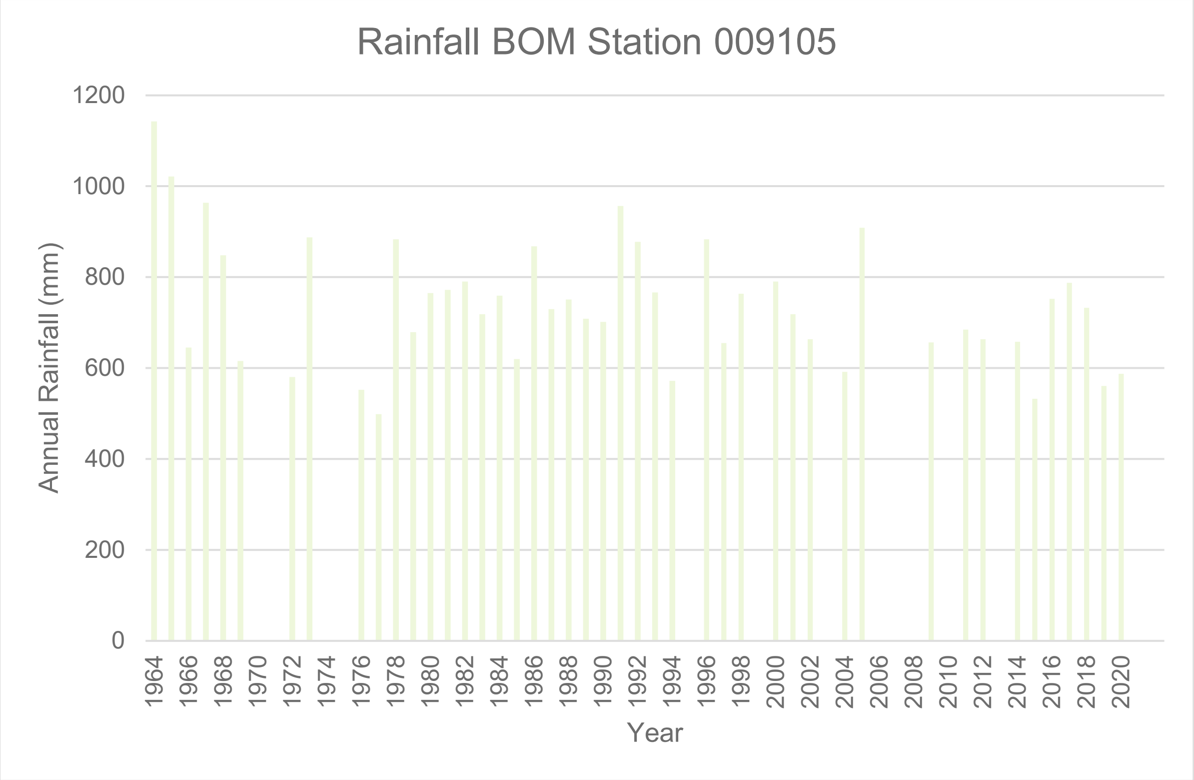

Plate 1: Annual Rainfall BOM Station 009105

3.3 Topography

The site is undulating and generally slopes towards Mariginiup Lake in the centre of the site. Figure 2 indicates the topography ranges from approximately 65 m AHD in the south of the site to approximately 42 m AHD around the perimeter of Lake Mariginiup. The eastern side of the site contains several low-lying ridges, creating trapped low points.

The southeast corner of the site slopes in a south easterly direction towards Lake Jandabup.

3.4 Soil and Geology

Based on the Geology Map from the Department of Mines, Industry Regulation and Safety (DMIRS 2020), most of the site's developable area is mapped as Spearwood Sands. In addition, the perimeter of Lake Marigíniup is identified as peaty clays, and one small section of the site on the eastern boundary is mapped as Bassendean Sand. Soil mapping is detailed in Figure 3. The geological units of the site are described below:

- S7 – Sand, white to pale yellowish-brown and olive-yellow, medium to coarse-grained, subangular quartz and trace feldspar, moderately sorted, of residual origin
- Cps - Peaty clays, dark grey and black with variable sand and organic content, of lacustrine origin
- S8 – Sand, White to pale grey at the surface, yellow at depth, fine to medium-grained, moderately well sorted, subangular to subrounded, quartz of aeolian origin.

3.4.1 Onsite Soil Investigations

Field investigations were undertaken between May and June 2021 by Douglas Partners (Preliminary Geotechnical Investigation - East Wanneroo Precinct 7, Caporn Street, Marginiup, WA 2021) (Appendix D), which consisted of:

- The excavation of 20 test pits to the maximum depth of 3 m
- Eight cone penetration tests CPT pushed to termination depths of 10.2 m
- The drilling of eight boreholes to a maximum depth of 3 m
- Perth sand penetrometer testing adjacent to each test pit and borehole
- Ten in-situ infiltration tests.

Ground conditions of the site generally comprise of:

- Topsoil – dark grey-brown sandy topsoil, with or trace silt and organics, generally 0.1 m thick at the majority of the locations.
- Fill – Sand, silty sand and sandy gravel fill was encountered from the surface to depths of between 0.3 m and 1.3 m at locations 11, 12, 18 to 21 and 32.
- Sand - fine to medium-grained, generally pale grey or yellow-brown, trace or with silt, from the surface or underlying the topsoil or fill, to termination depths of between 2 m and 10.2 m. The sand was generally loose or loose to medium dense conditions near-surface, increasing density with depth.

3.4.2 Infiltration Testing

During the field investigation carried out by Douglas Partners (Preliminary Geotechnical Investigation - East Wanneroo Precinct 7, Caporn Street, Marginiup, WA 2021), ten in-situ permeability tests were carried out using the falling head method. These were carried out between 0.8 m and 1.2 m deep at locations 1, 4, 5, 9, 10, 15 to 17, 32 and 33 (Appendix D).

Measured permeability was > 20 m/day for most locations except for location 1, which reported a permeability of 8 m/day (Table 4). Location 1 is on the far east of the site, near the site's boundary.

Table 4: Permeability Tests Results

Test location	Depth (m)	Measured Permeability (m/day)
1	1	8
4	1	>20
5	1	>20
9	1	>20
10	0.8	>20
15	0.8	>20
16	1	>20
17	0.9	>20
32	1.2	>20
33	1.15	>20

The geotechnical report recommended a design permeability value of 5 m/day for the site due to the loose nature of the sand. This will account for the densification of the sand, likely to occur during earthworks (Douglas Partners 2021).

3.5 Acid Sulphate Soils

Lake Mariginiup is mapped as having a high to moderate risk of acid sulphate soils (ASS) occurring within 3 m of the natural soil surface. The very northeast corner of the site is mapped as having a moderate to low risk of ASS beyond 3 m of the natural soil surface (DWER 2021a).

The remainder of the site is mapped as having no risk of containing ASS (Figure 4).

3.6 Contamination

A search of DWER's Contaminated Sites Database has identified that the site does not contain any sites registered under the *Contaminated Sites Act 2003* (DWER, Contaminated sites database 2021b).

3.7 Surface Water

The site (and wider EWDSP) does not contain any rivers, creeks, or other significant waterways.

The site is characterised by highly conductive sandy soils, resulting in water predominantly infiltrating and evaporating. As a result, surface water is generally confined to wetlands, such as Lake Mariginiup.

3.8 Groundwater

The Water Register (DWER 2021) indicates that groundwater below the site is a multilayered system consisting of:

- Perth – Superficial Swan Aquifer in the Mariginiup Subarea
- Perth – Leederville aquifer in the Wanneroo Confined Subarea
- Perth – Yarragadee North aquifers in the Wanneroo Confined Subarea.

The highly conductive sandy soils prevalent throughout the site result in local hydrology dominated by infiltration and evapotranspiration with almost no runoff. Infiltrated rainwater directly recharges the Gnangara groundwater system. Wetlands are surface expressions of the Superficial aquifer in low lying land between elevated sand dunes.

The quality of pre-development groundwater and depth to groundwater requires consideration for managing the total water cycle.

3.8.1 Regional Water Levels

Based on the historical maximum groundwater levels in DWER's Groundwater Map (DWER 2021c), groundwater levels range from 47 m AHD in the east of the site to 39 m AHD in the west. Minimum groundwater levels range from 44 m AHD to 37 m AHD. Groundwater generally moves from the east towards Lake Mariginiup and from the Lake to the southwest. Depth to groundwater varies from approximately 0 m to 2 m around the perimeter of the Lake Mariginiup to approximately 10 m on the eastern boundary along Rousset Road and up to 25 m on the western edge along some sections of Pinjar Road.

3.8.2 Groundwater Monitoring

A groundwater monitoring program was conducted by 360 Environmental between July 2019 and October 2020. Two winters were monitored with levels recorded at four (4) bores (Figure 5). Groundwater levels were identified as relatively stable, with slight variation in groundwater levels for each bore. The results are presented in Table 5. No data was recorded at GW04, which was dry on all occasions.

Table 5: Groundwater Levels

Date	GW01		GW02		GW03		GW04
	m AHD	m BGL	m AHD	m BGL	m AHD	m BGL	m AHD
Jul-19	40.29	5.49	41.30	2.96	43.98	2.48	Dry
Aug-19	40.3	5.48	41.40	2.86	44.01	2.45	Dry
Sep-19	40.43	5.35	41.35	2.91	44.14	2.32	Dry
Oct-19	40.38	5.40	41.16	3.10	44.08	2.38	Dry
Nov-19	40.32	5.46	41.14	3.12	44.01	2.45	Dry
May-20	39.43	6.35	40.56	3.70	43.10	3.36	Dry
Jun-20	40.48*	5.3*	40.76	3.50	43.37	3.09	Dry
Jul-20	39.86	5.92	40.95	3.31	43.66	2.80	Dry
Aug-20	40.22	5.56	41.10	3.16	43.88	2.58	Dry
Sep-20	40.21	5.58	41.14	3.12	43.83	2.63	Dry
Oct-20	40.20	5.58	41.10	3.16	43.76	2.70	Dry

*Suspected incorrect measurement

Plate 2 shows the groundwater level for the monitoring period 2019 to 2020.

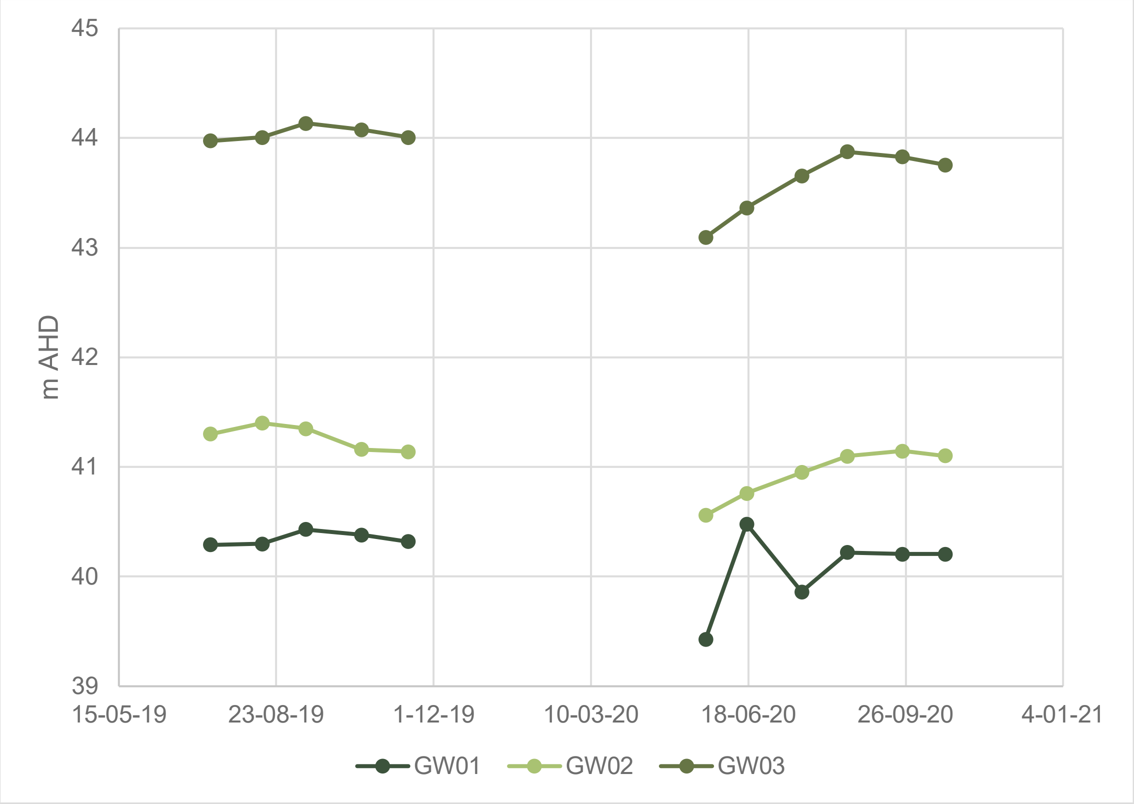

Plate 2: Groundwater Level Monitoring Results

The groundwater levels monitored across the site were generally consistent with the regional groundwater level data reported in DWER's Groundwater Map (DWER 2021c).

3.8.3 Average Annual Maximum Groundwater Levels

The average annual maximum groundwater level (AAMGL) for the period between 1986 and 1995 was chosen as the controlled groundwater level (CGL) for developments within East Wanneroo, as discussed further in the DWMS (Urbaqua 2021). There are 26 wells within or bordering the site with a long-term groundwater level monitoring dataset. AAMGLs were calculated for the 26 DWER wells, two of which are located at Lake Mariginiup and Lake Jandabup. The 26 DWER monitoring wells and corresponding AAMGLs are detailed in Table 6.

Table 6: DWER Monitoring Bore AAMGLs

DWER WIN ID	Easting (MGA 50)	Northing (MGA50)	AAMGL
61610663	386291	6489661	38.186
61610684	387359	6488475	38.851
61610685	387347	6489119	42.021
61610686	386625	6488378	38.045
61610687	387221	6488814	38.826
61610688	387224	6489707	41.815
61610689	386847	6489703	38.747
61610694	387463	6490170	42.047

DWER WIN ID	Easting (MGA 50)	Northing (MGA50)	AAMGL
61610733	388307	6488925	42.882
61610734	388538	6488504	43.332
61610736	388531	6489413	43.150
61610737	388531	6489416	43.518
61610738	388531	6489419	43.567
61610742	388312	6489997	43.130
61610735	389256	6489816	44.575
61610736	388531	6489413	43.151
61610737	388531	6489416	43.518
61610738	388531	6489419	43.567
61610739	389259	6489331	44.240
61610740	389262	6489329	44.289
61610741	389264	6489328	44.281
61610742	388312	6489997	43.130
61610743	389679	6489468	44.817
61610744	389679	6489466	44.851
61610745	389680	6489470	45.464
61610782	389847	6489580	45.991

Groundwater level contours for the site were developed by RPS (Groundwater Modelling Report, Precinct 7, East Wanneroo District Structure Plan 2021) based on the AAMGL data and are detailed in Figure 6. The AAMGL at the site ranges from 45 m AHD to the east to approximately 38.6 m AHD on the west. Groundwater flows from westerly towards Lake Mariginiup and from Lake Mariginiup to the southwest.

3.8.4 Regional Groundwater Quality

The DWMS analysed the data at DWER groundwater monitoring sites 61611440 and 61610736, located close to Lake Mariginiup. The results at these locations were compared to ANZECC water quality guidelines (ANZG 2018), and the following was reported:

- Before 2005, pH was frequently below recommended levels
- Since 2005 pH has been consistently below recommended levels
- Nitrogen is generally well above recommended levels
- Ammonia (NH4) and total kjeldahl nitrogen (TKN) appear to be slightly increasing with time
- There is no discernible trend in nitrite or nitrate (NO3/NO2) levels
- Phosphorous is generally within recommended levels
- Total phosphorus (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.

3.8.5 Site Groundwater Quality Monitoring

360 Environmental undertook groundwater quality monitoring in October 2019 and May 2020 at the four (4) monitoring well locations (GW01-GW04), as detailed in Figure 5. In-situ physiochemical parameters were recorded, and groundwater samples were collected and sent to a National Association of Testing Authorities (NATA) laboratory for the analysis of:

- Ammonia (NH4-N)
- Nitrites (NO2)
- Nitrates (NO3)
- Total Kjedahl nitrogen (TKN)
- Total nitrogen (TN)
- Total phosphorus (TP)
- Reactive phosphorus (Reactive P).

Results were compared to ANZECC & ARMCANZ Fresh Water Guidelines (ANZG 2018).

Table 7 provides the results of the groundwater quality monitoring.

Table 7: Groundwater Quality Results

	ANZECC (2018) Freshwater Guideline	GW01			GW02			GW03		
		Oct 19	May 20	Aug 20	Oct 19	May 20	Aug 20	Oct 19	May 20	Aug 20
In-situ parameters										
Temperature		20	21	19.9	18.3	21.6	18.1	20.2	22.6	18.5
pH	6.5 – 8.5	5.13	5.99	5.29	5.25	5.55	5.34	4.89	4.16	3.97
EC (mS/cm)	0.12 – 0.30	1.45	2.63	1.16	0.94	1.14	0.98	0.13	0.11	0.30
DO (mg/L)		1.52	0.19	4.28	0.52	0.11	0.47	0.24	0.14	3.75
Redox (mV)		196	-110	218	-76	-124	60	61	129	301
Nutrients										
NH4-N	0.9	2.4	7.9	0.5	0.84	1	0.25	0.3	0.46	0.18
NO2		0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NO3	0.7	2.9	0.01	6	0.18	<0.01	<0.01	1.4	<0.01	15
TKN		2.5	9.7	0.7	4.3	4.8	4.8	1.5	0.9	1
TN		5.4	9.7	6.7	4.5	4.9	4.8	2.9	0.9	16
TP		0.25	0.29	0.28	0.23	0.23	0.26	0.24	0.11	0.3
Reactive P		0.02	0.03	0.04	0.10	0.02	0.06	0.16	0.02	0.21

* GW04 was dry during all monitoring rounds

The results of the groundwater quality monitoring can be summarised as:

- pH was acidic during all monitoring occasions at all wells and below the adopted ANZECC trigger value
- Salinity (determined from electrical conductivity (EC) results) varied from fresh to brackish and exceeded the trigger value at GW01 and GW02
- NH4-N exceeded the trigger value at GW01 on both monitoring occasions and GW02 in May 2020
- NO2 was consistent across all locations and rounds
- NO3 is generally consistent except for the October 2019 measurement at GW01
- TN was elevated at all locations.

3.8.6 Groundwater Licence Allocation

Groundwater at the site is currently used for various purposes, including horticulture and agriculture. The number of existing licences and allocation limits are provided in Appendix E. The total licenced groundwater allocation for the site is 1,356.63 ML from the Perth-Superficial Swan Aquifer.

Agricultural activities are likely to cease when land development for residential purposes commences. This will result in changing groundwater demands within the site.

The likely changes to groundwater demands and the potential changes to groundwater levels for the site associated with these changes have been assessed as part of the groundwater modelling completed by RPS (Integrated Water Management Framework: East Wanneroo District Structure Plan 2019) and discussed further in Section 7.

3.9 Wetland Mapping

Lake Mariginiup, located in the centre of the site, is mapped as a Conservation Category Wetland (UFI 7953) (DBCA 2017). The Lake is 145.22 ha in size.

Lake Jandabup is located approximately 430m east of the site and is the largest wetland situated in the EWDSP. The closest section of Jandabup Lake to the site is categorised as Resource Enhancement Wetland. Wetland Mapping is detailed in Figure 7.

3.9.1 Ministerial Wetland Criteria

Ministerial Statement No. 819 – Gnangara Mound Groundwater Resources (including East Gnangara, Shire of Swan) establishes environmental conditions and commitments associated with allocating groundwater for public and private use under Part IV of the *Environmental Protection Act 1986.*

Some of the critical 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 (Urbaqua 2021).

Lake Mariginiup and Lake Jandabup have water level criteria set in Ministerial Statement No. 819. At Lake Mariginiup, water levels should not fall between 42.1 m AHD and 41.5 m AHD (spring minimum) at a rate of more than two in six years, with the absolute minimum criteria being 41.5 m AHD (DoW, Perth Shallow Groundwater Systems Investigations: Lake Mariginiup 2010).

3.9.2 Lake Mariginiup

Lake Mariginiup (ID:7953) is situated at the interface between the Spearwood Dunes in the west and Bassendean Dunes in the east. It is a circular Lake of the Gnangara suite. The hydrogeology of Lake Mariginiup is connected to the flow system of the Gnangara Mound. Hence, surface water fluctuations are generally related to changes in groundwater levels.

The Lake has previously been classified as a permanently inundated flow-through Lake. However, the Lake is now dry for many months of the year.

Protection of the ecological values at the Lake began in the late 1980s by recognising the importance of the Lake's high-water quality, rich aquatic fauna and wading waterbird habitat and by setting water level criteria. Criteria levels are generally based on ecological water requirements, which are the water regimes necessary to maintain a low level of risk to the ecological values of the Lake (DoW, Perth Shallow Groundwater Systems Investigations: Lake Mariginiup 2010).

3.9.3 Wetland Water Levels

Although water level declines have been observed In Lake Mariginiup, particularly since the mid-1990s. Water levels were relatively stable from 1978 to the early 1990s.

However, the DWMS (Urbaqua 2021) identified that for 25 years, between 1977 and 2001, annual minimum and maximum water levels have been non-compliant with their respective criteria, consistently since 1994 and before that.

While the DWMS established a suitable baseline period (a ten-year period from 1986 to 1995) where, on average, water levels were compliant with criteria set in Ministerial statement No. 819, it was observed that Lake Mariginiup was non-compliant with its preferred minimum peak criteria (42.1 m) for two years but was compliant on average and fully compliant with its absolute minimum peak criteria (41.5 m).

Previous investigations describe Lake Mariginiup as a through-flow Lake with a significant connection with groundwater flow of the Gnangara Mound and interaction with over half of the Superficial aquifer for most of the year. However, since the late 1960s, groundwater and Lake levels have declined, such that the Lake is now dry for more than six months a year, and maximum water levels in winter have been reduced. As a result, groundwater flow is now weakly connected with the Lake. It interacts with less than one-third of the Superficial Aquifer (DoW, Perth Shallow Groundwater Systems Investigations: Lake Mariginiup 2010).

3.9.4 Wetland Water Quality

DWER wetland water quality sampling locations 6164637 and 6162577 are located at Lake Mariginiup.

Lake Mariginiup presents acidic pH values, high nitrogen, and moderate phosphorus concentrations (Urbaqua 2021).

Existing land uses, the regional decline of the water table, and the changes in the interaction between surface water and groundwater at Lake Mariginiup have affected groundwater and Lake water chemistry (DoW, Perth Shallow Groundwater Systems Investigations: Lake Mariginiup 2010). These hydrogeochemical changes are associated with several factors:

- The progressive drying of podsolic soils to the east of Lake Mariginiup has increased the solubility of aluminium and acidity stored in the soils. Groundwater discharging into Lake Mariginiup from the east has very low pH, and concentrations of aluminium, zinc and nickel are well above the Department of Environment's freshwater ecosystem trigger levels.

- The Lakebed sediments contain actual and potential acid sulfate soils with little buffering capacity.
- The chemistry of shallow groundwater flowing westwards from the Lake is mainly influenced by rainfall and has little interaction with Lake water.

The hydrogeochemical changes at Lake Mariginiup have resulted in the deterioration of the health of the ecosystems associated with it. Significant changes include the encroachment of sedge species into the wetland basin, reduced waterbird wading habitat and declining family richness of macroinvertebrates. In addition, poor water quality is a threat to the system. To improve the ecological condition at Lake Mariginiup, water levels would need to increase. This may occur over the next 15+ years with urbanization and groundwater levels rising due to decreasing groundwater abstraction ensuring water levels rise within Ministerial criteria thresholds (DoW, Perth Shallow Groundwater Systems Investigations: Lake Mariginiup 2010).

However, the Lake's water quality can be impacted by urbanization via the installation of drainage systems, potentially mobilising groundwater with legacy nutrients and metals and possibly altering the Lake’s hydrology.

3.10 Flora and Vegetation

A desktop assessment and outcomes from the Flora and Vegetation Survey completed by 360 Environmental (East Wanneroo Environmental Assessment Report 2021) showed no threatened flora species pursuant to the *Environmental Protection and Biodiversity Conservation Act 1999* and/or gazetted as Threatened/Declared Rare Flora pursuant to the *Biodiversity Conservation Act 2016* during the survey.

However, one DBCA listed Priority flora was recorded, *Jacksonia sericea* (P4). The presence of these species is unlikely to form a statutory constraint for the proposed development.

Vegetation condition within the survey area ranged from Very Good to Completely Degraded, and 38 vegetation types were mapped within the Survey Area. Two vegetation types FCT SCP 21A and 28, were identified as being a sub-community of the Commonwealth Banksia Woodlands of the Swan Coastal Plain TEC. However, the vegetation representing these FCTs does not meet the protection criteria (360 Environmental 2021).

3.11 Fauna and Habitat

The site occurs within the modelled breeding distributions of the Carnaby’s Black Cockatoo and Forest Red-tailed Black Cockatoo and outside the modelled distribution of the Baudin’s Black Cockatoo. A total of 32.58ha of black cockatoo foraging habitat was recorded, of which 18.9ha was of Very High Quality, 12.50ha was of High Quality,0.65ha of Medium Quality, 0.51ha was of Low Quality Additionally, a pair of Carnaby’s Black Cockatoo was observed, and evidence of foraging in the form of chewed Marri nuts was recorded within the survey area.

A PMST and Nature map search details that the site has 11 threatened ecological species protected under the State and Federal Government environmental regulations (360 Environmental 2021).

3.12 Heritage

3.12.1 Aboriginal Heritage

The Department of Planning, Lands and Heritage (DPLH) Aboriginal Heritage Inquiry System identified that the site has one registered site (ID 3741), Lake Mariginiup, a mythological hunting place. On the northwestern edge of Lake Mariginiup is an unregistered site (ID 28616), Lake Mariginiup Scarred Tree. Northeast of the site is site 22160, which is unregistered. The site is an artefact type of site (AHIS,2021).

Approximately 1.4km north of the site is an unregistered site, Lake Adams (ID 336), classified under mythological, hunting place, plant resource, water resource type. The site is under the Whadjuk People Indigenous Land use agreement (WI2017/015).

3.12.2 European Heritage

One European heritage site, Berriman House (Place number 09514), is located at 89 Caporn Street Mariginup. Berriman house is a single-storey limestone house with an iron roof, tall brick chimney, timber-framed doors, and windows. It is significant as it represents the early successful farming venture on the shores of Lake Mariginiup.

Northwest of the site, approximately 3.5 km, is Charles Aubrey Gibbs house (17921). The site has historical and social significance as an example of a house constructed of concrete blocks in the immediate post World War II period characterized by shortages of building materials (State Heritage Office, 2021).

3.13 Key Site Constraints

3.13.1 Groundwater levels and quality

The key risks to development are associated with predicted groundwater level rise due to urbanisation and reduced local abstraction for horticultural irrigation. Groundwater rise can cause 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 can mobilise nutrients and other contaminants that will need to be managed through the development of water management systems incorporating groundwater treatment strategies.

3.13.2 Wetlands levels and quality

Wetlands are sensitive to changes in both in-depth and the duration of inundation. Mobilisation of nutrients could also impact the ecological functioning of wetlands post-development. Changes in groundwater levels and nutrient concentration could result in the declining health of the wetlands.

Post-development groundwater levels should mimic predevelopment conditions to ensure ecological health of the wetlands is maintained, and Ministerial Wetland Criteria absolute and preferred minimums wetland levels are met.

3.13.3 Acid Sulphate Soils (ASS)

Although not identified at the site (outside of Lake Mariginiup), ASS could be present. An ASS investigation may be warranted subject to the following being undertaken at the site:

- Earthworks that will disturb more than 100 m^3 of soil
- Dewatering or soil draining activity.

To manage the risk of exposure to the ASS, the POS can be designed in areas of high risk. Therefore, an ASS risk assessment will be required to be completed as part of the LSP. The assessment result will determine the development of an ASS Management Plan and Dewatering Management Plan to manage the ASS risk associated with the development.

3.13.4 Flora and Fauna

Clearing of native flora and fauna is a risk of urbanisation. The site contains a DBCA listed Priority flora species. The presence of these species is unlikely to form a statutory constraint for the proposed development. DWER and DBCA should deal with it on a case-by-case basis.

The proponent will retain native vegetation in POS areas, regional ecological linkages, wetland buffers, and road verge where possible. Any amenity planting in streetscapes and POS will be undertaken with local native plant species. The LSP has considered the retention of native vegetation. Future management of this native vegetation will be addressed at the subdivision stage.

A Vegetation Management Plan will likely be required to reduce the risk of introducing or distributing pathogens or weed species to the retained vegetation within site.

A Black Cockatoo Habitat Assessment (360 Environmental (East Wanneroo Environmental Assessment Report 2021) detailed the health, foraging habitat, and retention of potential of Black Cockatoo trees. A total of 494 trees were identified as having a DBH greater than 500 mm and 70 trees contained black cockatoo hollows as detailed in Figure 8. The LSP incorporates the foraging habitats, breeding trees (including hollows) into the overall design, particularly within the Public Open Space, Regional Ecological Linkages, wetland buffers and road verges.

EPBC Referrals may be necessary to address the impact onon black cockatoo foraging habitat and breeding and roosting trees should clearing be required as part of the LSP.

4.0 Water Servicing

4.1 Potable Water Supply

The *East Wanneroo – Precinct 7 Engineering Infrastructure* Report (Tabec, 2023) states that the site can be serviced by the Water Corporation integrated water supply scheme (IWSS).

4.2 Wastewater Management

The development will be connected to the Water Corporation deep sewer network. A new wastewater pumping station will be provided for the development at the southern end of the site between Mariginiup Lake and Caporn Street. The asset will be referred to as Jandabup WWPS 'A.' Further details on wastewater servicing for the site are provided in the *East Wanneroo – Precinct 7 Engineering Infrastructure* Report (Tabec, 2023).

4.3 Irrigation Water Supply

Several existing groundwater licences for the site will be transferred as land is acquired to provide an irrigation water supply for POS (Appendix E).

The total licensed groundwater allocation for the site is 1,356.63 ML.

An irrigation schedule was prepared as part of the concept landscape designs. The preliminary irrigation schedule indicated that a 47,517 kl/yr will be required for permanent irrigation and 96,584 kL/yr for establishment irrigation.

This is well within the total licenced groundwater allocation for the site.

5.0 Water Conservation Strategy

5.1 Proposed Water Conservation Strategy

The development of the site will incorporate the following water conservation strategies:

- The use of Waterwise landscaping and efficient irrigation design within the site. The proposed LSP includes small areas of landscaping and open space, which will limit the amount of water required outside of the building envelopes. The site also contains mature vegetation which can be retained to reduce the need to establish newly planted vegetation which requires higher rates of irrigation for establishment.
- Groundwater will be used as the water source for irrigation to reduce potable water consumption.
- The use of water-efficient fixtures and fittings within site. Water-efficient shower heads and tap fittings are already mandated as part of the Building Code of Australia (ABCB, 2011).
- Promotion of rainwater tanks at the point of sale.
- Promotion of front of lot landscaping packages that will utilise Waterwise garden principles.

5.2 Water Balance

At this stage of the planning process, a detailed design of the proposed development has not been undertaken. However, the water balance for development (as provided in Appendix G) has been calculated based on the rates and methodology presented in the Water Corporation Water Balance Tool. It was assumed that groundwater would be used for POS irrigation, and native POS would not require irrigation.

An area of 7m^2 per resident for active POS has been assumed (DLGSCI 2021) to be irrigated at 6,750 kL/ha/yr. Additionally, the development will also cater for 800 high school students and 800 primary school students.

The water balance assumes an average 2.6 persons per lot for single lot dwellings. The water balance results indicate an average consumption of 92 kL/person/year if no water conservation measures other than those mandated as part of the Building Code of Australia are adopted.

If households within the development adopt the proposed water conservation measures, as described in Section 5.1, at typical uptake rates, as calculated from data from the Australian Bureau of Statistics (ABS 2010), the water balance indicates that households will use 48kL/person/year.

This value is below the 100 kL/person/year target (Government of Western Australia 2007) and achieves the BUWM goal of not more than 40 – 60 kL/person/year.

5.3 Subsoil water harvesting and reuse

As described in Section 7, groundwater is expected to rise post-development due to change of land use resulting in decreased groundwater abstraction and use, resulting in the need to install subsoil drainage throughout some areas of the site (RPS 2021). It has been proposed that subsoil water is collected and transferred to a district scheme for treatment and reuse.

The use of subsoil water as an alternative water source should be investigated in detail at the UWMP stage in line with district-level subsoil drainage investigations.

The groundwater model simulations have determined that the average monthly subsoil flow rates from the site range from 1.5 L/s in March to 23 L/s in August, and an average peak seasonal subsoil drainage of ~25 L/s of water will be discharged via subsoil drains from the portion of the site, east of Lake Mariginiup.

While the use of this resource is yet to be determined at the district scale, it may also assist in supplementing wetlands and helping maintain healthy water levels (where required).

5.4 Water Conservation Criteria Compliance

A summary of the water conservation management criteria proposed for the site and how the proposed development will satisfy the requirements is detailed in Table 8.

Table 8: Water Conservation Criteria Compliance

Criteria		Demonstration of Compliance
WC1	Minimise irrigation requirements for landscaped areas and streetscapes	Waterwise native species will be used in landscaped areas throughout the site, and native vegetation will be retained, where possible, to reduce irrigation requirements.
WC2	Achieve an average rate of 6,750 kL/ha/year of water for irrigation of Public Open Space (POS) and design POS to maximise irrigation efficiency	The irrigation needs for the site have been calculated based on an irrigation rate of 6,750kL/ha/yr.
WC3	Minimise the net use of water within households to meet the target of 100 kL/person/year (Government of Western Australia 2007)	The water balance indicates that the net use of water will be 92 kL/person/year. If households within the development adopt the proposed water conservation measures, the water balance indicates that households will use 48kL/person/year.
WC4	Minimise external house use of potable water	The promotion of rainwater tanks and Waterwise landscaping packages as well as education material at the point of sale will help minimise external house potable water use.
WC5	Use fit for purpose water sources to support the development	The site will be connected to the IWSS for all in house use. POS and landscaped areas will be irrigated using groundwater. Rainwater tanks will be promoted at the point of sale for external lot uses.

6.0 Stormwater Management Strategy

A Conceptual Stormwater Management Strategy has been developed for the site which demonstrates that the site can effectively manage stormwater generated during the small, minor, and major rainfall events.

The site's drainage requirements have been calculated based on a hydraulic conductivity of 5 m/day. This is in accordance with the design permeability values recommended in the geotechnical report (Douglas Partners 2021).

The post-development site earth worked levels have been developed to reduce the cut to fill requirements for the site, helping to maintain predevelopment catchments and retain vegetation across the site. In addition, in accordance with the DWMS (Urbaqua 2021), wetlands within the site will be used for the retention of minor (20% AEP) and major (1% AEP) event flood storage.

The site will utilise various water sensitive urban design strategies within the development to achieve the design criteria stated in Section 2.1. The WSUD strategies that will be used for stormwater management throughout the site to remove gross pollutants, sediments, and nutrients from runoff before infiltration or discharge to Lake Mariginiup include:

- Soakwells
- Gross pollutant traps
- Bio retention areas
- Erosion control structures.

6.1 Stormwater Modelling

Stormwater modelling for the site was performed using XP SWMM to determine the drainage basin's sizes. Australian Rainfall and Runoff (ARR 2019) ensemble events were used to model the catchment runoff. The mean storm was chosen to represent the likely runoff from the catchments. Appendix H provides the detail of the stormwater modelling and was based upon the engineering earthworks plans (Appendix I). Appendix H also provides further details on the approach and assumptions used to inform the modelling. The development catchments and land use breakdowns used in the modelling are detailed in Table 9.

Table 9: Catchment Land Use (ha)

Catch ID	Area	Road	R30	R40	Special Use	POS	School
A	11.722	5.308	0	3.786	0	2.628	0
B	11.565	7.283	0	4.282	0	0	0
C	10.442	6.967	0	3.475	0	0	0
D	18.683	7.914	0	5.097	0	1.701	3.971
E	4.36	1.976	0	2.299	0	0.085	0
F	13.749	5.95	0	6.495	1.26	0.044	0
G	16.336	0.418	0	2.709	0	4.141	9.068
H	10.871	3.408	0	3.455	0	0	4.008
I	15.547	9.146	0.095	5.94	0	0.366	0
J	16.36	1.413	8.815	6.132	0	0	0

Catch ID	Area	Road	R30	R40	Special Use	POS	School
K	22.141	13.826	0	8.273	0	0.042	0
L	12.762	6.296	0	5.947	0	0.519	0
M	9.734	3.143	0	5.141	0	1.45	0
N	11.946	6.446	0	4.166	0	1.334	0
O	9.739	3.998	0	4.144	0	1.597	0
P	20.032	13.53	0	6.39	0	0.112	0
R	1.84	0	0	1.617	0	0.223	0
S	15.606	9.875	0	5.719	0	0.009	0.003
U	7.664	4.407	0	3.257	0	0	0
TOTAL	**241.099**	**111.304**	**8.91**	**88.324**	**1.26**	**14.251**	**17.05**
% of Total	**100%**	**46%**	**4%**	**37%**	**1%**	**6%**	**7%**

The runoff and loss coefficients for each of the land use types used in the XP SWMM model for the development are detailed in Appendix H.

Catchments with a direct link to Lake Mariginiup or Lake Jandabup were modelled to retain the first 15 mm in bio-retention areas (BRA) with all excess runoff discharging to Lake Mariginiup or Lake Jandabup. Catchments with no link to Lake Mariginiup or Lake Jandabup were modelled to fully retain up to the major event in flood storage areas (FSA) within POS. The BRAs are sized to retain and treat the first 15 mm of runoff.

How the stormwater management strategy and modelling reflect on the stormwater management for the site, and the results of the stormwater modelling, are discussed in the following sections.

6.2 Lot drainage

6.2.1 Residential Lot Drainage

All residential lots will fully retain all runoff up to the major event (1% AEP). Rainfall on pervious areas will infiltrate directly at source. Runoff generated from impervious areas will be infiltrated within soakwells on lot.

6.2.2 Commercial Lot Drainage

Commercial lots will fully retain all runoff up to the major event (1% AEP) on lot. Detailed design to support the management of stormwater runoff on lot will be the proponent's responsibility, the details of which will be provided at the detailed design stage within subsequent urban water management plans (UWMP).

6.2.3 School Lot Drainage

All runoff up to and including the major event (1% AEP) will be fully retained on school lots. Detailed designs to support the management of on lot stormwater retention will be the responsibility of the Department of Education.

6.3 Development Drainage

The stormwater drainage will utilise a range of structural measures to retain and treat stormwater runoff in events up to the major rainfall event. The proposed structural measures are discussed in the following sections.

6.3.1 Gross Pollutant traps

Runoff generated from storm events can transport contaminants and gross pollutants to downstream receiving water bodies and environments. Gross pollutant traps (GPT) will remove many of these pollutants and some mobilised sediments and contaminants.

GPTs will be utilised in the piped drainage network to provide treatment of road runoff prior to infiltration in storage areas. The specific location of the GPTs will be determined at the detailed design stage of the development.

6.3.2 Bio Retention Areas

Small event (15 mm) runoff from the road network not retained higher in the catchment will be retained and infiltrated in BRAs in public open space (POS).

Catchments that border Lake Mariginiup or Lake Jandabup will only retain the small event runoff (first 15 mm) within BRAs, with all excess runoff overflowing into Lake Mariginiup, as discussed in Section 6.1.6. Indicative locations of BRAs are shown in the LSP, and Preliminary Landscape Master Plans provided in Appendix C and Appendix F respectively.

BRAs have been designed to have a maximum depth of 500 mm and 1 in 6 side slopes. They will be vegetated with plant species suitable for nutrient uptake, consistent with the Vegetation guidelines for stormwater biofilters in the South West of Western Australia (Monash 2014). BRAs will be designed to have a minimum 300 mm clearance between the top water level (TWL) and habitable floor levels. A minimum 300 mm clearance will also be maintained between the invert of BRAs and the CGL.

Site-specific testing will be carried out on native soils at the proposed location of the BRAs at the detailed design stage to determine the suitability of the native soils to provide treatment during infiltration. Where native soils are shown to exhibit low PRI (<10), BRAs will be underlain with 300 mm of an appropriate treatment media.

6.3.3 Flood Storage Areas

Catchments that do not directly connect to Lake Mariginiup or Lake Jandabup will fully retain all events up to the major event runoff within the catchment. All excess runoff (greater than the first 15 mm) will be retained in FSAs located within POS. Indicative locations of FSAs are detailed in the LSP and Preliminary Landscape Master Plans in Appendix C and Appendix F respectively.

FSAs will have a maximum of 1.2 m depth and 1 in 6 side slopes, which will be either vegetated or turfed, depending on the overall requirements for the POS. FSAs will maintain a minimum 300 mm clearance between TWLs and habitable floor levels.

6.3.4 Wetland Storage

The DWMS (Urbaqua 2021) proposed that, where possible, wetlands may be utilised for minor and major event flood storage. Consistent with the Decision Process for Stormwater Management in WA (DWER, Decision Process for Stormwater Management in WA 2017), small rainfall event management structures will be located outside wetland buffers to minimise hydrological impacts. Excess runoff directed towards Lake Mariginiup will be via overland flow paths and vegetated surfaces.

6.3.5 Erosion Control Measures

The flows discharging from BRAs into Lake Mariginiup or Lake Jandabup will be managed to ensure the protection of the downstream receiving environment through the use of erosion control structures.

The erosion control structures will be subject to detailed design at the UWMP stage. However, a staged design approach will be used, which is summarised below:

- Stage 1 – Larger sized material and rock pitching will be used to attenuate flows immediately downstream of the BRAs
- Stage 2 – Jute/erosion matting densely planted with suitable species will further reduce flows
- Stage 3 – Planting densities will gradually thin and integrate with existing vegetation as flow rates are further reduced before entering the wetland.

The staged approach will reduce flow rates while providing a natural linkage from POS and BRAs to the wetland.

6.3.6 Cross Precinct Drainage

The DWMS indicates that there is cross precinct runoff from Precinct 6, crossing Caporn Street in two locations. All flows from the minor event (first 15 mm) from Precinct 6 will be required to be retained and treated on site, hence Precinct 7 will only be subject to potential cross precinct flows in the minor and major rainfall event. These flow rates are shown in Figure 2 of Appendix H as being: Flow 6a at a flow rate of 8.9 m/s, and Flow 6b at a flow rate of 8.6 m/s.

The volume of runoff and flow rates will be subject to the overall design and stormwater management strategy developed for Precinct 6. Notwithstanding this, Precinct 7 LSP has made allowance to accommodate these flows by providing a direct overland flow linkage between Caporn Street and Lake Mariginiup to ensure that roads remain passable in the minor and major events, and that serviceability, amenity and safety are maintained. The LSP has accommodated this potential cross-precinct runoff in the following way:

- Major event runoff from Precinct 6, will be conveyed via the road network and/or reserves to Lake Mariginiup. Flow 6b will flow west along a 15m wide drainage reserve abutting the high school on Capron St (as shown in the LSP) to a drainage reserve at the current Lot 2 Caporn Street, where it will connect with Flow 6a and be directed overland, northward to Lake Mariginiup.
- The need to accommodate these flows will be reviewed once Precinct 6 drainage design is further developed. If it is determined that it is not required, the 15 m drainage reserve may be returned to being part of the high school land, and the drainage reserve at current Lot 2 is sized such that it can become residential lots.

6.4 Stormwater Modelling results

As discussed in Sections 6.2 and 6.3, the site proposes utilising soakwells, BRAs, FSAs, and wetlands to retain all events up to the major rainfall event on-site.

As discussed in Section 6.1, stormwater retention structures have generally been sized assuming a design infiltration rate of 5 m/day.

Indicative locations of the retention basin are detailed in the LSP and Preliminary Landscape Master Plans (Appendix C and Appendix F).

Appendix H provides a complete explanation of modelling and should be reviewed before utilising the information provided in this Section.

6.4.1 Small Event (First 15mm)

The first 15 mm from impervious areas generated within the site will be infiltrated at source through a combination of soakwells, bottomless pits and landscaped areas, and within BRAs located throughout the site within the POS.

The design depths, inundation areas, and volumes are detailed in Table 10. Basins E, K, L, M, N, O and R have been omitted from Table 10 as these are sized through the XPSWMM modelling to contain the 1:100yr event (details provided further below).

Table 10: Small Event (15 mm), Bioretention Basin Sizing

Basin	Base Area (m^2)	Top area (m^2)	Depth (m)	Volume (m^3)
A	490	792	0.5	318
B	564	885	0.5	359
C	444	733	0.5	291
D	686	1036	0.5	428
F	898	1294	0.5	545
G	333	588	0.5	227
H	441	729	0.5	290
I	814	1193	0.5	499
J	842	1227	0.5	514
P	882	1275	0.5	536
S	780	1151	0.5	480
U	583	909	0.5	370

6.4.2 Minor and Major Rainfall Events

Minor (20% AEP) and major (1% AEP) rainfall events will be managed by discharging stormwater, mainly to Lake Mariginiup but also to Lake Jandabup (catchments U and P), via multiple-use corridors for those catchments that have a connection to the two lakes. Any runoff overflow towards the lakes will be via overland flow paths across vegetated surfaces to provide water quality treatment and maintain the quality of receiving environments.

Catchments that do not have a connection to the two lakes will fully retain runoff from the major event within POS areas.

The modelled sizing details for basins which are not adjacent to the lakes and thus provide a flood storage function (i.e. Basins E, K, L, M, N, O and R) are provided in Table 11. The modelled basin geometry for these basins is 1.2m depth and 1:6 batters.

Table 11: Basin sizing details for Basins E, K, L, M, N, O and R

Catchment	Base area (m^2)	15 mm Event			Minor Event (20% AEP)			Major Event (1% AEP)		
		Depth (m)	TWL area (m^2)	Volume (m^3)	Depth (m)	TWL area (m^2)	Volume (m^3)	Depth (m)	TWL area (m^2)	Volume (m^3)
E	440	0.55	760	324	0.72	880	467	1.18	1250	945
K	2620	0.4	3140	1143	0.59	3400	1757	1.19	4300	4083
L	1520	0.47	1990	831	0.66	2200	1232	1.19	2850	2560
M	1190	0.49	1630	690	0.68	1820	1019	1.2	2390	2106
N	1020	0.49	1440	598	0.68	1610	892	1.19	2150	1853
O	960	0.5	1370	576	0.69	1540	850	1.19	2060	1750
R	210	0.59	470	195	0.76	560	285	1.19	840	583

6.4.3 Wetland Storage

As discussed in Section 6.3.3, catchments directly connecting to the Lake Mariginiup or Lake Jandabup will use the lakes for storage in minor and major events.

Initial post-development modelling indicated that approximately 15,900 m^3 of runoff would enter Lake Mariginiup in a major rainfall event. This volume distributed over the total wetland, the area of which is approximately 147.6 ha, will represent a total depth of 11 mm.

6.5 Non-Structural Water Quality Treatment

A range of non-structural treatment measures will be implemented across the site to help reduce nutrient loads and pollutants within stormwater runoff. These measures may include:

- Retaining native vegetation to reduce nutrient requirements for the establishment of new vegetation
- Using native vegetation throughout landscaped areas within POS and road verges, which require less fertiliser for establishment and maintenance
- Using drought turf tolerant species that require minimal nutrients and water
- Street sweeping to remove contaminants bound in sediments from entering the stormwater drainage network
- Providing education literature to residents regarding fertiliser usage, and low nutrient-dependent plant species and nutrient absorbing vegetation.

6.6 Stormwater Criteria Compliance

A summary of the stormwater management criteria proposed for the site and how the proposed development will satisfy the requirements is detailed in Table 12.

Table 12: Stormwater Management Criteria Compliance

Criteria	Criteria Description	Demonstration of Compliance
SW1	Retain and treat the small event runoff as close to source as possible	Lots will retain up to the major event runoff on lot within soakwells and pervious garden areas. Road runoff will be retained and treated in vegetated BRAs within POS.
SW2	Minor event runoff to be managed within road reserves, POS, and wetlands to maintain serviceability, amenity, and safety	The stormwater drainage network will be designed to ensure that the site remains serviceable in the minor rainfall event. Catchments that directly connect to Lake Mariginiup or Lake Jandabup will use the lakes to store the minor event runoff. Catchments with no connection to the lakes will fully retain the minor event runoff within FSAs in POS.
SW3	Major event runoff to be fully retained on site	Major event runoff will be fully retained on lot. Catchments that border Lake Mariginiup or Lake Jandabup will utilise the lakes to store runoff in the major event. Catchments with no connection to the lakes will fully retain the major event runoff within FSAs in POS.
SW4	Habitable floor levels to be constructed at least 500mm above the 1% AEP water level of adjacent storage areas and wetlands	Habitable floor levels will be designed to maintain a minimum 500 mm clearance to the TWLs in the storage areas and wetland.
SWQ1	Provide stormwater quality treatment measures throughout the site to maintain the water quality of receiving environments	The site will retain and treat the first 15mm of runoff using soakwells, gross pollutant traps, and BRAs located in POS.
SWQ2	Treatment areas to be sized to a minimum of 2% of total connected impervious area	Treatment areas are sized to a minimum of 2.0 % of total connected impervious areas.

7.0 Groundwater Management Strategy

As discussed in Section 3.8.3, the AAMGL between 1986 and 1995 is the adopted controlled groundwater level (CGL) for the site as detailed in the DWMS (Urbaqua 2021). Figure 6 identifies the groundwater contours, as modelled by RPS (Integrated Water Management Framework: East Wanneroo District Structure Plan 2019) using the AAMGL derived from 25 DWER bores in and around the site. The CGL ranges from 45 m AHD in the east to 35 m AHD in the west.

7.1 Groundwater modelling and subsoil drainage

7.1.1 Background

The East Wanneroo DWMS (Urbaqua 2021) identifies groundwater level rise as a critical risk to development. Rising groundwater can increase wetland levels, causing increased depths and durations of inundation and/or waterlogging of wetlands and vegetation. Key risks to the development 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

- Increased prevalence of mosquitoes and other nuisance insects
- Sterilisation of land for development due to unfeasible costs of earthworks and imported sand.

RPS Groundwater Modelling Report (2021) (Appendix J) developed a groundwater model to better understand the risk posed by groundwater level rise. The objectives of the groundwater modelling were twofold:

- Estimate post-development groundwater level changes across the site, including at the key environmental locations of Lake Jandabup and Lake Mariginiup. This would be used to estimate areas of the site that would require subsoil drainage.
- Estimate subsoil drainage volumes that require management. This would inform the design of the groundwater management system.

7.1.2 Subsoil requirement

The Stormwater Modelling Memo (Appendix H) states the following regarding the findings of the RPS report and the requirements for subsoil drainage in Precinct 7:

> *The RPS assessment identified areas where the separation from this post-development groundwater level to the preliminary design earthworks levels across Precinct 7 was less than 3 metres.*
>
> *These areas were nominated by RPS as potential subsoil drainage areas to control post-development groundwater level in Precinct 7, by discharging intercepted groundwater to Lake Mariginiup. The areas identified by RPS (2021) comprised a relatively small portion of Precinct 7 abutting the eastern and southern sides of the Lake.*
>
> *It is understood that a district-scale groundwater / lake water level management system will be implemented to facilitate development of the broader EWDSP area. Therefore, the preliminary assessment by RPS described above is not considered to reflect the likely post-development groundwater levels or the extent of subsoil drainage that will actually be required in Precinct 7.*
>
> *The minimum design earthworks level along the eastern and southern sides of Lake Mariginiup is approximately 45.5 mAHD (and only in very minor areas, with design levels typically being much higher than this). A 2020 review into the water level thresholds for the management of Gnangara Mound wetlands in accordance with Ministerial Statement No. 819 (Kavazos et al., 2020) proposes a maximum water level threshold for Lake Mariginiup of 42.6 mAHD. This is, therefore, the maximum level at which the district-scale groundwater level control system would maintain water levels in Lake Mariginiup (other than, potentially, for short periods following large or successive rainfall events).*
>
> *Whilst more significant groundwater rise / mounding beneath the Precinct 7 development area is possible, it is considered unlikely that subsoil drainage will be required in Precinct 7, with the possible exception of some localised areas fringing Lake Mariginiup. Based on the preliminary design levels described above (ie. minimum 45.5 mAHD), any such subsoil drainage will be able to outlet well above the maximum / controlled water level in Lake Mariginiup for treatment prior to discharge to the Lake.*
>
> *It is understood that subsoil drainage (if required) will be required to be treated outside of wetland buffers and then overland flow into the Lake, with no or minimal alteration of natural surface levels through wetland buffer areas. This design outcome is achievable based on the preliminary design levels, and it is noted that there also exists opportunity to locally adjust (ie. lift) the design earthworks levels at the detailed design*

> *stage if required in any locations to facilitate subsoil drainage treatment and outlet level requirements.*
>
> *It is anticipated that specific locations requiring subsoil drainage will be defined at the subdivision stage and documented in future Urban Water Management Plans, once the district-scale groundwater management system and associated groundwater modelling is further progressed."*

7.1.3 Subsoil treatment

If subsoil drainage and discharge is determined to be required at the subdivision stage, treatment of the subsoil discharge is required, and the following requirements are recommended to be included in the UWMP:

- There will be free flowing outlets to subsoil treatment areas
- Subsoil treatment areas would be constructed with soil amendment and be planted out within nutrient stripping vegetation
- Given the requirement for a free-flowing outlet, then this area will have a very shallow grade away from the subsoil headwall outlet and, where feasible, will not be bunded to detain subsoil flows
- Subsoil water quality treatment would occur in this treatment area and from a landscape outcome perspective be viewed as a constructed wetland area
- Treatment of the subsoil drainage will occur outside of the wetland buffer.

The Preliminary Landscape Master Plans (Appendix F) shows a proposed area in POS 20 that could be utilised for treatment of subsoil discharge if required. It also shows an area set aside for a subsoil pump station which may be required if the discharge is managed via a district scale groundwater management system. The requirements for these areas will be further investigated at subdivision stage, and once further information regarding district scale groundwater management has been received.

7.2 Groundwater Quality

The main principle for groundwater quality management is to maintain or improve the groundwater quality exiting the site post-development. This will be achieved through a range of measures, previously stated in Section 6.5, which includes:

- Retaining native vegetation to reduce nutrient requirements for the establishment of new vegetation
- Using native vegetation throughout landscaped areas within POS and road verges, which require less fertiliser for establishment and maintenance
- Using drought turf tolerant species that require minimal nutrients and water
- Street sweeping to remove contaminants bound in sediments from entering the stormwater drainage network
- Providing education literature to residents regarding fertiliser usage, and low nutrient-dependent plant species and nutrient absorbing vegetation
- Directing stormwater to vegetated BRAs prior to infiltration
- Use of reticulated sewerage throughout the development.

The above management practices will ensure that groundwater quality will be maintained.

7.3 Groundwater Criteria Compliance

A summary of the groundwater management criteria proposed for the site and how the proposed development will satisfy the requirements is detailed in Table 13.

Table 13: Groundwater Criteria Compliance Summary

Criteria		Demonstration of Compliance
GW1	Maintain groundwater quality using landscaped stormwater features and the use of Waterwise and low nutrient demand landscaping	Groundwater quality will be managed through the retention and treatment of the first 15 mm of runoff from impervious areas of the site and the treatment of subsoil drainage (if required) within vegetated swales prior to discharge to Lake Mariginiup or Lake Jandabup, or to a district scale system.
GW2	Use subsoil drainage as required to manage groundwater separation distance	The preliminary modelling by RPS indicates a section of the site east of Lake Mariginiup and a small section in the northeast of the site may require subsoil drainage to maintain separation to groundwater. As discussed in Section 7.1 the requirement for subsoil drainage is uncertain. The requirements for subsoils drainage throughout the site will be confirmed at the detailed design stage.
GW3	Provide sufficient separation distance to controlled groundwater levels from the base of stormwater management structures	All stormwater management structures will be constructed to maintain a minimum 300 mm separation between in invert structure and the controlled groundwater level for the site.
GW4	Harvest and reuse groundwater collected from subsurface drainage systems	Subsoil drainage will be deployed if and where necessary. A potential location for the groundwater pumping station infrastructure of approximately 500 m^2 is at POS 20 north of Rowley Place and to the east of Lake Mariginiup. This location is the closest to the proposed district scheme for joining the header main and treatment area. Uncertainty about the need for subsoil drainage, and the proposed district scale management of subsoil water means that no investigation has been undertaken for reuse subsoil discharge at this stage.

8.0 Receiving environments

The proposed water management systems are designed to treat stormwater prior to releasing it back to the environment, ensuring stormwater quality design criteria and criteria relating to receiving environments are met.

Protection of the receiving environments also involves managing the post-development use of nutrients. A treatment train approach, including structural and non-structural controls, will be implemented to achieve this protection.

Non-structural controls are an essential part of the treatment train process as these contribute to the reduction of stormwater volumes and pollutants. These differ from structural controls as they are not fixed, permanent infrastructure and can offer relatively inexpensive and flexible approaches (DoW, Stormwater Management Manual for Western Australia 2004-2007).

As discussed in Section 6.5, the potential non-structural controls for the site are:

- Retaining native vegetation to reduce nutrient requirements for the establishment of new vegetation
- Using native vegetation throughout landscaped areas within POS and road verges, which require less fertiliser for establishment and maintenance
- Using drought turf tolerant species that require minimal nutrients and water
- Street sweeping to remove contaminants bound in sediments from entering the stormwater drainage network
- Providing education literature to residents regarding fertiliser usage, low nutrient-dependent plant species and nutrient absorbing vegetation.

Structural controls for the site will be implemented to retain and infiltrate up to the major event in POS for catchments with no connection to Lake Mariginiup or Lake Jandabup. Catchments that border either lake will retain and treat the first 15 mm of runoff within BRAs and convey the minor and major event flow via vegetate swales to the lakes.

As discussed further in Section 6.3, the structural controls that will be implemented to mitigate the effects of runoff before entering receiving environments are:

- Gross pollutant traps
- Bio-retention areas
- Soakwells
- Erosion control measures.

8.1 Nutrient export assessment

The DWMS recommends an objective for the Mariginiup precinct is to reduce nitrogen and phosphorus emissions to the receiving environments post-development. To determine if the site's development will have a net reduction in nitrogen and phosphorus inputs to the environment, a comparison of predevelopment and post development land uses and nutrient inputs was assessed using the DWER’s Urban Nutrient Decision Outcomes (UNDO) tool. Appendix K provides the pre-development UNDO model report and Appendix L provides the post-development UNDO model report. These reports were based on the previous draft Precinct 7 Local Structure Plan completed in November 2021.

8.1.1 Pre-development Nutrient Modelling

To determine the predevelopment nutrient inputs for the site, the site was broken down into land uses categories. The land use categories we assessed using satellite imagery. Land use for the site was broken down into three broad categories; Rural Residential, Roads, and POS. The UNDO tool does not have a land use category for agricultural land uses such as market gardens found throughout the site. Therefore, areas of the site identified as market gardens were modelled as non-native POS due to the nutrient-intensive requirements of such land uses. The breakdown of land uses is detailed in Table 14.

Table 14: UNDO Predevelopment Land Uses

Land Use Type	Area (%)
Rural Residential – No livestock	25
Public Open Space – Non-native gardens	59
Public Open Space – Natural	10
Roads	6
Total	**100**

The results of the UNDO modelling for the pre-development environment indicate a nutrient export for the site of 6.47 kg/ha/yr for nitrogen and 0.13 kg/ha/yr for phosphorus.

8.1.2 Post-Development Nutrient Modelling

The UNDO tool was used to provide a conceptual understanding of the nutrient export from the site's future development.

The site was divided into thirteen (13) subregions, which align with POS provision throughout the development, to assess the predicted nutrients inputs for the proposed development. Nitrogen and Phosphorus inputs were estimated based on the land use in each subregion. The assumptions made in the calculations were:

- The lot breakdown was based on the Hesperia preliminary lot mix
- Roads consisted of 80% impervious roads and 20% road reserve with non-native gardens
- Soil PRI is 5
- Groundwater slope is 0.5%.

An analysis of POS was based on the 2021 Concept Landscape Plans, as detailed in Table 15. The assumed depth to groundwater for each subregion is also provided in Table 15.

Table 15: UNDO Depth to Groundwater and POS Provision

Subregion	Depth to Groundwater (m)	Native Gardens	Nature	Sport	Recreation
1	3	26%	59%	-	15%
2	2	-	91%	-	9%
3	9	-	89%	-	11%
4	3.5	-	87%	-	13%
5	1.5	-	62%	35%	3%
6	12	-	92%	-	8%
7	12.5	17%	83%	-	-
8	7.5	-	91%	-	9%
9	4	11%	89%	-	-
10	9	32%	68%	-	-
11	4	-	89%	-	11%
12	2	18%	82%	-	-
13	2	6%	94%	-	-

The results of the UNDO modelling for the post-development environment indicate a nutrient export for the site of 1.29 kg/ha/yr for nitrogen and 0.05 kg/ha/yr for phosphorus.

The results of the nutrient modelling indicate that the development at the site will reduce nutrient inputs for the site compared to pre-development rates, which achieves the DWMS indicative objective of reducing nutrient inputs.

Detailed nutrient load calculations are to be undertaken at the UWMP phase and will be subject to the outcome of the detailed designs for the development.

8.2 Flora and vegetation

The site will retain remnant vegetation within POS areas (maintaining ecological linkages), Lake Mariginiup buffer and road verges (where possible). Any amenity planting in streetscapes and POS will be undertaken with local native plant species (360 Environmental 2021).

Lake Mariginiup has been identified as having Aboriginal Heritage significance. A 50 m foreshore buffer has been applied to the Lake. The Lake’s buffer is proposed to be revegetated and rehabilitated with DBCA advice and guidance.

The site’s natural landforms have been retained where possible to ensure the hydrological functioning of receiving environments is maintained. Where proposed stormwater discharge to the lakes has been proposed, discharge will be via vegetated flow paths or swales.

8.3 Fauna

POS will be used to secure a variety of fauna habitats, such as Lake Mariginiup buffer area, as a transition zone from a sensitive area to the development area.

The site will retain significant trees within POS, road reservations and regional ecological linkages. Roads intersecting the linkages will be minimised.

Black Cockatoo habitat within POS will be retained. Trees identified as having a DBH greater than 100 mm have been mapped (Figure 8). Planning of the site has endeavoured to incorporate the foraging habitats and hollows into the overall design particularly within the POS and regional ecological linkages.

8.4 Receiving Environment Criteria Compliance

A summary of the receiving environment management criteria proposed for the site, and the manner in which the proposed development will satisfy the criteria is detailed in Table 16.

Table 16: Receiving Environment Criteria Compliance

Criteria		Demonstration of Compliance
EV1	Manage post-development hydrology to maintain hydrological, and ecological functions of receiving environments	The first 15 mm of runoff will be treated before infiltration with all excess runoff discharging to Lakes Mariginiup or Jandabup. The stormwater modelling indicated that the additional runoff into Lake Mariginiup from a major (1% AEP) event would equate to an additional 11 mm depth. The Wet 2050 future climate simulation undertaken by RPS indicates that discharge of the subsoil drainage into Lake Mariginiup would raise the average monthly Lake level to ~42.5 m AHD, below the absolute maximum Lake elevation of 42.6 m AHD recommended in the DWMS. UNDO modelling indicates that there will be a net reduction in exported nutrient post development.

Criteria		Demonstration of Compliance
EV2	Integrate vegetated overland flow paths to wetlands	Where proposed stormwater discharge to the Lake has been proposed, discharge will be via vegetated flow paths or swales.
EV3	Manage, protect, or restore wetlands	The Lake's buffer is proposed to be revegetated and rehabilitated with DBCA advice and guidance.
EV4	Retain natural landforms and vegetation (wherever possible) to increase urban biodiversity and amenity	Site earthworks have been developed to retain where possible predevelopment drainage catchments and landforms. In addition, the site will retain remnant vegetation within POS areas maintaining ecological linkages, the Lake Marigíniup buffer, and road verges (where possible). Any amenity planting in streetscapes and POS will be undertaken with local native plant species.
EV5	Maintain or reduce pre-development exported phosphorus and nitrogen to wetlands	UNDO modelling indicates that post-development nitrogen and phosphorus concentrations will be reduced.

9.0 Urban Water Management Plan

The water management strategies and criteria presented in this LWMS have been developed based on an interpretation of the guidance documents and concept designs for the site. The preparation of an Urban Water Management Plan (UWMP) at the subdivision stage will be required to address details not provided within this LWMS. The main areas that will require further clarification are:

- Finalised landscape plans
- Detailed stormwater drainage design including the location and sizing of drainage infrastructure and required storage for the first flush and minor (20% AEP) and major (1% AEP) rainfall events
- Final earthworks plans and finished lot levels
- Engineering plans including earthworks, roads and drainage infrastructure
- Confirmation that the Water Corporation has or is due to complete the upgrades required to service the site for wastewater disposal
- Confirmation that the groundwater licence(s) have been transferred and a licence to take water for irrigation is available
- The groundwater management system, including asset ownership and maintenance has been confirmed and is accordance with any further groundwater modelling and management strategies as agreed between the DPLH and the CoW
- Further investigation into the use of subsoil drainage based on any updated information regarding groundwater management system, groundwater controls and lake level management
- Details of subsoil discharge treatment if required
- Consideration of re-use of subsoil drainage if required
- Strategies for wetland management which are in accordance with the wider wetlands management plan and associated foreshore management plan, instigated by the DPLH and other agencies.

The areas listed above to be determined at subdivision stage should comply with this LWMS and the DWMS where reasonable or justification is to be provided.

10.0 Maintenance and Monitoring

The continued functioning and performance of the stormwater structures implemented throughout the site will require maintenance to ensure their continued performance and monitoring of the downstream receiving environments to confirm their effectiveness. The maintenance and monitoring programs will be detailed at the UWMP stage but have been summarised in the following sections.

10.1 Maintenance

The design and construction of the stormwater management system will be undertaken in a manner that promotes the long-term health of the associated WSUD features and downstream receiving environments. These areas often require active ongoing management, particularly in the first years after construction, to ensure that the features continue to provide their intended function.

The UWMP will incorporate maintenance requirements of managed stormwater before handover to the CoW, including

- Maintaining the amenity and function of the stormwater management system eg nutrients, water quality, gross pollutants and sediments
- Minimising the potential for environmental impacts and disturbance to surrounding residents in the longer term eg vegetation/fauna values
- Ensuring that the system is in an appropriate and sustainable condition
- Providing suitable monitoring regime.

10.2 Monitoring

Monitoring will be required to confirm that the structural and non-structural measures being implemented across the site are performing as intended. It is proposed that monitoring of POS and groundwater be undertaken for two years after practical completion of the civil and landscaping works. Wetland monitoring will be based on the outcome of a Wetland Management Plan (WMP) that will be developed at the district scale and funded through a developer contributions scheme.

10.2.1 POS Monitoring

The UWMP will outline the frequency of visual assessment to monitor the landscaped areas and outline possible remedial actions that should be undertaken.

10.2.2 Groundwater Monitoring

Groundwater quality monitoring is required to ensure that the development is not negatively impacting groundwater quality or groundwater-dependent ecosystems. Six post-development monitoring bore locations have been selected at up-gradient, mid-gradient, and down-gradient groundwater contour locations (Figure 5). These locations have also been selected to be in or near POS areas and where possible near the pre-development monitoring bore locations. This is to assist with the comparison of pre and post development data. Monitoring should be undertaken quarterly for two years. Table 17 details the monitoring requirements.

Table 17: Monitoring schedule and reporting

Monitoring type	Locations	Method	Frequency, timing, and responsibility	Parameter
Groundwater Level	As per Figure 5	Electrical depth probe or similar	Quarterly for 2 years by Developer (Jan, April, July, Sept).	Water Level (mAHD)
Groundwater Quality	As per Figure 5	Pumped bore	Quarterly for 2 years by Developer (typically Jan, April, July, Sept).`	In-situ: pH, EC, temp Lab: TN, TKN, NOX, Ammonia, TP, FRP, selected metals

10.2.3 Wetland Monitoring

Wetland monitoring will be based on the outcome of the wetland management plan that will be developed at the district scale and funded through a developer contributions scheme.

10.3 Post-development Trigger Values

To allow an assessment of the measured water quality parameters, a comparison will be made to trigger values. Post-development trigger values should be based on the pre-development monitoring results provided in Section 3.8.5. and in consideration of Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018).

10.3.1 Contingency actions

If the analytical results from samples taken during monitoring exceed adopted trigger values by more than 20%, then resampling should be retaken to confirm the result. Once the result is confirmed, several contingency measures may be employed. These actions are outlined in Table 18.

Table 18: Contingency Actions

Monitoring type	Criteria for Assessment	Criteria Assessment Frequency	Contingency Action
Groundwater Level	Groundwater levels not to exceed CGL.	After monitoring occasion	1. Review design and operation of subsoil and stormwater drainage system. 2. Perform maintenance as required.
Groundwater Quality	Nutrient concentrations in shallow bores should not exceed 20% of the maximum recorded pre-development level.	Annual review of water quality targets	1. Identify and remove any point sources if possible. 2. Remove sediment-bound nutrients by removing POS/basin sediments 3. Consider reinforcement of Community Education/Awareness program. 4. Review operational and maintenance (e.g. fertilising, cleaning) practices. 5. Consider alterations to POS areas including landscape regimes and soil amendment. 6. Consider modifications to the stormwater system.

11.0 Implementation of the LWMS

11.1 Developer Contributions

A number of actions have been proposed to be undertaken at the district scale. These actions are instigated by the Department of Planning, Lands and Heritage (DPLH) and other agencies. They are funded through the district developer contribution scheme in accordance with State Planning Policy 3.6: Infrastructure Contributions (DPLH 2021) to include:

- Development of a wetland management plan for critical sites including Lake Mariginiup and Lake Jandabup.
- Planning and design of the district groundwater management strategy. This LWMS has provided details to assist with this planning (refer to Section 7).

11.2 Roles and Responsibilities

This LWMS provides a framework that the proponent can use to assist in implementing stormwater management methods that have been based on site-specific investigations, are consistent with relevant State policies and have been endorsed by the CoW. The responsibility for working within the framework established within the LWMS rests with the proponent and contractors. However, it is anticipated that future management actions beyond the proposed management timeframes will be the responsibility of the CoW.

An appropriate implementation plan which includes a monitoring and maintenance schedule will be detailed in the future UWMP (or similar). The complete subdivision of the site is expected to occur over a minimum period of 15 years. The timing and areas of the site will be driven by market demands which cannot be determined at this stage.

Table 19 details the roles and responsibilities for water management during the subdivision and construction phase of the development and post-development.

Table 19: Roles and Responsibilities

Action	Developer	City	Regulator
Preparation of UWMP	✓		
Assessment / Approval of the UWMP (or similar)		✓	
Preparation of Wetland Management Plan		✓	✓
Construction of Stormwater System	✓		
Maintenance and Street Sweeping Prior to Handover	✓		
Maintenance and Street Sweeping Following Handover		✓	

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It is important to recognise that site conditions, including the extent and concentration of contaminants, can change with time. This is particularly relevant if this report, including the data, opinions, conclusions, and recommendations it contains, are to be used a considerable time after it was prepared. In these circumstances, further investigation of the site may be necessary.

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Appendix A Figures

Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

SLR Project No.: 675.V64450.00000

6 December 2023

Legend

▭ Site Boundary

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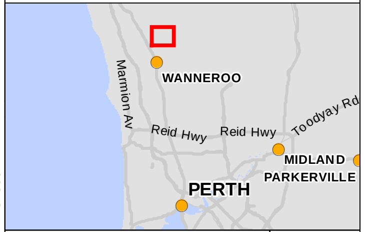

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Hesperia

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Local Water Management Strategy

Figure 1
Site Location

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K:\Projects\10. WAM\4450 Precinct 7 Feature Survey\4450 F01 Site Location.mxd

Legend

🟨 Site Boundary

Topographic Contours 1m interval (mAHD)

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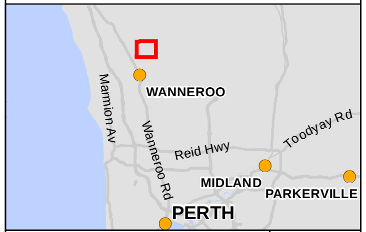

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Local Water Management Strategy

Figure 2
Topography

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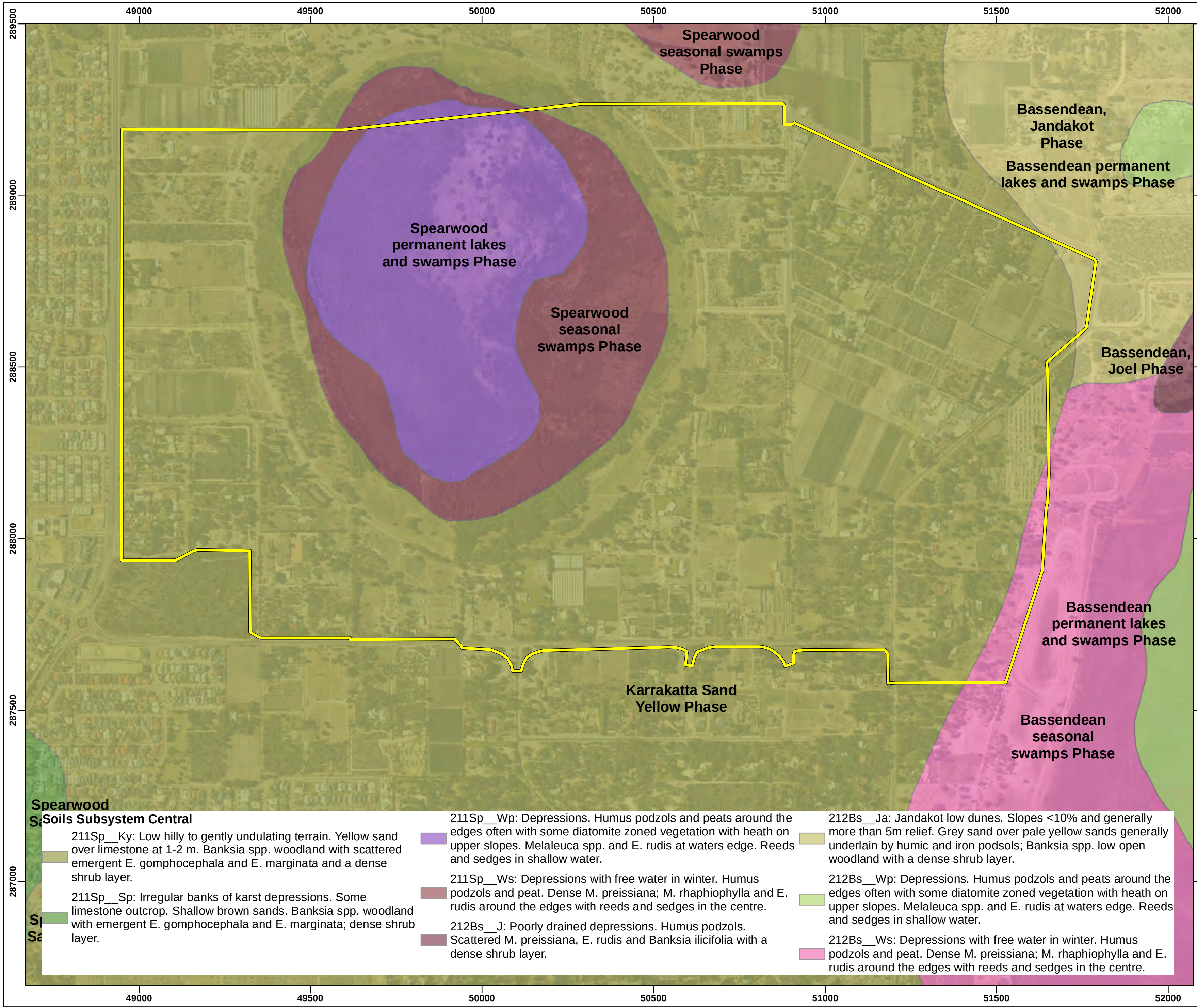

Soils Subsystem Central

■	211Sp__Ky: Low hilly to gently undulating terrain. Yellow sand over limestone at 1-2 m. Banksia spp. woodland with scattered emergent E. gomphocephala and E. marginata and a dense shrub layer.
■	211Sp__Sp: Irregular banks of karst depressions. Some limestone outcrop. Shallow brown sands. Banksia spp. woodland with emergent E. gomphocephala and E. marginata; dense shrub layer.
■	211Sp__Wp: Depressions. Humus podzols and peats around the edges often with some diatomite zoned vegetation with heath on upper slopes. Melaleuca spp. and E. rudis at waters edge. Reeds and sedges in shallow water.
■	211Sp__Ws: Depressions with free water in winter. Humus podzols and peat. Dense M. preissiana; M. rhaphiophylla and E. rudis around the edges with reeds and sedges in the centre.
■	212Bs__J: Poorly drained depressions. Humus podzols. Scattered M. preissiana, E. rudis and Banksia ilicifolia with a dense shrub layer.
■	212Bs__Ja: Jandakot low dunes. Slopes <10% and generally more than 5m relief. Grey sand over pale yellow sands generally underlain by humic and iron podsols; Banksia spp. low open woodland with a dense shrub layer.
■	212Bs__Wp: Depressions. Humus podzols and peats around the edges often with some diatomite zoned vegetation with heath on upper slopes. Melaleuca spp. and E. rudis at waters edge. Reeds and sedges in shallow water.
■	212Bs__Ws: Depressions with free water in winter. Humus podzols and peat. Dense M. preissiana; M. rhaphiophylla and E. rudis around the edges with reeds and sedges in the centre.

Legend

☐ Site

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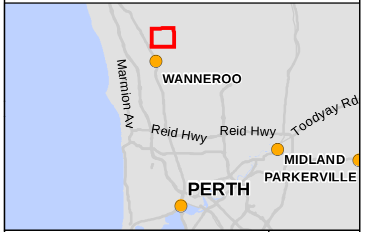

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Local Water Management Strategy

Figure 3
Soil Type

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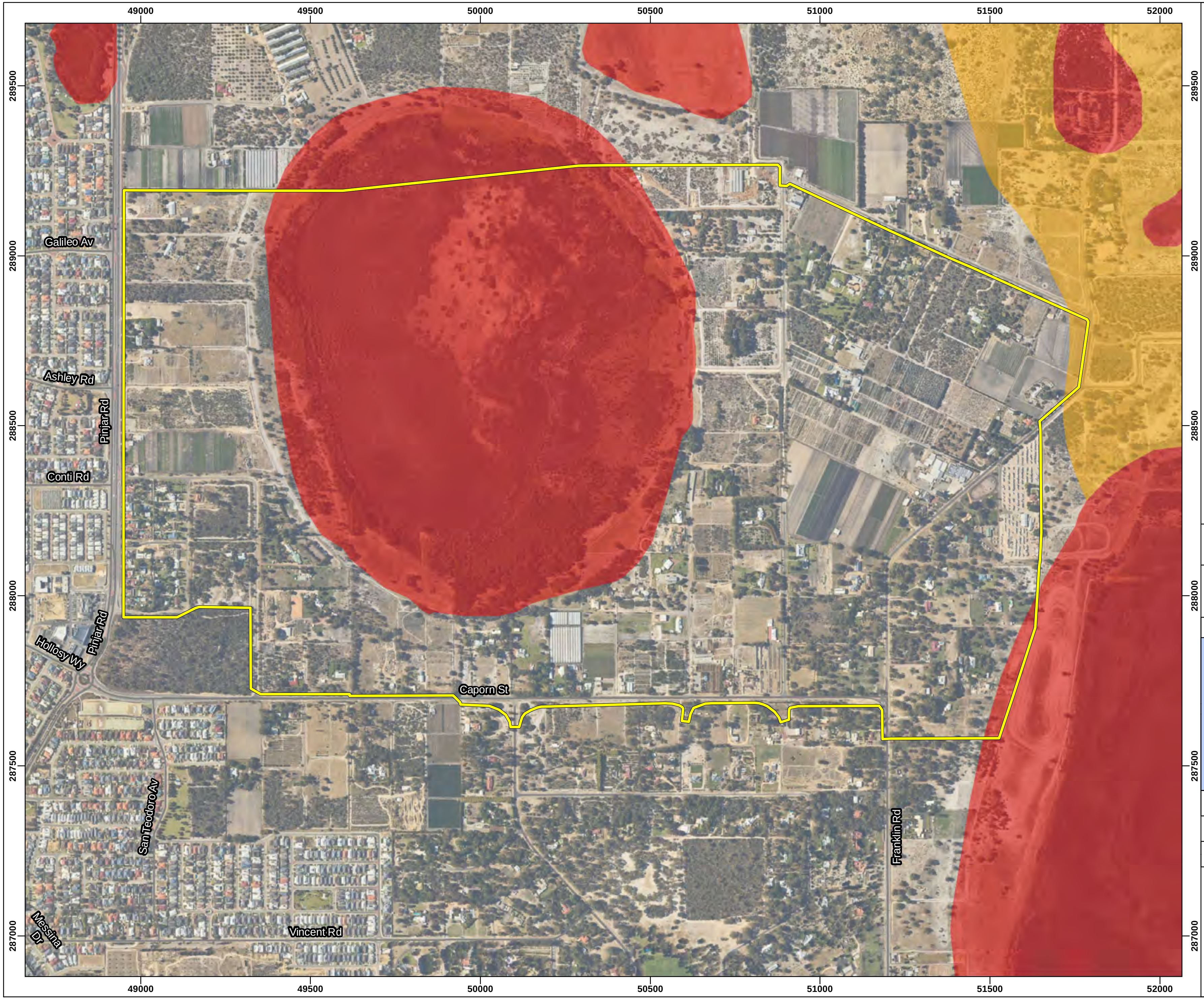

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□ Site Boundary

Acid Sulfate Soils Risk

🟥 High to moderate risk

🟧 Moderate to low risk

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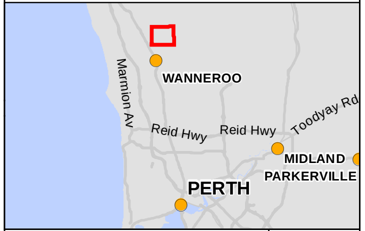

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Local Water Management Strategy

Figure 4
Acid Sulfate Soils

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▭	Site Boundary
⊕	Groundwater Bore Locations

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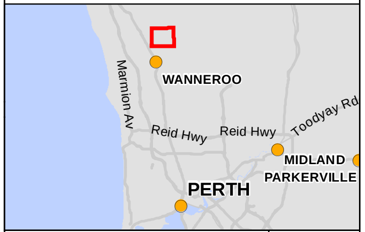

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Figure 5

Groundwater Monitoring Bore Location

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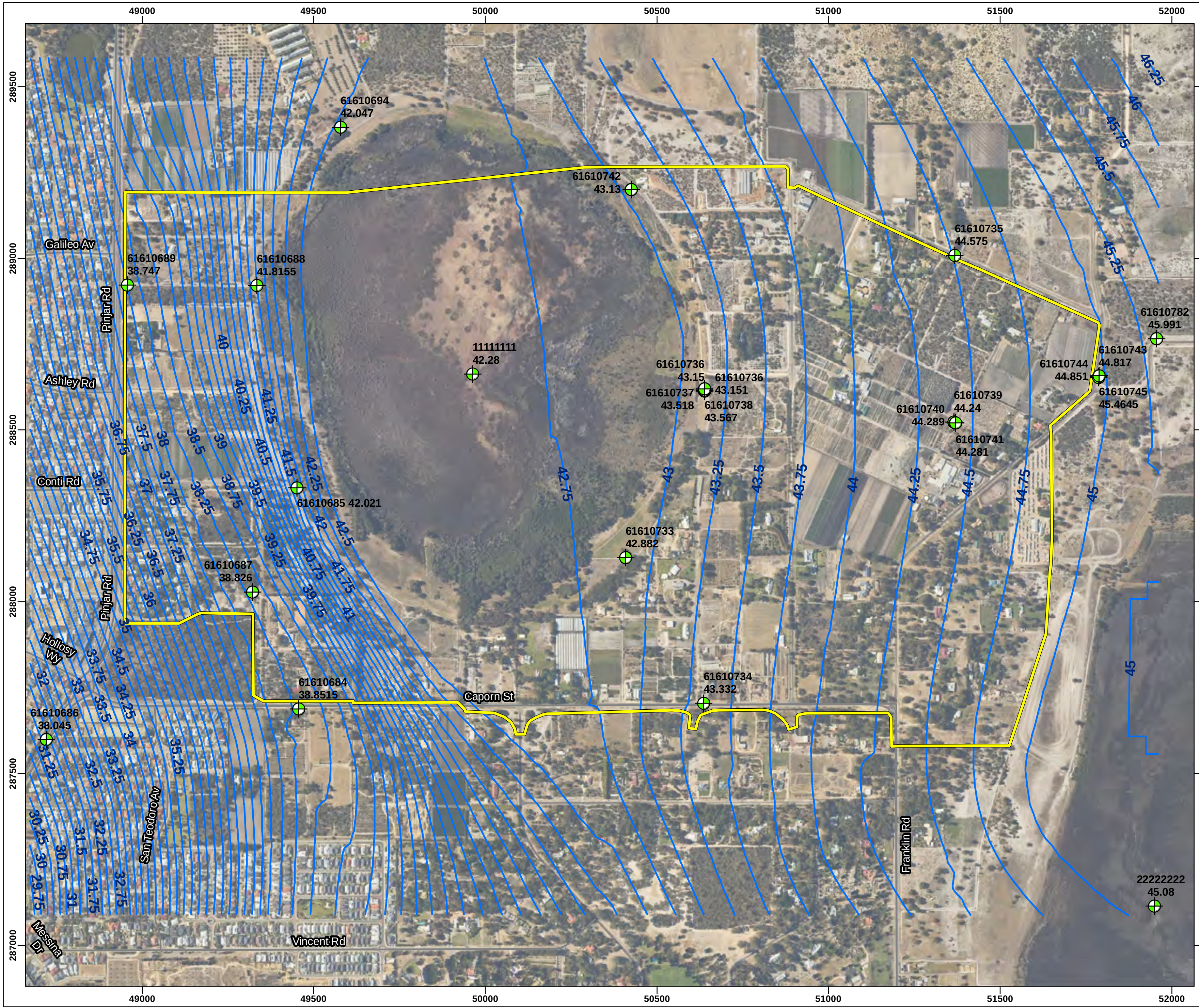

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- Site Boundary
- AAMGL (mAHD)
- Control Groundwater Level 1986 to 1995 (mAHD)

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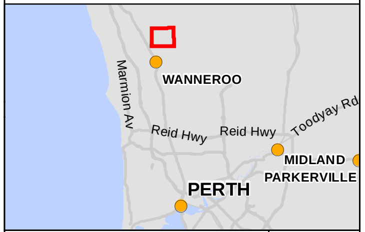

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Local Water Management Strategy

Figure 6

Controlled Grounwater levels

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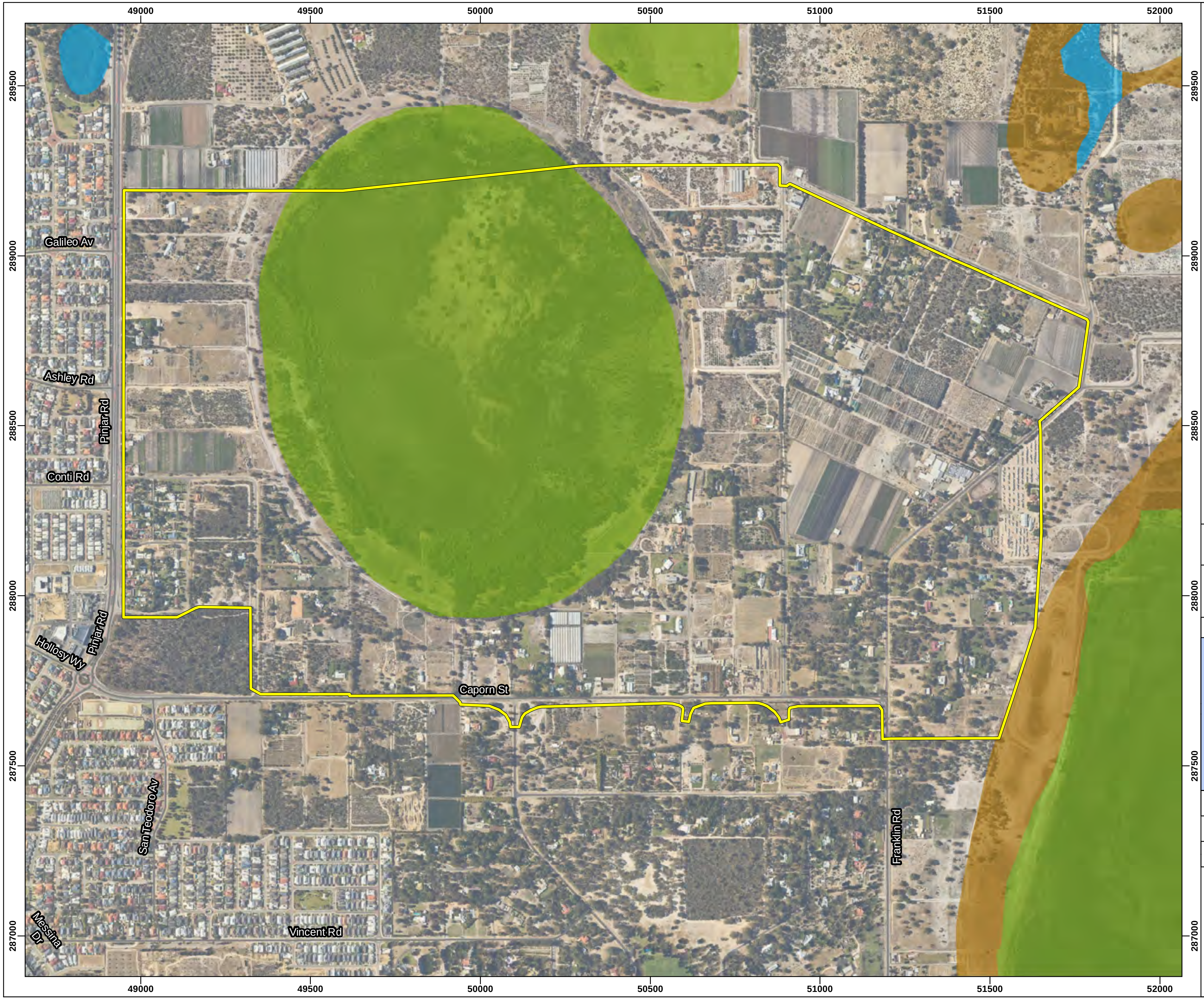

Legend

☐ Site Boundary

Geomorphic Wetlands Swan Coastal Plain DBCA_019

🟩 Conservation

🟦 Resource Enhancement

🟫 Multiple Use

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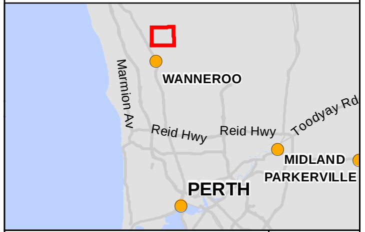

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Local Water Management Strategy

Figure 7
Wetland Mapping

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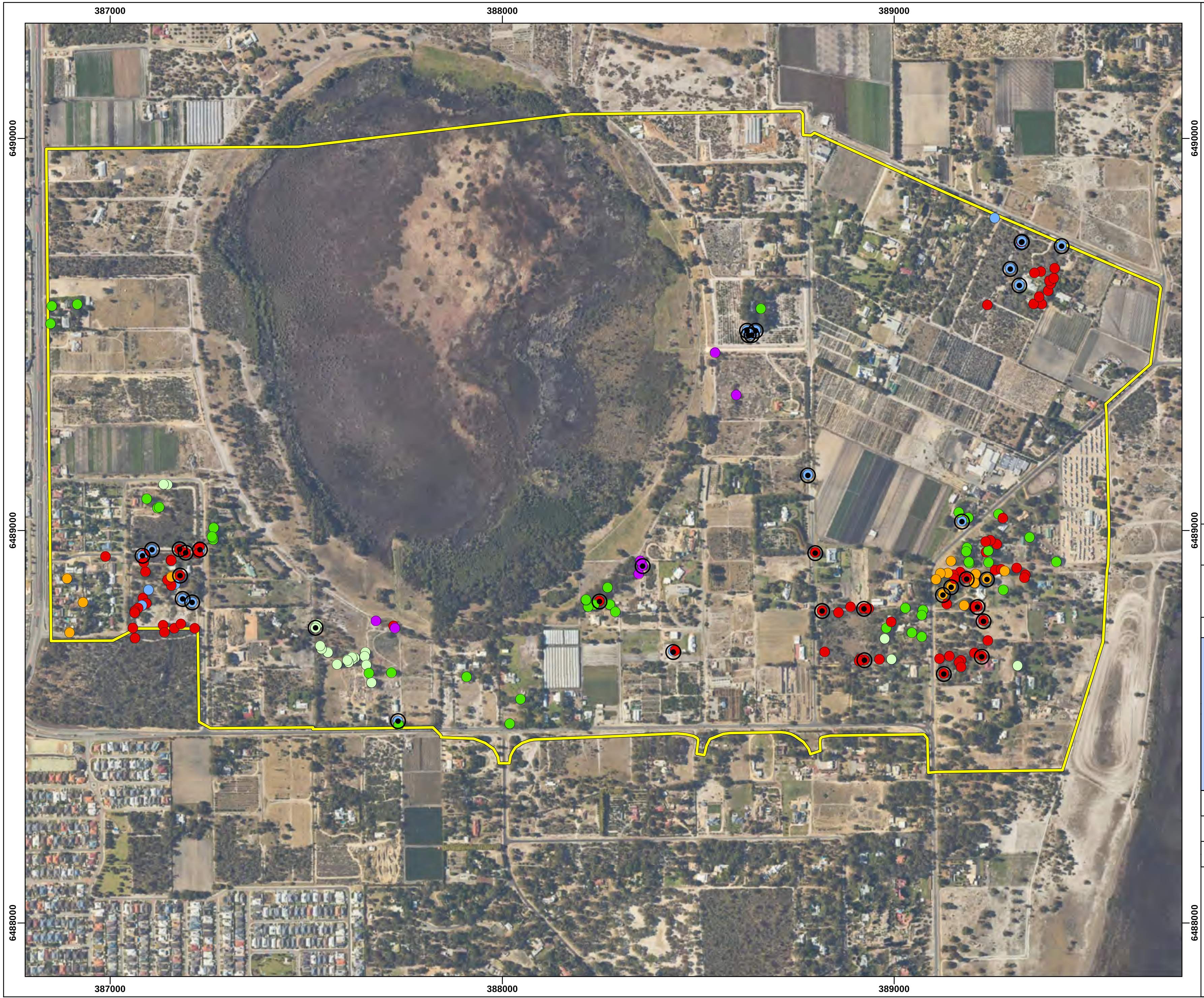

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▭ Site Boundary

Potential Black Cockatoo Breeding Trees Species

- ● *Eucalyptus rudis*
- ● Introduced Eucalypt
- ● Jarrah (*Eucalyptus marginata*)
- ● Marri (*Corymbia calophylla*)
- ● Stag
- ● Tuart (*Eucalyptus gomphocephala*)
- ⊙ Potentially Suitable Breeding Hollow >120mm

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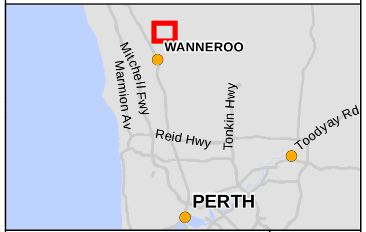
LOCALITY MAP



PROJECT ID			DATE
4450			15/12/2021
HORIZONTAL DATUM AND PROJECTION GDA 1994 MGA Zone 50			
CREATED	CHECKED	APPROVED	REVISION
LF	PD	PD	0

Hesperia

Precinct 7 , East Wanneroo Road

Local Water Management Strategy

Figure 8
Potential Black Cockatoo Breeding Trees

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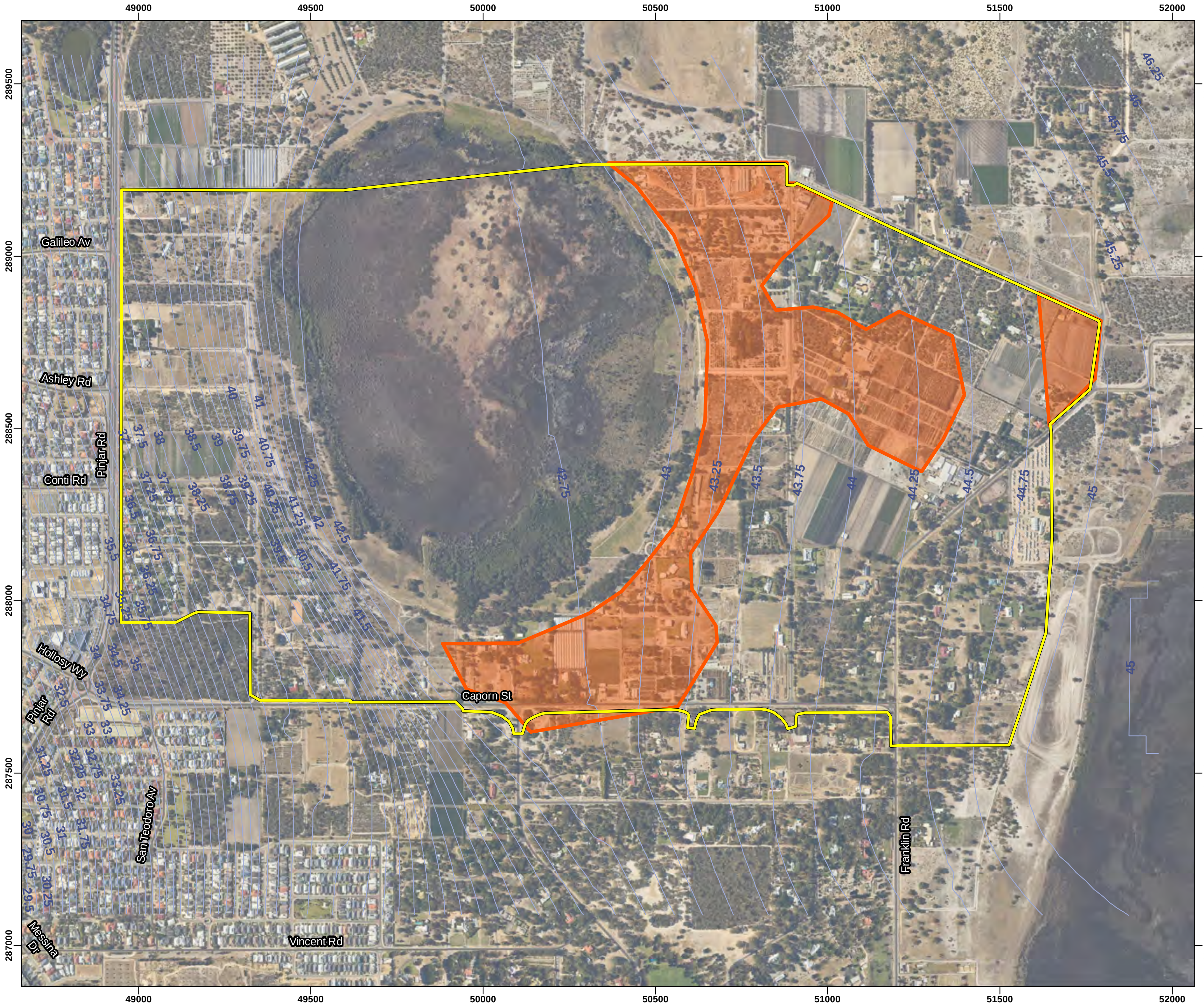

Legend

▭ Site Boundary

━ Indicative Subsoil Drainage

— Maximum Groundwater Contours 1986 to 1995 (mAHD)

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2021
- OTHER DATA SOURCED LANDGATE 2021
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2021
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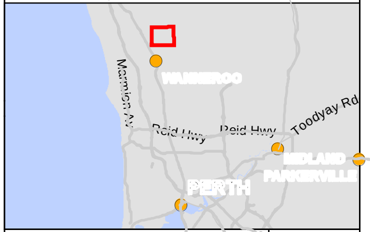
LOCALITY MAP



PROJECT ID	DATE
4450	15/12/2021

HOF D PROJECTION
GDA 1994 Perth Coastal Grid 1994

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LF	NC	NC	0

Hesperia

Precinct 7 East Wanneroo

Local Water Management Strategy

Figure 9

Subsoil Drainage

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K:\Projects\10. WAM\4450 Precinct 7 Feature Survey\4450 F09 Conceptual Groundwater Management Scheme.mxd

Appendix B District Structure Plan

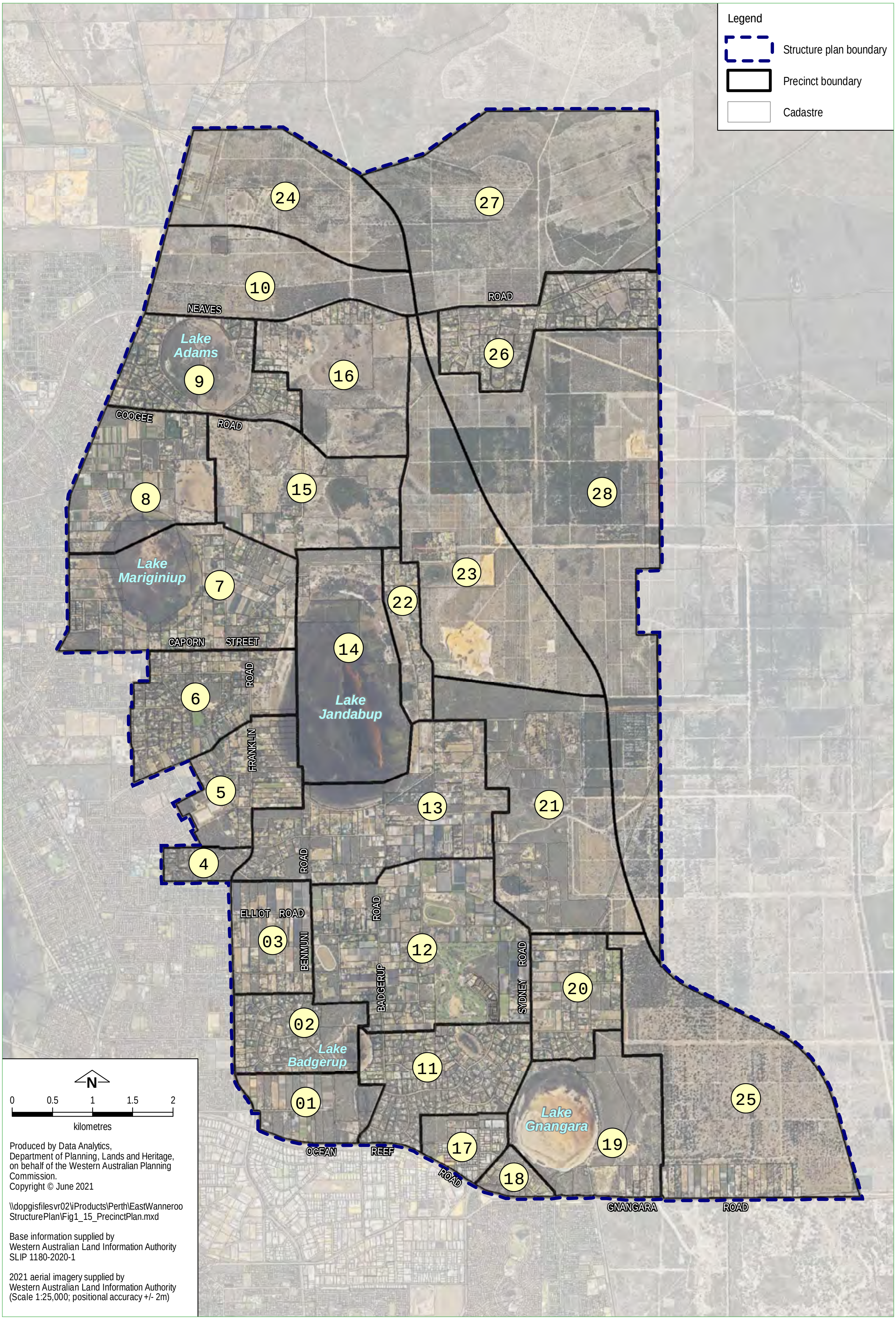
Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

SLR Project No.: 675.V64450.00000

6 December 2023



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\\dopgisfilesvr02\iProducts\Perth\EastWanneroo
StructurePlan\Fig1_15_PrecinctPlan.mxd

Base information supplied by
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2021 aerial imagery supplied by
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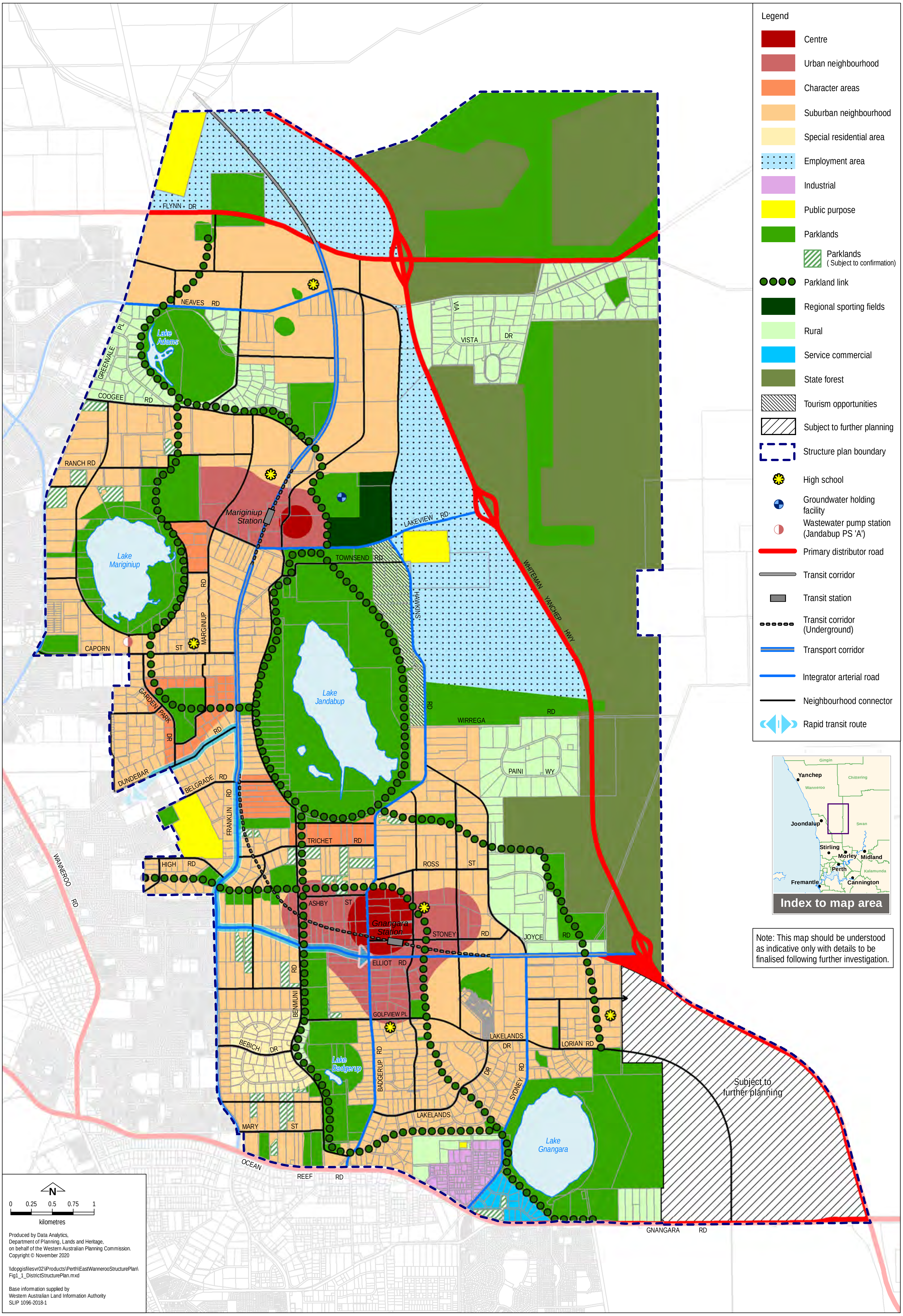
(Scale 1:25,000; positional accuracy +/- 2m)

Figure 1.15: Precinct Plan

Figure 1.1 East Wanneroo District Structure Plan



Note: This map should be understood as indicative only with details to be finalised following further investigation.

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Appendix C Local Structure Plan

Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

SLR Project No.: 675.V64450.00000

6 December 2023

LEGEND

- ⬚ STRUCTURE PLAN AREA

MRS RESERVES

- ▨ PARKS AND RECREATION

LOCAL SCHEME

- 🟧 RESIDENTIAL R30-R60*
- ■ RESIDENTIAL R40-R80
- 🟩 PUBLIC OPEN SPACE
- HS PUBLIC PURPOSES - HIGH SCHOOL
- PS PUBLIC PURPOSES - PRIMARY SCHOOL
- WC PUBLIC PURPOSES - WATER CORPORATION
- ▨ PUBLIC PURPOSES
- SU1 SPECIAL USE 1 (LOCAL CENTRE)

MOVEMENT NETWORK

- ═ INTEGRATOR A (35m)
- ═ NEIGHBOURHOOD CONNECTOR A (25m)
- ═ NEIGHBOURHOOD CONNECTOR B (20m)
- ═ ACCESS STREET A (24m)
- ━ ACCESS STREET B (17.9m)
- ━ ACCESS STREET C (15m**)
- ╌ INDICATIVE EXTERNAL ROADS
- ○ ROUNDABOUT INTERSECTION***
- ▼ LEFT-IN/LEFT-OUT INTERSECTION***

OTHER

- ⬚ CHARACTER AREA*
- ⬚ CONSERVATION AREA
- ╌ 150m ODOUR BUFFER TO WWPS
- ━ WETLAND CORE
- ╌ 50m WETLAND BUFFER
- ╌ RAPID TRANSIT ROUTE
- ● GREEN STREET*

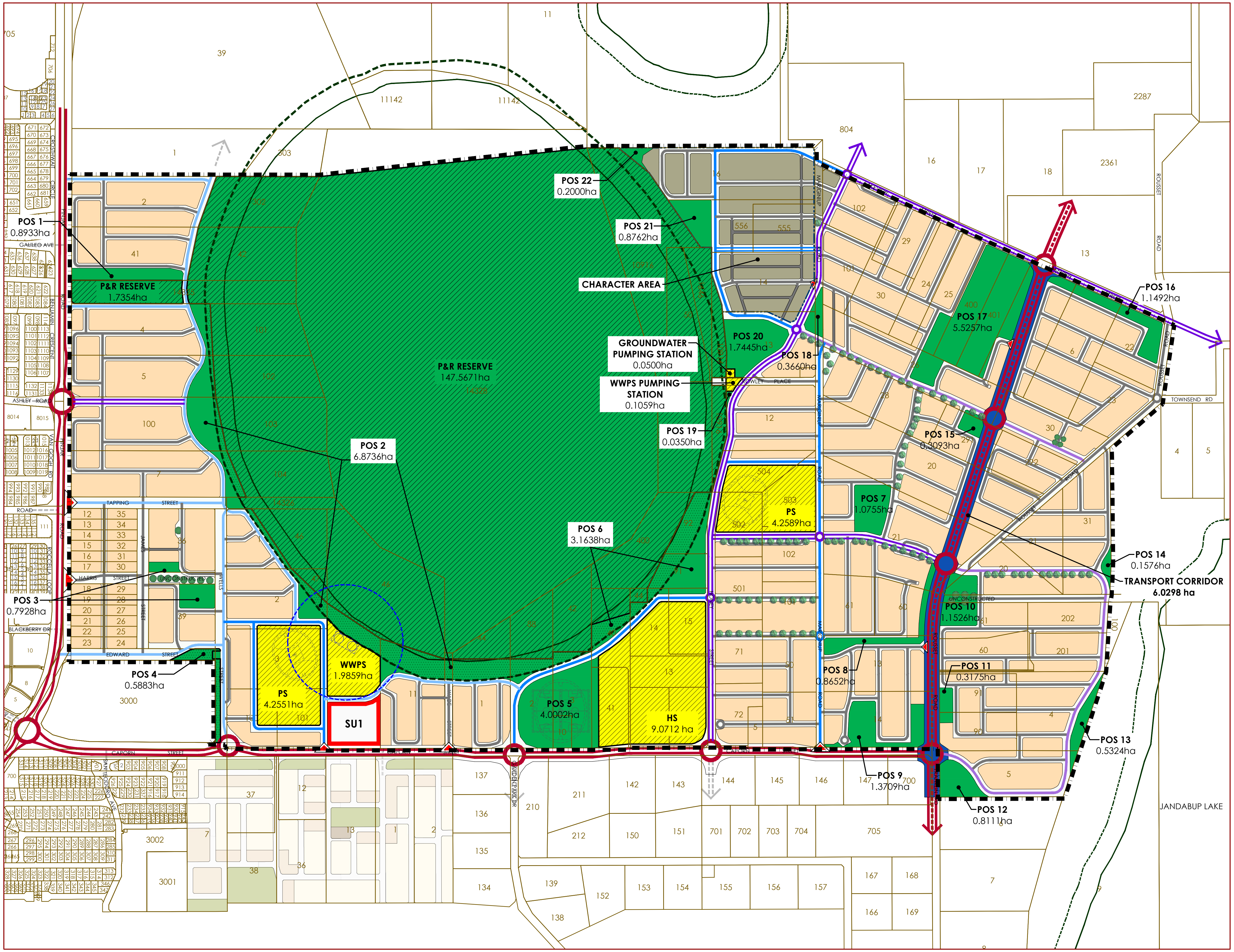
NOTES:

*REFER TO STRUCTURE PLAN REPORT FOR DETAIL.

**MAY BE REDUCED TO 13m ADJACENT TO PUBLIC OPEN SPACE (EXCLUDING AREAS IDENTIFIED FOR CONSERVATION PURPOSES), OR 10m WHERE USED AS A CONTROLLED ACCESS PLACE.

***ALL OTHER INTERSECTIONS TO BE PRIORITY CONTROLLED.

All areas and dimensions are subject to survey, engineering and detailed design and may change without notice. © Copyright of Burgess Design Group.



NORTH

0 50 100 150 200 250m

SCALE 1:10,000 (A3)

PLAN 1: STRUCTURE PLAN MAP

EAST WANNEROO: PRECINCT 7

MARIGINIUP

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Plan No: HES MAR 03-05f-02
Date: 21.11.23
Client: HESPERIA
Planner: JB/AC

CITY OF WANNEROO

Appendix D Geotechnical Report

Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

SLR Project No.: 675.V64450.00000

6 December 2023

Douglas Partners
Geotechnics / Environment / Groundwater

Report on
Preliminary Geotechnical Investigation

East Wanneroo Precinct 7
Caporn Street, Mariginiup, WA

Prepared for
Hesperia Projects Pty Ltd

Project 202866.01
June 2021

Integrated Practical Solutions

Document History

Document details

Project No.	202866.01	Document No.	R.001.Rev0
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Site address	Caporn Street, Mariginiup, WA		
Report prepared for	Hesperia Projects Pty Ltd		
File name	202866.01.R.001.Rev0.DP Report - East Wanneroo Development		

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Status	Electronic	Paper	Issued to
Revision 0	1	-	Mr Stuart Duplock, Hesperia Projects Pty Ltd
Revision 0	1	-	Mr Tim Tjhung, Hesperia Projects Pty Ltd

The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

	Signature	Date
Author		30 June 2021
Reviewer		30 June 2021

FS 604853

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Table of Contents

Report on Preliminary Geotechnical Investigation
East Wanneroo Precinct 7
Caporn Street, Mariginiup, WA

1. Introduction

This report presents the results of a preliminary geotechnical investigation undertaken for the proposed East Wanneroo Precinct 7 residential development located on Caporn Street, Mariginiup, WA. The investigation was commissioned in a signed contract dated 12 March 2021 by Mr Judd Dyer of Hesperia Projects Pty Ltd and was undertaken in accordance with Douglas Partners' proposal PER200454 dated 4 February 2021.

It is understood that the proposed development of the site includes a large-scale residential development, with associated residential lots, schools, a local centre, pavements and public open space.

The aim of the investigation was to assess the subsurface soil and groundwater conditions across the site in order to provide preliminary comments on:

- The geotechnical suitability of the site for the proposed development.
- The site classification in accordance with the requirements of AS 2870-2011 and earthworks requirements to improve this classification, if required.
- Site preparation, compaction, excavatability and re-use of existing soils for filling, so as to allow the proposed development.
- The depth to groundwater, if encountered.
- The permeability of the soils and suitability for on-site stormwater disposal.

The investigation included eight cone penetration tests (CPT), excavation of 20 test pits, eight boreholes drilled with a hand auger, ten in situ infiltration tests and laboratory testing of selected soil samples. The details of the field work are presented in this report, together with comments and recommendations on the items listed above.

2. Site Description

The site comprises an irregular shaped area, approximately 224 ha in size. It is bounded by Pinjar Road to the west, Caporn Street to the south, Jandabup Lake and Rousset Road to the east and Mariginiup Lake and Lakeview Street to the north (Refer to Drawing 1, Appendix A).

At the time of the field work, the site comprised several rural residential lots, with existing structures such as houses and sheds. Several lots also comprised market gardens and paddocks. Vegetation across the site mainly comprised grassed areas and natural bushland, with native trees and bushes.

Based on a survey plan provided by the client, the ground surface level across the site is undulating, although it generally falls towards Mariginiup Lake in the centre of the site, with surface levels of approximately RL 63 m AHD near the western site boundary and RL 59 m AHD near the eastern end of Caporn Street, falling to RL 43 m AHD along the edge of Mariginiup Lake.

The Muchea 1:50 000 Environmental Geology indicates that shallow sub surface conditions across the majority of the site comprise sand derived from Tamala Limestone, described as pale and olive yellow, medium to coarse-grained sub-angular quartz, moderately sorted sand of residual origin. The far eastern boundary of the site is shown as intersecting Bassendean Sand, described as very light grey at surface, yellow at depth, fine to medium-grained, sub-rounded quartz, moderately well sorted sand of eolian origin. Within the vicinity of the western boundary of the development area, Swamp Deposits comprising peaty clay are shown to underlie Mariginiup Lake and the surrounding fringe. The peaty clay is an organic soil, described as dark grey and black with variable sand content, of lacustrine origin.

Information available from the Perth Groundwater Atlas indicates that the regional groundwater level at the site in May 2003 (i.e. near seasonal low levels) varied between approximately RL 38 m AHD on the western boundary of the site to approximately RL 44 m AHD on the eastern boundary. The Atlas also provides some estimated maximum groundwater levels, which suggest maximum levels of approximately RL 40 m AHD on the western boundary of the site to approximately RL 47 m AHD on the eastern boundary. Publicly available LiDAR data of the ground surface elevation indicates that the May 2003 regional groundwater levels were generally within 0 m to 2 m of the existing ground surface near Mariginiup Lake. Elsewhere across the site, the depth to groundwater is generally indicated as being between approximately 5 m to 10 m below the existing surface, depending on the surface elevation levels.

3. Field Work Methods

Field work for the investigation was carried out on 19, 26, 27, 28 May and 3 June 2021 and comprised:

- The supervision of eight CPT (Locations 1 to 8).
- The excavation of 20 test pits (Locations 10 to 15, 17 to 20 and 22 to 31).
- The drilling of eight boreholes (Locations 1, 4, 5, 9, 16, 21, 32 and 33).
- Perth sand penetrometer (PSP) testing adjacent to each test pit and borehole location.
- Ten in situ infiltration tests (Adjacent to locations 1, 4, 5, 9, 10, 15 to 17, 32 and 33).

The CPTs were carried out by using a 36 mm diameter instrumented cone with a following 130 mm long friction sleeve attached to rods of the same diameter, pushed continuously at a rate of 20 mm/sec into the soil by hydraulic thrust from a truck rig. Strain gauges in the cone and sleeve measure resistance to penetration and friction along the sleeve. This data is recorded on a computer and analysed to allow the assessment of the type, properties and condition of the materials penetrated. The CPTs were pushed to termination depths of up to 10.2 m. Upon withdrawing the CPT probe, each location was dipped in attempt to measure groundwater levels.

The test pits were excavated to a maximum depth of 3.0 m using a 5-tonne excavator, equipped with an 800 mm wide bucket.

The boreholes were drilled to a maximum depth of 3.0 m using a 110 mm diameter hand auger. Borehole locations 1, 4 and 5 were drilled adjacent to CPT locations 1, 4 and 5 to allow for infiltration testing and sampling.

PSP tests were carried out at adjacent to the test pit and borehole locations in accordance with AS 1289.6.3.3 to assess the in-situ density of the shallow soils.

Each test pit and borehole was logged in general accordance with AS 1726–2017 by a suitably experienced engineer from Douglas Partners. Soil samples were recovered from selected locations for subsequent laboratory testing.

The infiltration tests were performed using the falling head method at depths of between 0.8 m and 1.2 m at locations 1, 4, 5, 9, 10, 15 to 17, 32 and 33.

Test locations were determined using a handheld GPS and are marked on Drawing 1. Surface levels have been derived from publicly available LiDAR data (DEM derived from 5 m grid).

4. Field Work Results

4.1 Ground Conditions

Detailed logs of the ground conditions and results of the field testing are presented in Appendix B, together with notes defining descriptive terms and classification methods, in Appendix A.

Ground conditions across the site generally comprised:

- **Topsoil SP & SP-SM** – dark grey-brown sandy topsoil, with or trace silt and organics, generally 0.1 m thick at the majority of test locations.
- **Fill SP, SP-SM, SM & GP** – Sand, silty sand and sandy gravel fill was encountered from surface to depths of between 0.3 m and 1.3 m at locations 11, 12, 18 to 21 and 32.
- **Sand SP & SP-SM** – fine to medium grained, generally pale grey or yellow-brown, trace or with silt, from surface or underlying the topsoil or fill, to termination depths of between 2 m and 10.2 m. The sand was generally in a loose or loose to medium dense condition near surface, increasing in density with depth. The depth of the base of loose and loose to medium dense sand encountered within the CPTs is shown in Table 1.

Table 1: Summary of Base of Loose and Loose to Medium Dense Soils in CPT

Test Location	Ground Surface Level [1] (m AHD)	Depth to Base of Loose Soils(m)	Level of Base of Loose Soils [2] (m AHD)
1	53.4	No loose soils	No loose soils
2	55.7	1.5	54.2
3	55.2	2.5	52.7
4	56.2	3.3	52.9
5	58.3	2.2	56.1
6	49.3	3.8	45.5
7	53.2	1.6	51.6
8	58.4	7.2	51.2

Notes for Table 1: [1]: Surface level estimated using LiDAR data.
[2]: Level of Base of Loose Soils = Estimated Surface Level – Depth to Base of Loose Soils.

4.2 Groundwater

No free groundwater was observed within any of the CPTs, test pits or boreholes undertaken between 19 May and 3 June, to depths of up to 10 m. The test locations were immediately backfilled following sampling, which precluded longer-term monitoring of groundwater levels. It should be noted that groundwater levels are affected by climatic conditions and land usage and will therefore vary with time.

4.3 Permeability

Ten in-situ infiltration tests using the falling head method were carried out between depths of between 0.8 m and 1.2 m at locations 1, 4, 5, 9, 10, 15 to 17, 32 and 33. An estimated permeability value has been derived from the in situ permeability test data using a method based on a formula by Hvorslev (1951). Results of the permeability analysis are summarised in Table 2.

Table 2: Summary of Permeability Analysis

Test Location	Depth (m)	Measured Permeability (m/day) [1]	In situ Ground Conditions at Testing Depth
1	1.0	8	Sand, trace silt, medium dense
4	1.0	>20	Sand, with silt, loose to medium dense
5	1.0	>20	Sand, trace silt, loose
9	1.0	>20	Sand, trace silt, medium dense
10	0.8	>20	Sand, trace silt, medium dense
15	0.8	>20	Sand, trace silt, loose to medium dense
16	1.0	>20	Sand, with silt, loose
17	0.9	>20	Sand, trace silt, medium dense
32	1.2	>20	Sand, trace silt, medium dense
33	1.15	>20	Sand, trace silt, medium dense

5. Laboratory Testing

A geotechnical laboratory testing programme was carried out by a NATA registered laboratory and comprised the determination of:

- the particle size distribution of 12 samples; and
- the organic content of six samples.

The test report sheets are given in Appendix C and the results are summarised in Table 3.

Table 3: Results of Laboratory Testing for Soil Identification

Test Location	Depth (m)	Fines (%)	d_{10} (mm)	d_{60} (mm)	Organic Content (%)	Material
1	1.0	3	0.19	0.50	-	Sand, trace silt
4	1.0	7	0.16	0.50	-	Sand, with silt
9	0.05	-	-	-	3.6	Topsoil (Sand), trace silt
9	0.9 – 1.2	1	0.21	0.50	-	Sand, trace silt
10	0.6 – 0.8	2	0.17	0.40	-	Sand, trace silt
12	0.1	12	<0.075	0.36	1.7	Fill (Silty Sand), trace gravel
15	1.3	3	0.18	0.50	-	Sand, trace silt
16	1.0	9	0.15	0.50	-	Sand, with silt
19	0.45	14	<0.075	0.53	10.1	Fill (Silty Sand), trace gravel
20	0.1	7	0.16	0.53	3.1	Fill (Sand), with silt
24	0 – 0.1	-	-	-	10.3	Topsoil (Sand), with silt
26	0.3	4	0.19	0.50	1.6	Sand, trace silt
32	1.2	3	0.18	0.55	-	Sand, trace silt
33	1.15	1	0.3	0.61	-	Sand, trace silt

Where:
- The % fines is the amount of particles smaller than 75 µm.
- A d_{10} of 0.12 mm means that 10% of the sample particles are finer than 0.12 mm.
- A d_{60} of 0.49 mm means that 60% of the sample particles are finer than 0.49 mm.

6. Proposed Development

It is understood that the proposed development of the site includes a large-scale residential development, with associated residential lots, schools, a local centre, pavements, and public open space. It is also anticipated that proposed earthworks will involve significant cut to fill.

7. Comments

7.1 Site Suitability

The investigation indicates that the soils at the site generally comprise a thin layer of topsoil overlying sand to depths of up to 10 m, with uncontrolled fill present in some isolated locations, described in Section 4.1 above. Such ground conditions are generally considered suitable for the proposed development and will not impose any significant geotechnical constraints. Suitable site preparation should include the removal or treatment of any uncontrolled fill, the removal or blending of the surficial topsoil and proof rolling of the site, to densify any loose soils.

Therefore, from a geotechnical standpoint, the land is physically capable of development, provided that the provisions outlined in the subsequent subsections of the report are incorporated in the development plans, with particular emphasis on the treatment of the uncontrolled fill and densification of any loose soils.

7.2 Site Classification

The shallow ground conditions beneath the site generally comprise loose to medium dense sand with some areas of uncontrolled fill.

It is considered that following suitable site preparation, the site should be suitable for a classification of ‘Class A’, following an assessment by a geotechnical engineer. Suitable site preparation includes either treatment, or excavation and replacement of the uncontrolled fill where present across the site, and suitable densification of any loose soils. Further discussion on site preparation is provided in Section 7.5.

7.3 Excavation Conditions

The encountered ground conditions generally comprise loose to medium dense sand, increasing in density with depth.

Conventional earthmoving equipment (such as large excavators and scrapers) should be generally suitable for excavations across the site within the encountered granular soils.

7.4 Geotechnical Suitability for Re-Use of In Situ Materials

7.4.1 Re-Use of Natural Sand

The encountered natural sand (trace fines) is considered geotechnically suitable for reuse as structural fill material provided it is free from organic matter and particles greater than 150 mm in size. The natural sand with silt is also considered suitable for re-use as structural fill, however it may have a reduced infiltration capacity, compared to the sand with trace fines. Consideration should be given to using the sand with silt in deeper areas of fill, to mitigate any reduced soil permeability.

7.4.2 Re-Use of Uncontrolled Fill

It is considered that, from geotechnical considerations, the sand fraction of any uncontrolled fill across the site could be re-used as structural fill provided it is suitably treated. Such treatment could include excavation, screening and blending in order to remove any deleterious material, and any particles greater than 150 mm in size. In particular, the uncontrolled fill at location 19 had a significant organic content, as well as many deleterious materials throughout, and would require screening prior to any possible blending and re-use.

Uncontrolled fill is likely to be encountered across other areas of the site. It is suggested that any uncontrolled fill encountered across the site is assessed by Douglas Partners to determine its re-use potential. Owing to the nature of these rural residential lots, the uncontrolled fill is likely to be variable, and treatment options will be determined based on the encountered materials.

It should be noted that this study has not assessed whether unacceptable levels of contaminants exist within the filling material. Such levels, if they occur, may limit or prevent the use of this material.

7.4.3 Topsoil

Topsoil was encountered across the site to depths of generally 0.1 m.

Based on the results of the investigation, the topsoil at the site is generally considered suitable for re-use as part of a topsoil and clean sand blend, for use as a structural fill material, provided that the topsoil is suitably prepared, and the controls outlined below are adopted. A preliminary blending ratio of 2:1 (clean sand:topsoil) is suggested, based on observations made during the site investigation and the laboratory results regarding organic content. It is noted that the organic content for the topsoil at location 24 was significantly higher than other locations. The organic content of this material is likely to be reduced following screening.

A final blend ratio should be confirmed by Douglas Partners, following an assessment on any screened materials.

It is suggested that any large roots or vegetation are first removed or screened from the topsoil, prior to blending. It is suggested that stripped topsoil is passed through a mechanical screening plant.

Following screening, topsoil should be sufficiently mixed with clean sand so that it forms a generally homogenous material.

The blending of topsoil with clean sand may decrease the permeability of the sand, therefore some consideration should be given to possible adverse implication on site drainage, if blended topsoil material is used. Blended topsoil should be used in deeper areas of fill.

7.5 Site Preparation

7.5.1 Site Stripping

All deleterious material, including vegetation, topsoil and uncontrolled fill should be stripped from the proposed development areas of the site.

Any tree roots remaining from clearing operations within the proposed development area should be completely removed to a depth of 0.6 m, and the excavation backfilled with material of similar geotechnical properties to the surrounding ground and suitably compacted.

7.5.2 Proof Rolling and Compaction

Following the site stripping (Section 7.5.1), and excavation to formation level (in areas of cut) it is recommended that the exposed ground be proof rolled with a heavy smooth drum roller (say minimum 15 tonne deadweight) in vibrating mode.

Any areas that show signs of excessive deformation during compaction should be compacted until deformation ceases or, alternatively, the poor-quality material should be excavated and replaced with suitable structural fill and compacted.

Following proof rolling, the site should be inspected by a suitably experienced geotechnical engineer and tested using a Perth Sand Penetrometer (PSP), to confirm that any loose soils have been suitably densified.

Compaction control of sand could be carried out using a PSP test in accordance with test method AS 1289.6.3.3.

7.5.3 Imported Fill

If required, imported fill should comprise free draining, cohesionless, well graded sand that:

- contains less than 5% by weight of particles less than 75 microns in size;
- contains no particles greater than 150 mm in size; and
- is free of organic and other deleterious materials.

It is recommended that test certificates are reviewed and approved by the geotechnical engineer prior to importing material to site.

Other materials could be considered, provided they are granular and non-reactive, and following review by a geotechnical engineer.

7.5.4 Fill Placement

Any fill should be placed in layers not exceeding 300 mm loose thickness and compacted near optimum moisture content with a heavy smooth drum roller (minimum 12 tonne deadweight).

7.5.5 Compaction Testing

Compaction control of the sand at this site could be carried out using a Perth sand penetrometer (PSP) test in accordance with test method AS 1289.6.3.3. All areas within the proposed building envelopes should be compacted to achieve a minimum blow count of 8 blows per 300 mm penetration to a depth of not less than 1.0 m below foundation level.

The top 300 mm in the base of any excavation should be re-compacted using a vibratory plate compactor prior to construction of any footings. Inspection of footing excavations by a geotechnical engineer is also recommended.

7.6 Stormwater Drainage and Permeability

Results of the permeability testing in Section 4.3 indicate a field permeability value of between 8 m/day and greater than 20 m/day for the sand encountered beneath the site.

Observed ground conditions and permeability results indicate that on-site stormwater disposal using soakwells and sumps is feasible where ground conditions at the base of such systems comprise sand and there is sufficient clearance above groundwater. A minimum clearance of 0.5 m is suggested between the base of drainage systems and maximum groundwater levels.

Given that the sand at the site is generally loose or loose to medium dense near surface, a design permeability value of 5 m/day is suggested, to account for densification of the sand that is likely to occur during earthworks.

The infiltration capability of sand often reduces over time due to silt build up at the base of soakwells and sumps, and therefore such systems should be regularly maintained.

8. References

AS 1289.6.3.3. (1997). *Methods for testing soils for engineering purposes - Soil strength and consolidation tests - Determination of the penetration resistance of a soil - Perth sand penetrometer test.* Reconfimed 2013: Standards Australia.

AS 1726. (2017). *Geotechnical Site Investigations.* Standards Australia.

AS 2870. (2011). *Residential Slabs and Footings.* Standards Australia.

Hvorslev, M. J. (1951). *Time Lag and Soil Permeability in Groundwater Observations.* Bulleton No 36, Vicksburg, Mississippi: Waterways Experiment Station, Corps of Engineers, US Army.

9. Limitations

Douglas Partners (DP) has prepared this report for this project at East Wanneroo Precinct 7, along Caporn Street, Mariginiup in accordance with DP's proposal dated 4 February 2021 and acceptance received from Mr Judd Dyer dated 12 March 2021. The work was carried out under the executed professional services agreement (dated 12 March 2021). This report is provided for the exclusive use of Hesperia Projects Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling and/or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling and/or testing locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

The assessment of atypical safety hazards arising from this advice is restricted to the (geotechnical / environmental / groundwater) components set out in this report and based on known project conditions and stated design advice and assumptions. While some recommendations for safe controls may be provided, detailed 'safety in design' assessment is outside the current scope of this report and requires additional project data and assessment.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The scope for work for this investigation/report did not include the assessment of surface or sub-surface materials or groundwater for contaminants, within or adjacent to the site. Should evidence of filling of unknown origin be noted in the report, and in particular the presence of building demolition materials, it should be recognised that there may be some risk that such filling may contain contaminants and hazardous building materials.

Douglas Partners Pty Ltd

Appendix A

About This Report
Drawing 1

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

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Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Cone Penetration Tests

Douglas Partners

Introduction

The Cone Penetration Test (CPT) is a sophisticated soil profiling test carried out in-situ. A special cone shaped probe is used which is connected to a digital data acquisition system. The cone and adjoining sleeve section contain a series of strain gauges and other transducers which continuously monitor and record various soil parameters as the cone penetrates the soils.

The soil parameters measured depend on the type of cone being used, however they always include the following basic measurements

Cone tip resistance	q_c
Sleeve friction	f_s
Inclination (from vertical)	i
Depth below ground	z

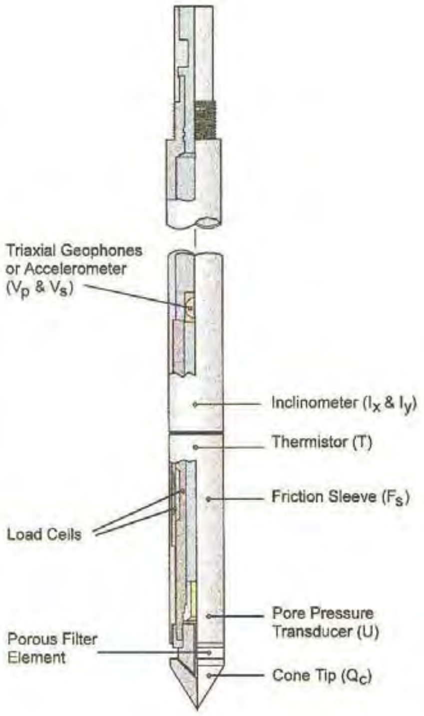

Figure 1: Cone Diagram

The inclinometer in the cone enables the verticality of the test to be confirmed and, if required, the vertical depth can be corrected.

The cone is thrust into the ground at a steady rate of about 20 mm/sec, usually using the hydraulic rams of a purpose built CPT rig, or a drilling rig. The testing is carried out in accordance with the Australian Standard AS1289 Test 6.5.1.

Figure 2: Purpose built CPT rig

The CPT can penetrate most soil types and is particularly suited to alluvial soils, being able to detect fine layering and strength variations. With sufficient thrust the cone can often penetrate a short distance into weathered rock. The cone will usually reach refusal in coarse filling, medium to coarse gravel and on very low strength or better rock. Tests have been successfully completed to more than 60 m.

Types of CPTs

Douglas Partners (and its subsidiary GroundTest) owns and operates the following types of CPT cones:

Type	Measures
Standard	Basic parameters (q_c, f_s, i & z)
Piezocone	Dynamic pore pressure (u) plus basic parameters. Dissipation tests estimate consolidation parameters
Conductivity	Bulk soil electrical conductivity (σ) plus basic parameters
Seismic	Shear wave velocity (V_s), compression wave velocity (V_p), plus basic parameters

Strata Interpretation

The CPT parameters can be used to infer the Soil Behaviour Type (SBT), based on normalised values of cone resistance (Qt) and friction ratio (Fr). These are used in conjunction with soil classification charts, such as the one below (after Robertson 1990)

Cone Penetration Tests

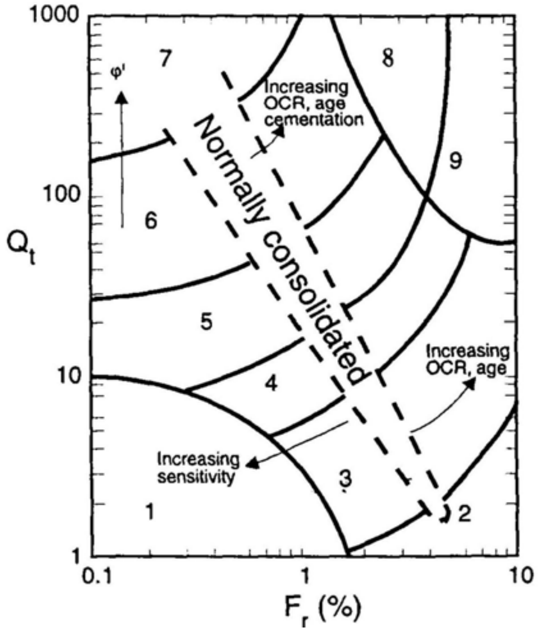

Figure 3: Soil Classification Chart

DP's in-house CPT software provides computer aided interpretation of soil strata, generating soil descriptions and strengths for each layer. The software can also produce plots of estimated soil parameters, including modulus, friction angle, relative density, shear strength and over consolidation ratio.

DP's CPT software helps our engineers quickly evaluate the critical soil layers and then focus on developing practical solutions for the client's project.

Engineering Applications

There are many uses for CPT data. The main applications are briefly introduced below:

Settlement

CPT provides a continuous profile of soil type and strength, providing an excellent basis for settlement analysis. Soil compressibility can be estimated from cone derived moduli, or known consolidation parameters for the critical layers (eg. from laboratory testing). Further, if pore pressure dissipation tests are undertaken using a piezocone, in-situ consolidation coefficients can be estimated to aid analysis.

Pile Capacity

The cone is, in effect, a small scale pile and, therefore, ideal for direct estimation of pile capacity. DP's in-house program ConePile can analyse most pile types and produces pile capacity versus depth plots. The analysis methods are based on proven static theory and empirical studies, taking account of scale effects, pile materials and method of installation. The results are expressed in limit state format, consistent with the Piling Code AS2159.

Dynamic or Earthquake Analysis

CPT and, in particular, Seismic CPT are suitable for dynamic foundation studies and earthquake response analyses, by profiling the low strain shear modulus G_0. Techniques have also been developed relating CPT results to the risk of soil liquefaction.

Other Applications

Other applications of CPT include ground improvement monitoring (testing before and after works), salinity and contaminant plume mapping (conductivity cone), preloading studies and verification of strength gain.

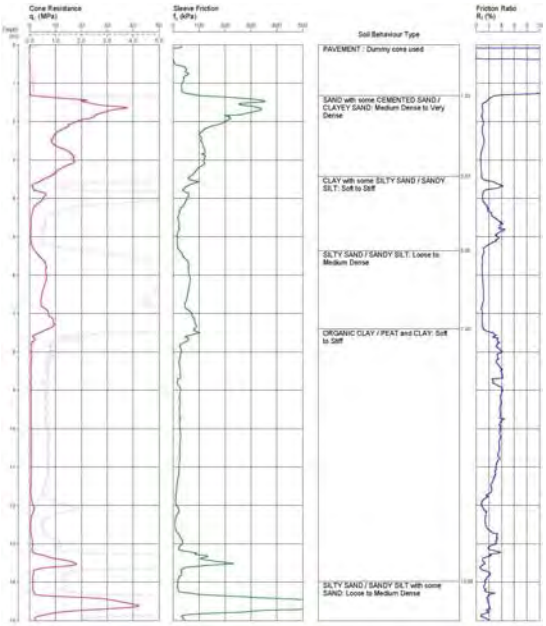

Figure 4: Sample Cone Plot

Sampling Methods

Sampling

Sampling is carried out during drilling or test pitting to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing it to obtain a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator. A potential disadvantage of this investigation method is the larger area of disturbance to the site.

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube samples.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively low reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

A continuous core sample can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in weak rocks and granular soils), this technique provides a very reliable method of investigation.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, Methods of Testing Soils for Engineering Purposes - Test 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

- In the case where full penetration is obtained with successive blow counts for each 150 mm of, say, 4, 6 and 7 as:

  4,6,7
  N=13

- In the case where the test is discontinued before the full penetration depth, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm as:

  15, 30/40 mm

The results of the SPT tests can be related empirically to the engineering properties of the soils.

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Normally there is a depth limitation of 1.2 m, but this may be extended in certain conditions by the use of extension rods. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.
- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various road authorities.

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are generally based on Australian Standard AS1726:2017, Geotechnical Site Investigations. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle size (mm)
Boulder	>200
Cobble	63 - 200
Gravel	2.36 - 63
Sand	0.075 - 2.36
Silt	0.002 - 0.075
Clay	<0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle size (mm)
Coarse gravel	19 - 63
Medium gravel	6.7 - 19
Fine gravel	2.36 – 6.7
Coarse sand	0.6 - 2.36
Medium sand	0.21 - 0.6
Fine sand	0.075 - 0.21

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

The proportions of secondary constituents of soils are described as follows:

In fine grained soils (>35% fines)

Term	Proportion of sand or gravel	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	>30%	Sandy Clay
With	15 – 30%	Clay with sand
Trace	0 - 15%	Clay with trace sand

In coarse grained soils (>65% coarse)
- with clays or silts

Term	Proportion of fines	Example
And	Specify	Sand (70%) and Clay (30%)
Adjective	>12%	Clayey Sand
With	5 - 12%	Sand with clay
Trace	0 - 5%	Sand with trace clay

In coarse grained soils (>65% coarse)
- with coarser fraction

Term	Proportion of coarser fraction	Example
And	Specify	Sand (60%) and Gravel (40%)
Adjective	>30%	Gravelly Sand
With	15 - 30%	Sand with gravel
Trace	0 - 15%	Sand with trace gravel

The presence of cobbles and boulders shall be specifically noted by beginning the description with ‘Mix of Soil and Cobbles/Boulders’ with the word order indicating the dominant first and the proportion of cobbles and boulders described together.

Soil Descriptions

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained shear strength (kPa)
Very soft	VS	<12
Soft	S	12 - 25
Firm	F	25 - 50
Stiff	St	50 - 100
Very stiff	VSt	100 - 200
Hard	H	>200
Friable	Fr	-

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (PSP). The relative density terms are given below:

Relative Density	Abbreviation	Density Index (%)
Very loose	VL	<15
Loose	L	15-35
Medium dense	MD	35-65
Dense	D	65-85
Very dense	VD	>85

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Extremely weathered material – formed from in-situ weathering of geological formations. Has soil strength but retains the structure or fabric of the parent rock;
- Alluvial soil – deposited by streams and rivers;
- Estuarine soil – deposited in coastal estuaries;
- Marine soil – deposited in a marine environment;
- Lacustrine soil – deposited in freshwater lakes;
- Aeolian soil – carried and deposited by wind;
- Colluvial soil – soil and rock debris transported down slopes by gravity;
- Topsoil – mantle of surface soil, often with high levels of organic material.
- Fill – any material which has been moved by man.

Moisture Condition – Coarse Grained Soils

For coarse grained soils the moisture condition should be described by appearance and feel using the following terms:

Dry (D)	Non-cohesive and free-running.
Moist (M)	Soil feels cool, darkened in colour. Soil tends to stick together. Sand forms weak ball but breaks easily.
Wet (W)	Soil feels cool, darkened in colour. Soil tends to stick together, free water forms when handling.

Moisture Condition – Fine Grained Soils

For fine grained soils the assessment of moisture content is relative to their plastic limit or liquid limit, as follows:

- ‘Moist, dry of plastic limit’ or ‘w <PL’ (i.e. hard and friable or powdery).
- ‘Moist, near plastic limit’ or ‘w ≈ PL (i.e. soil can be moulded at moisture content approximately equal to the plastic limit).
- ‘Moist, wet of plastic limit’ or ‘w >PL’ (i.e. soils usually weakened and free water forms on the hands when handling).
- ‘Wet’ or ‘w ≈LL’ (i.e. near the liquid limit).
- ‘Wet’ or ‘w >LL’ (i.e. wet of the liquid limit).

Symbols & Abbreviations

Douglas Partners

Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core drilling
R	Rotary drilling
SFA	Spiral flight augers
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

▷	Water seep
▽	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
E	Environmental sample
U_{50}	Undisturbed tube sample (50mm)
W	Water sample
pp	Pocket penetrometer (kPa)
PID	Photo ionisation detector
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	Lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

Graphic Symbols for Soil and Rock

General

■	Asphalt
▒	Road base
▒	Concrete
▩	Filling

Soils

▨	Topsoil
▒	Peat
▨	Clay
▨	Silty clay
▨	Sandy clay
▨	Gravelly clay
▨	Shaly clay
▥	Silt
▥	Clayey silt
▥	Sandy silt
░	Sand
░	Clayey sand
░	Silty sand
○	Gravel
○	Sandy gravel
○	Cobbles, boulders
△	Talus

Sedimentary Rocks

○	Boulder conglomerate
○	Conglomerate
░	Conglomeratic sandstone
░	Sandstone
▤	Siltstone
▤	Laminite
▤	Mudstone, claystone, shale
■	Coal
▦	Limestone

Metamorphic Rocks

∼	Slate, phyllite, schist
+	Gneiss
·	Quartzite

Igneous Rocks

+	Granite
×	Dolerite, basalt, andesite
×	Dacite, epidote
▽	Tuff, breccia
▭	Porphyry

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Test Locations

East Wanneroo Precinct 7

Caporn Street, Mariginiup, WA

CLIENT: Hesperia Projects Pty Ltd

PROJECT: 202866.01
Drawing No: 1
REV: 0
DATE: 28/6/2021

Appendix B

Field Work Results

CONE PENETRATION TEST

CLIENT: Hesperia Projects Pty Ltd

PROJECT: East Wanneroo Precinct 7

LOCATION: Caporn Street, Mariginiup, WA

REDUCED LEVEL: 53.4 m AHD*

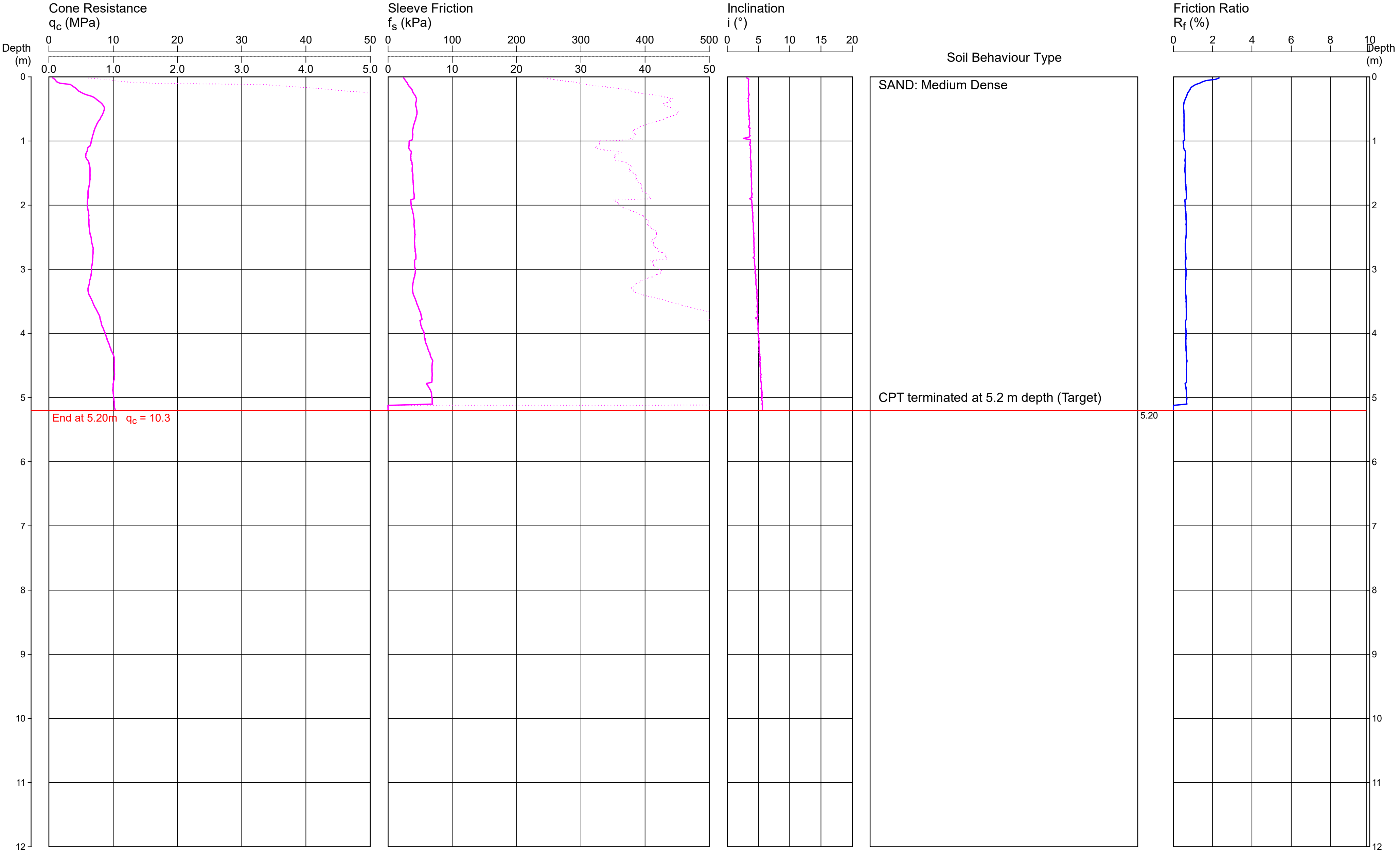
COORDINATES: 389476E 6489347N

CPT 01

Page 1 of 1

DATE 28/05/2021

PROJECT No: 202866.01



REMARKS: * Approximate surface level estimated using LiDAR data
Dry to 2.7 m depth

File: P:\202866.01 - MARIGINIUP, East Wanneroo Develop - GEO\4.0 Field Work\CPT\202866.01 - CPT 01.CP5
Cone ID: Probedrill **Type:** EC28

ConePlot Version 5.9.2
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BOREHOLE LOG

CLIENT: Hesperia Projects Pty Ltd		**SURFACE LEVEL:** 53.4 m AHD*	**BORE No:** 1
PROJECT: East Wanneroo Precinct 7		**EASTING:** 389476	**PROJECT No:** 202866.01
LOCATION: Caporn Street, Mariginiup, WA		**NORTHING:** 6489347	**DATE:** 27/5/2021
		DIP/AZIMUTH: 90°/--	**SHEET** 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm) 5 10 15 20
53		SAND SP: fine to medium grained, grey-brown, trace silt, moist, derived from Tamala Limestone, residual soil. - becoming yellow-brown from 0.2 m depth.							
52	1 1.0	Bore discontinued at 1.0m (Target depth)		D	1.0				1
51	2								
50	3								

RIG: 110 mm hand auger **DRILLER:** YC **LOGGED:** YC **CASING:** None

TYPE OF BORING: Hand auger

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: Location coordinates are in MGA94 Zone 50 J. *Surface level derived from publicly available LiDAR data.

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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CONE PENETRATION TEST

CLIENT: Hesperia Projects Pty Ltd

PROJECT: East Wanneroo Precinct 7

LOCATION: Caporn Street, Mariginiup, WA

REDUCED LEVEL: 55.7 m AHD*

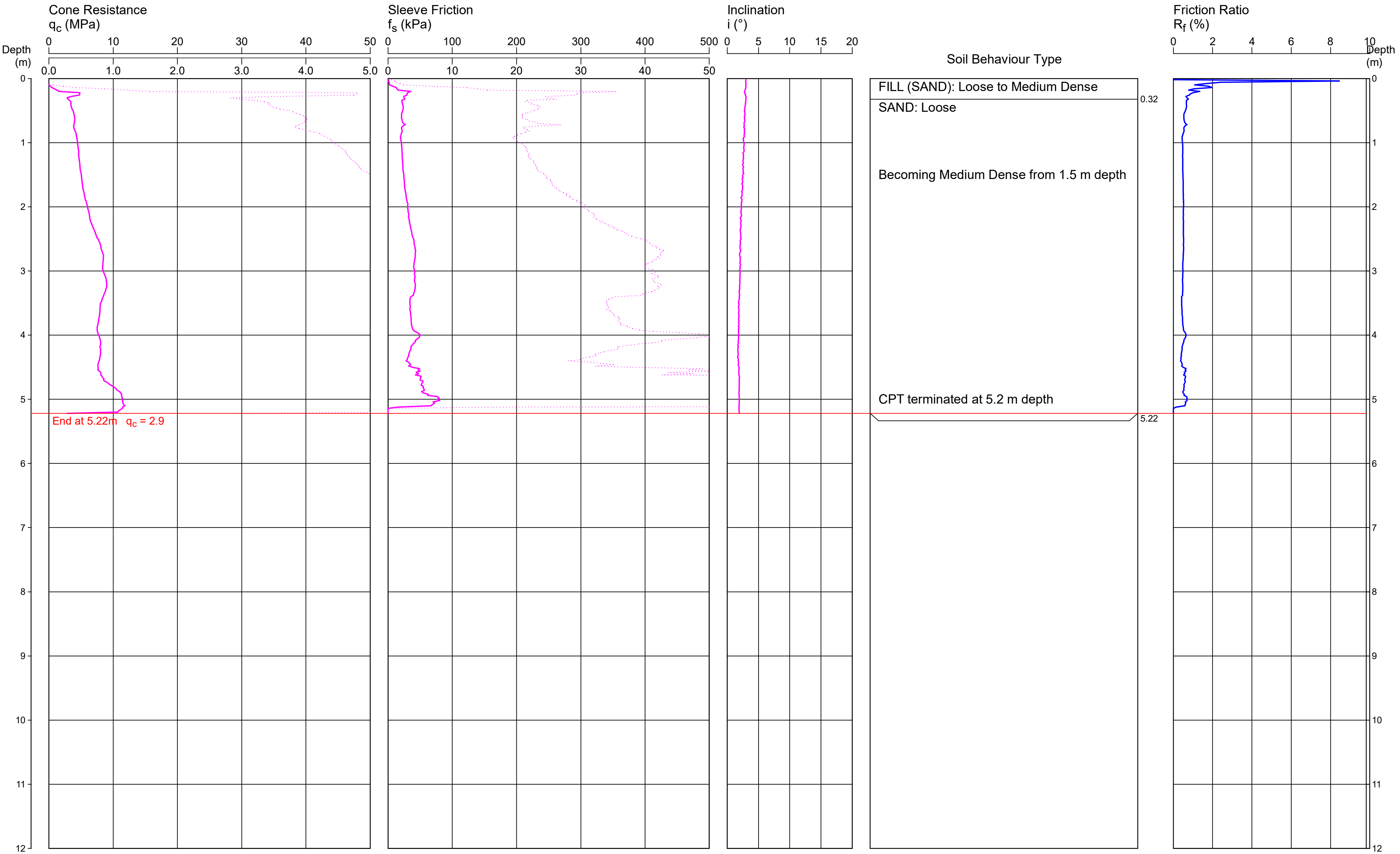
COORDINATES: 389011E 6489721N

CPT 02

Page 1 of 1

DATE 3/06/2021

PROJECT No: 202866.01



FILL (SAND): Loose to Medium Dense

SAND: Loose

Becoming Medium Dense from 1.5 m depth

CPT terminated at 5.2 m depth

REMARKS: * Approximate surface level estimated using LiDAR data
Dry to 4.8 m depth

File: P:\202866.01 - MARIGINIUP, East Wanneroo Develop - GEO\4.0 Field Work\CPT\202866.01 - CPT 02.CP5
Cone ID: Probedrill **Type:** EC28

ConePlot Version 5.9.2
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CONE PENETRATION TEST

CLIENT: Hesperia Projects Pty Ltd

PROJECT: East Wanneroo Precinct 7

LOCATION: Caporn Street, Mariginiup, WA

REDUCED LEVEL: 55.2 m AHD*

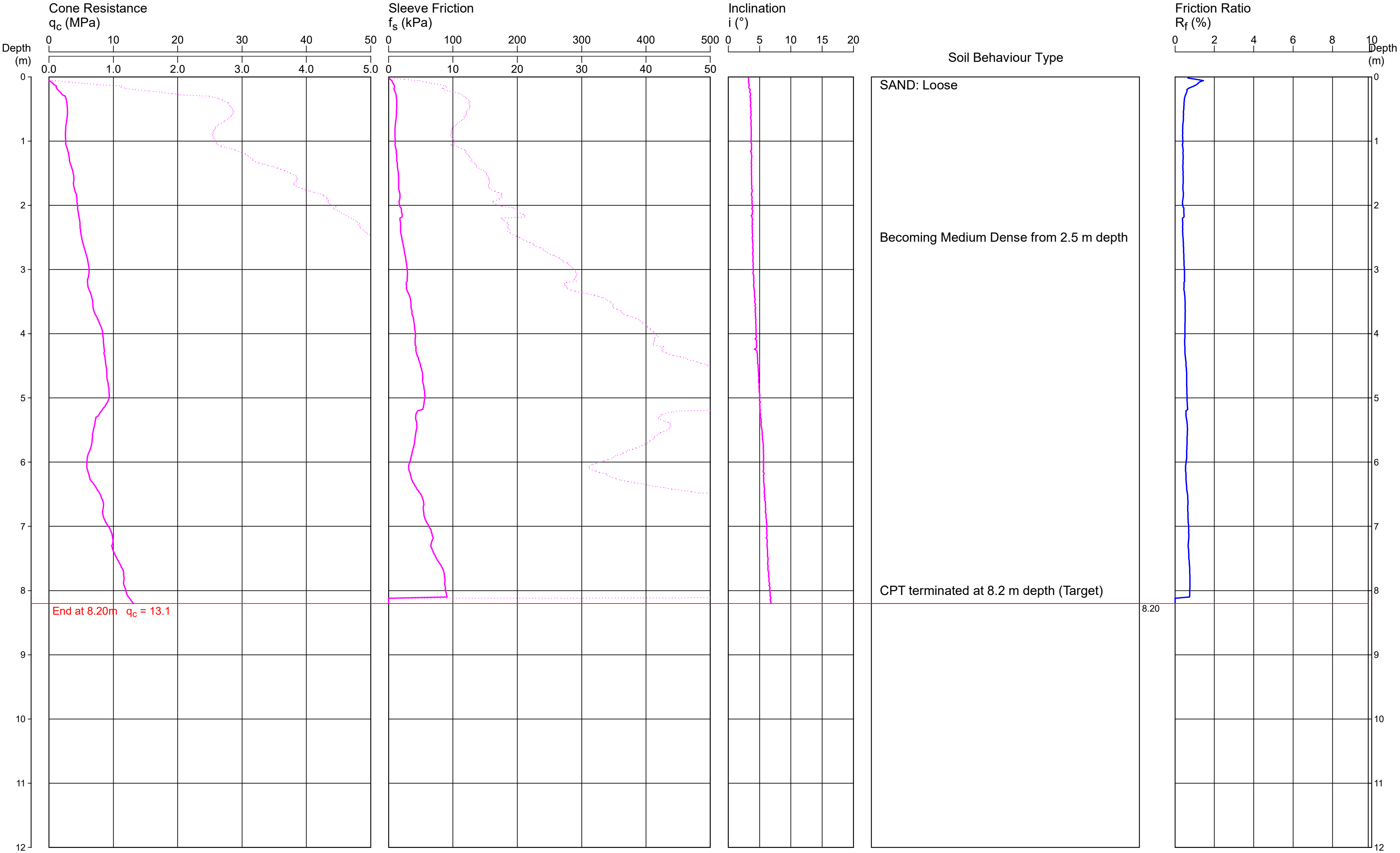
COORDINATES: 389157E 6488584N

CPT 03

Page 1 of 1

DATE 28/05/2021

PROJECT No: 202866.01



REMARKS: * Approximate surface level estimated using LiDAR data
Dry to 8.1 m depth

File: P:\202866.01 - MARIGINIUP, East Wanneroo Develop - GEO\4.0 Field Work\CPT\202866.01 - CPT 03.CP5
Cone ID: Probedrill **Type:** EC28

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CONE PENETRATION TEST

CLIENT: Hesperia Projects Pty Ltd

PROJECT: East Wanneroo Precinct 7

LOCATION: Caporn Street, Mariginiup, WA

REDUCED LEVEL: 56.2 m AHD*

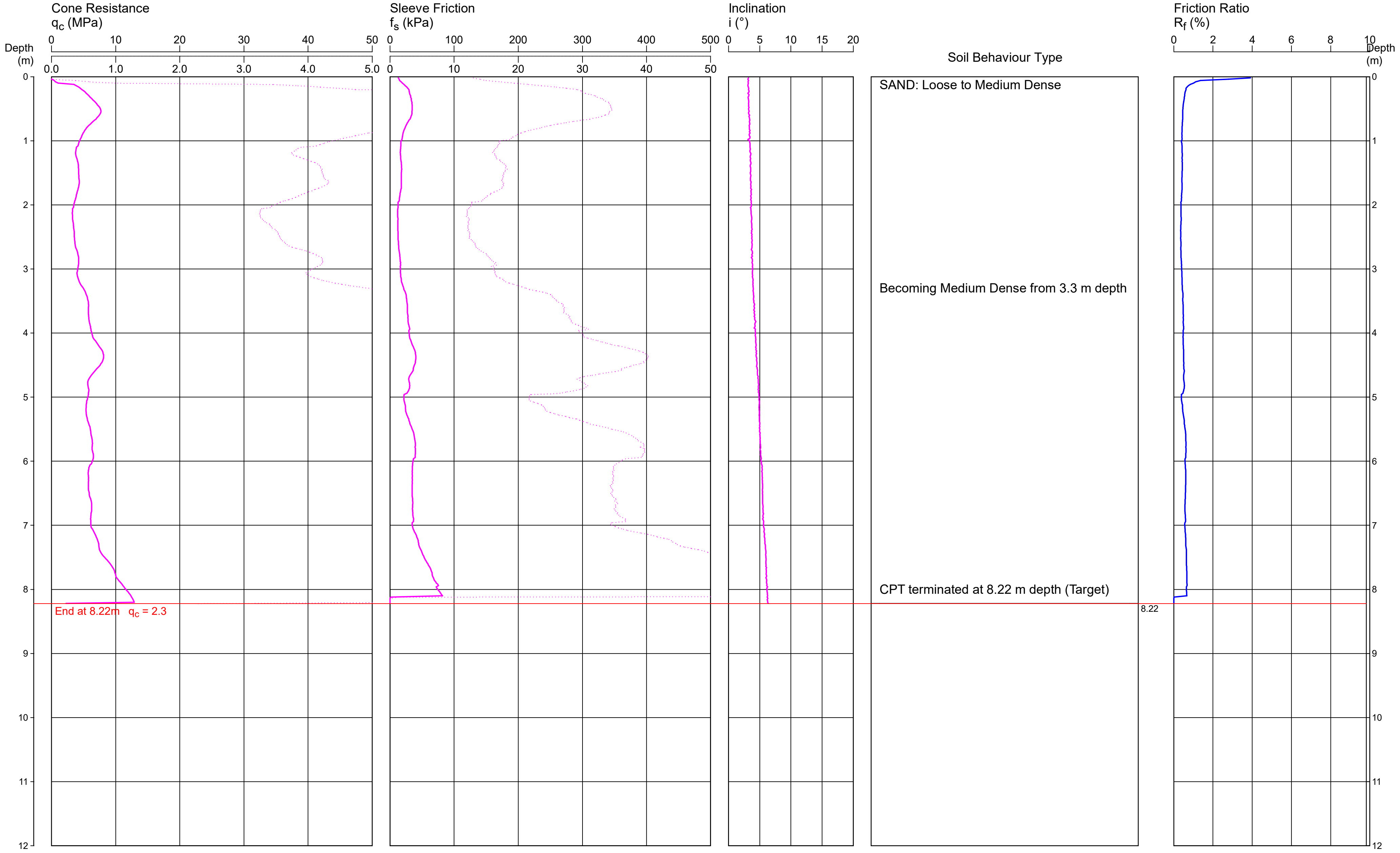
COORDINATES: 388820E 6488967N

CPT 04

Page 1 of 1

DATE 28/05/2021

PROJECT No: 202866.01



REMARKS: * Approximate surface level estimated using LiDAR data
Dry to 8.2 m depth

File: P:\202866.01 - MARIGINIUP, East Wanneroo Develop - GEO\4.0 Field Work\CPT\202866.01 - CPT 04.CP5
Cone ID: Probedrill **Type:** EC28

ConePlot Version 5.9.2
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BOREHOLE LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 56.2 m AHD*
EASTING: 388820
NORTHING: 6488967
DIP/AZIMUTH: 90°/--

BORE No: 4
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm) 5 10 15 20
56	0.1	TOPSOIL/SAND SP-SM: fine to medium grained, dark grey-brown, with silt, moist, topsoil.							
	0.5	SAND SP-SM: fine to medium grained, dark grey-brown, with silt, moist, possibly organic, derived from Tamala Limestone, residual soil.							
	1.0	SAND SP-SM: fine to medium grained, pale yellow-brown, with silt, moist, derived from Tamala Limestone, residual soil.		D	1.0				1
55	1	Bore discontinued at 1.0m (Target depth)							
54	2								
53	3								

RIG: 110 mm hand auger **DRILLER:** YC **LOGGED:** YC **CASING:** None

TYPE OF BORING: Hand auger

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: Location coordinates are in MGA94 Zone 50 J. *Surface level derived from publicly available LiDAR data.

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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CONE PENETRATION TEST

CLIENT: Hesperia Projects Pty Ltd

PROJECT: East Wanneroo Precinct 7

LOCATION: Caporn Street, Mariginiup, WA

REDUCED LEVEL: 58.3 m AHD*

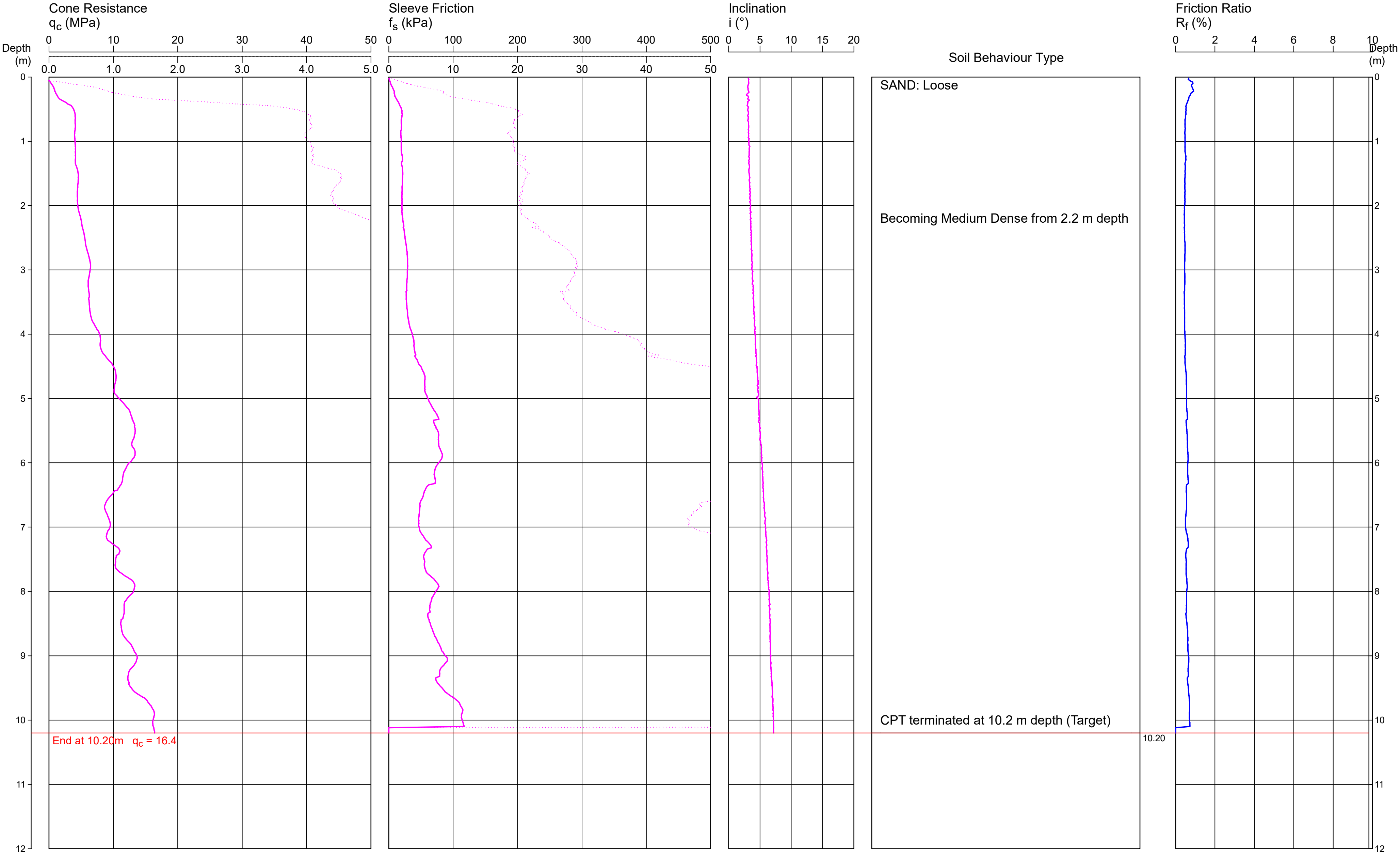
COORDINATES: 388701E 6488633N

CPT 05

Page 1 of 1

DATE 28/05/2021

PROJECT No: 202866.01



SAND: Loose

Becoming Medium Dense from 2.2 m depth

CPT terminated at 10.2 m depth (Target)

REMARKS: * Approximate surface level estimated using LiDAR data
Dry to 10.1 m depth

File: P:\202866.01 - MARIGINIUP, East Wanneroo Develop - GEO\4.0 Field Work\CPT\202866.01 - CPT 05.CP5
Cone ID: Probedrill **Type:** EC28

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BOREHOLE LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 58.3 m AHD*
EASTING: 388701
NORTHING: 6488633
DIP/AZIMUTH: 90°/--

BORE No: 5
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm) 5 10 15 20
		SAND SP-SM: fine to medium grained, grey-brown, with silt, moist, derived from Tamala Limestone, residual soil.							
	0.4	SAND SP: fine to medium grained, yellow-brown, trace silt, moist, derived from Tamala Limestone, residual soil.							
	1.0	Bore discontinued at 1.0m (Target depth)		D	1.0				1

RIG: 110 mm hand auger **DRILLER:** YC **LOGGED:** YC **CASING:** None
TYPE OF BORING: Hand auger
WATER OBSERVATIONS: No free groundwater observed.
REMARKS: Location coordinates are in MGA94 Zone 50 J. *Surface level derived from publicly available LiDAR data.

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	₮	Water level	V	Shear vane (kPa)

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CONE PENETRATION TEST

CLIENT: Hesperia Projects Pty Ltd

PROJECT: East Wanneroo Precinct 7

LOCATION: Caporn Street, Mariginiup, WA

REDUCED LEVEL: 49.3 m AHD*

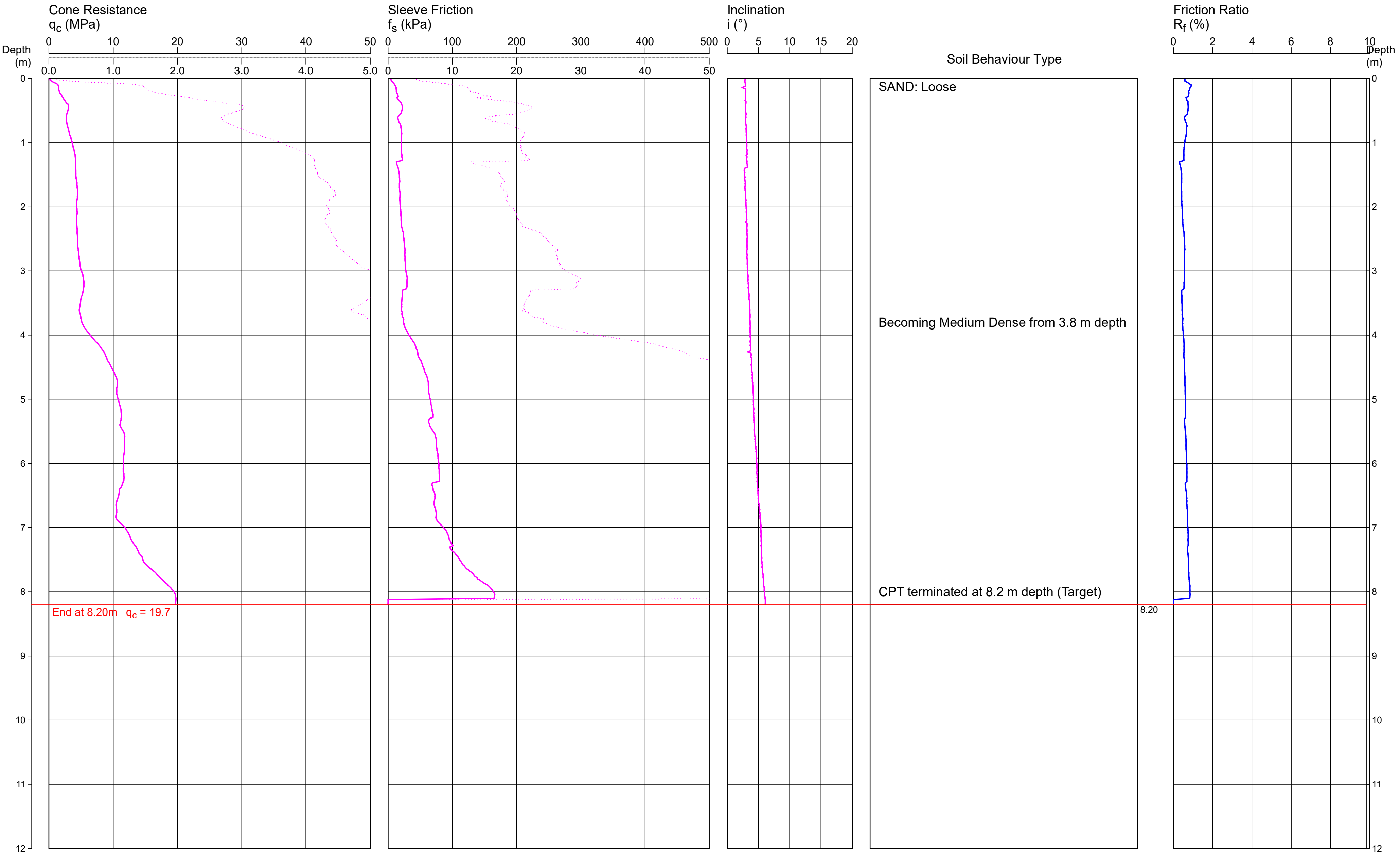
COORDINATES: 387198E 6488779N

CPT 06

Page 1 of 1

DATE 28/05/2021

PROJECT No: 202866.01



REMARKS: * Approximate surface level estimated using LiDAR data
Dry to 7.7 m depth

File: P:\202866.01 - MARIGINIUP, East Wanneroo Develop - GEO\4.0 Field Work\CPT\202866.01 - CPT 06.CP5
Cone ID: Probedrill **Type:** EC28

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CONE PENETRATION TEST

CLIENT: Hesperia Projects Pty Ltd

PROJECT: East Wanneroo Precinct 7

LOCATION: Caporn Street, Mariginiup, WA

REDUCED LEVEL: 53.2 m AHD*

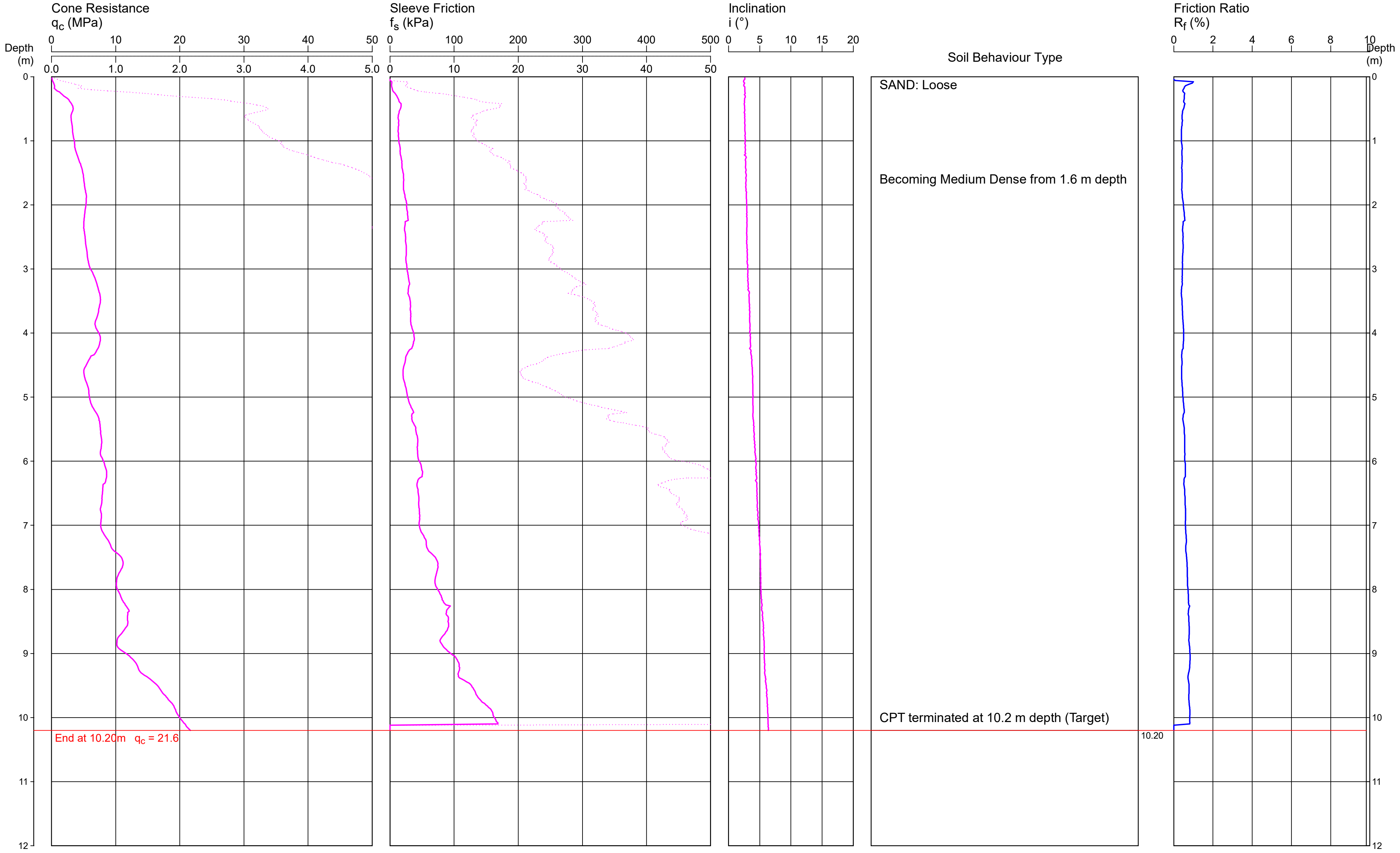
COORDINATES: 387115E 6489114N

CPT 07

Page 1 of 1

DATE 28/05/2021

PROJECT No: 202866.01



REMARKS: * Approximate surface level estimated using LiDAR data
Dry to 8.2 m depth

File: P:\202866.01 - MARIGINIUP, East Wanneroo Develop - GEO\4.0 Field Work\CPT\202866.01 - CPT 07.CP5
Cone ID: Probedrill **Type:** EC28

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CONE PENETRATION TEST

CLIENT: Hesperia Projects Pty Ltd

PROJECT: East Wanneroo Precinct 7

LOCATION: Caporn Street, Mariginiup, WA

REDUCED LEVEL: 58.4 m AHD*

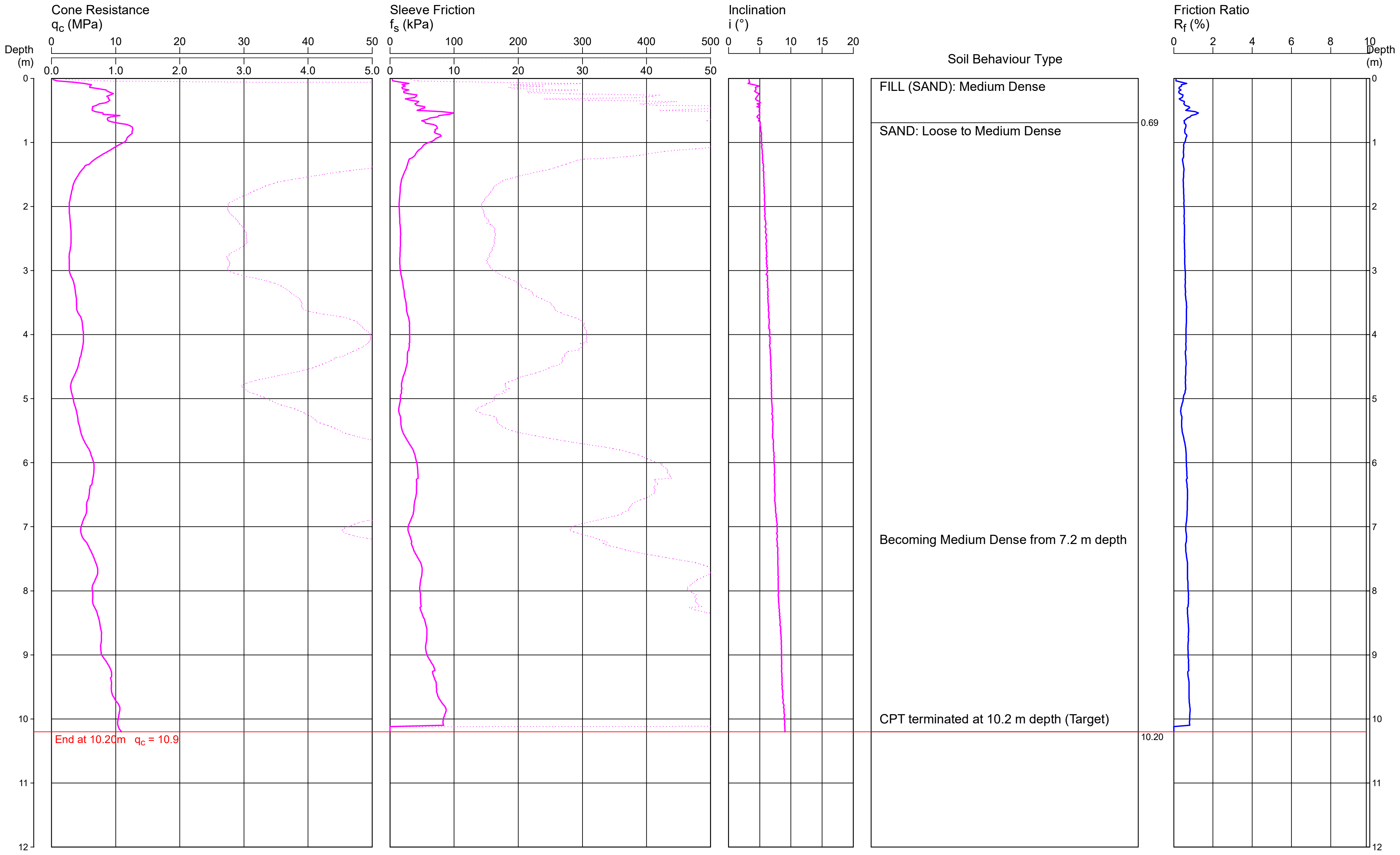
COORDINATES: 386958E 6489595N

CPT 08

Page 1 of 1

DATE 28/05/2021

PROJECT No: 202866.01



REMARKS: * Approximate surface level estimated using LiDAR data
Dry to 10 m depth

File: P:\202866.01 - MARIGINIUP, East Wanneroo Develop - GEO\4.0 Field Work\CPT\202866.01 - CPT 08.CP5
Cone ID: Probedrill **Type:** EC28

ConePlot Version 5.9.2
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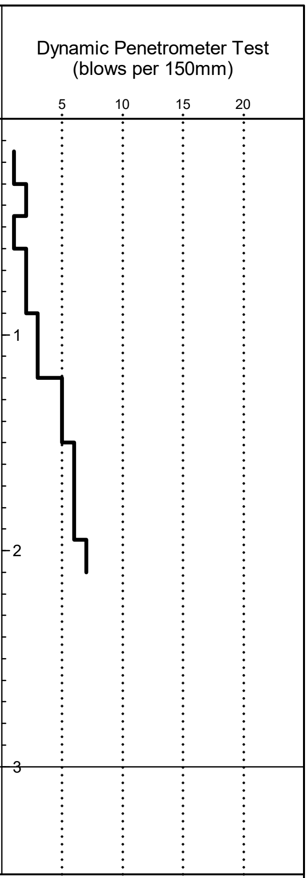
BOREHOLE LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 46.7 m AHD*
EASTING: 388563
NORTHING: 6489342
DIP/AZIMUTH: 90°/--

BORE No: 9
PROJECT No: 202866.01
DATE: 19/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water
	0.1	TOPSOIL/SAND SP: fine to medium grained, dark grey-brown, trace silt, trace rootlets, dry to moist, topsoil.		D	0.05			
46	1	SAND SP: fine to medium grained, dark grey-brown, trace silt, moist, loose to medium dense, derived from Tamala Limestone, residual soil. - becoming grey-brown from 0.7 m depth. - becoming medium dense from 0.9 m depth. - becoming pale grey-brown from 1.3 m depth.		D	0.9 1.2			
45	2							
44	2.5	SAND SP: fine to medium grained, dark brown, moist, derived from Tamala Limestone, residual soil.		D	2.5 2.8			
	3 3.0	Bore discontinued at 3.0m (Target depth)						



RIG: 110 mm hand auger **DRILLER:** GG **LOGGED:** GG **CASING:** None

TYPE OF BORING: Hand auger

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: Location coordinates are in MGA94 Zone 50 J. *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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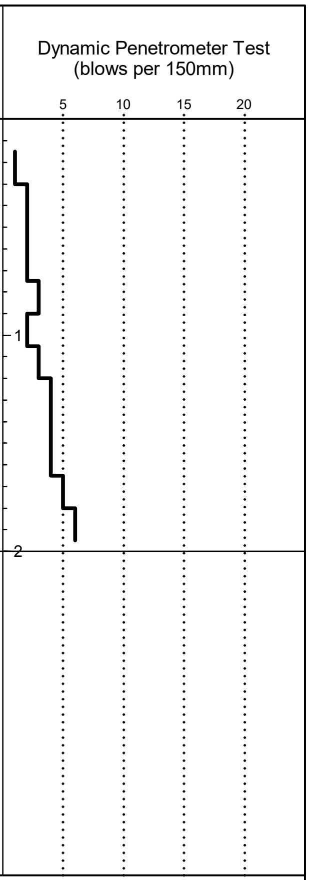
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 44.8 m AHD*
EASTING: 387182
NORTHING: 6489628

PIT No: 10
PROJECT No: 202866.01
DATE: 26/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
	0.1	TOPSOIL/SAND SP: fine to medium grained, grey, trace silt, with rootlets, dry to moist, topsoil.						
44	1	SAND SP: fine to medium grained, grey, trace silt, moist, medium dense, Bassendean Sand. - becoming pale-grey from 0.5 m depth. - becoming white from 1.0m depth.		D	0.6 0.8			
43	2 2.0	Pit discontinued at 2.0m (Collapsing conditions)						
42	3							



RIG: 5 tonne excavator (800 mm wide bucket)
LOGGED: DJB
SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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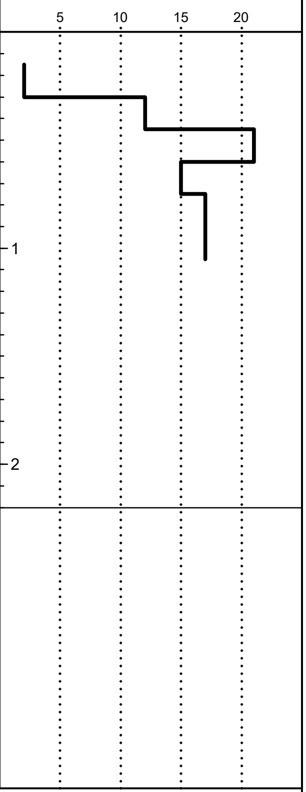
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 57.6 m AHD*
EASTING: 386916
NORTHING: 6489335

PIT No: 11
PROJECT No: 202866.01
DATE: 26/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Dynamic Penetrometer Test (blows per 150mm)
				Type	Depth	Sample	Results & Comments		
		FILL/SAND SP: fine to medium grained, brown, trace silt, trace limestone gravel, moist.	☒						
	0.3	FILL/Sandy GRAVEL GP: fine to medium grained, pale-yellow, trace silt, with crushed limestone, trace gravel, dense, moist.	☒						
57	0.5	FILL/Sandy GRAVEL GP: fine to medium grained, grey-brown, trace silt, with crushed limestone, trace gravel, dense, moist.	☒						
56	0.65	SAND SP: fine to medium grained, from yellow-grey, trace silt, moist, dense, derived from Tamala Limestone, residual soil. - becoming dry-moist from 1.5 m depth.	⁘						
55	2.2	Pit discontinued at 2.2m (Collapsing conditions)							



RIG: 5 tonne excavator (800 mm wide bucket)

LOGGED: DJB

SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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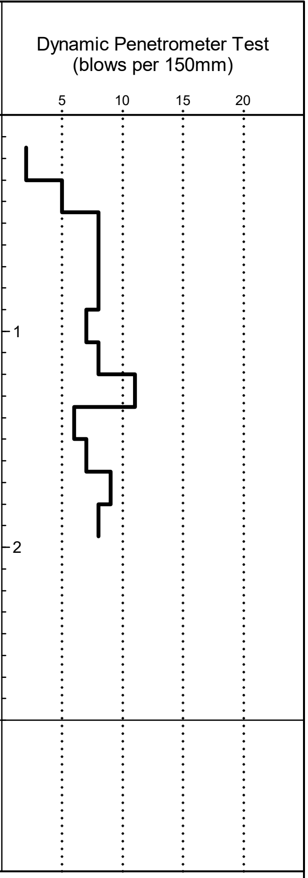
TEST PIT LOG

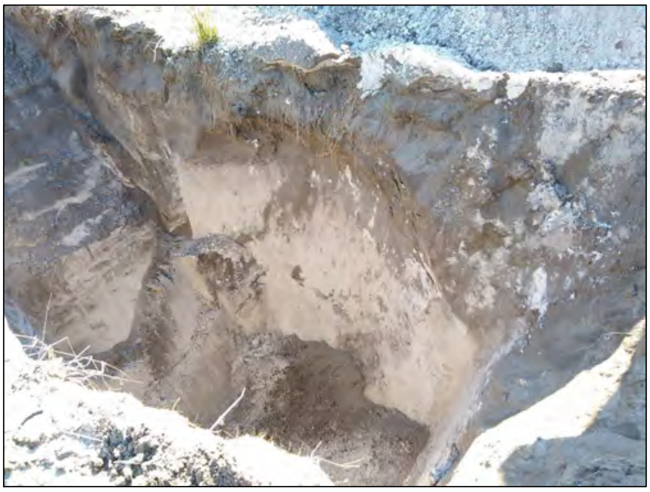
CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 44.8 m AHD*
EASTING: 387218
NORTHING: 6489326

PIT No: 12
PROJECT No: 202866.01
DATE: 26/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		FILL/Silty SAND SM: fine to medium grained, grey, trace gravel, dry to moist, fill. With a piece of wood (0.1x0.2x0.7m).		D	0.1			
44 43	0.5 1 2	SAND SP: fine to medium grained, pale-grey, trace silt, dry to moist, dense, Bassendean Sand.						
42	2.8 3	Pit discontinued at 2.8m (Collapsing conditions)						





RIG: 5 tonne excavator (800 mm wide bucket)

LOGGED: DJB

SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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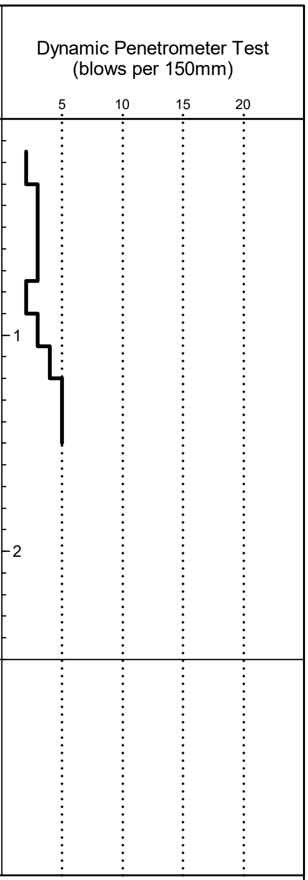
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 55.0 m AHD*
EASTING: 387090
NORTHING: 6488953

PIT No: 13
PROJECT No: 202866.01
DATE: 26/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
55		SAND SP-SM: fine to medium grained, grey, with silt, with roots to 0.4 m depth, moist, medium dense, Bassendean Sand. - becoming pale grey from 0.5 m depth.	⁘					
54	1							
53	2							
	2.5	Pit discontinued at 2.5m (Collapsing conditions)						
52	3							



RIG: 5 tonne excavator (800 mm wide bucket)
LOGGED: DJB
SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

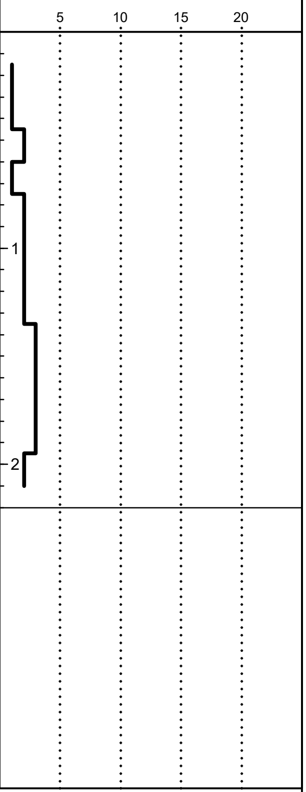
CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 47.6 m AHD*
EASTING: 387308
NORTHING: 6489039

PIT No: 14
PROJECT No: 202866.01
DATE: 26/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
47 46	1 2	SAND SP: fine to medium grained, grey, trace silt, moist, loose, derived from Tamala Limestone, residual soil. - becoming yellow-grey from 0.4 m depth. - becoming medium dense from 0.75 m depth.						
45	2.2 3	Pit discontinued at 2.2m (Collapsing conditions)						

Dynamic Penetrometer Test (blows per 150mm)



RIG: 5 tonne excavator (800 mm wide bucket)

LOGGED: DJB

SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Geotechnics | Environment | Groundwater

TEST PIT LOG

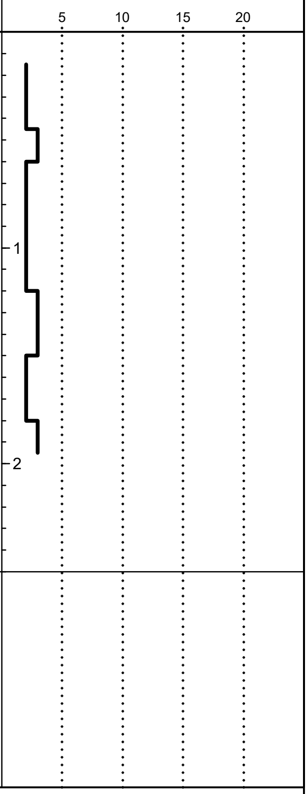
CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

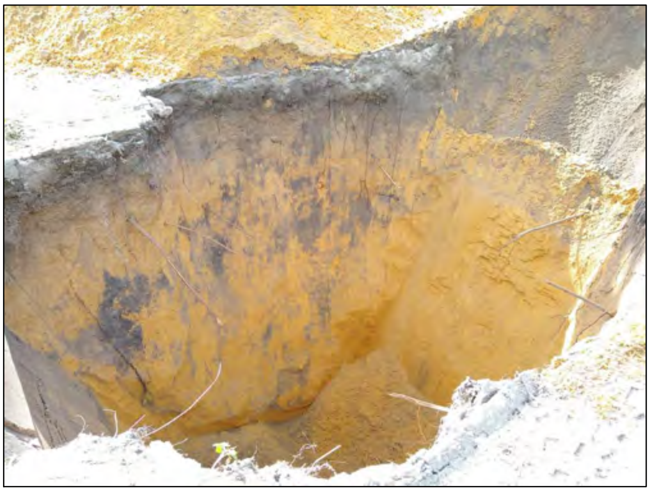
SURFACE LEVEL: 53.1 m AHD*
EASTING: 387113
NORTHING: 6488754

PIT No: 15
PROJECT No: 202866.01
DATE: 26/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water
				Type	Depth	Sample	Results & Comments	
53		SAND SP: fine to medium grained, grey, trace silt, moist, loose to medium dense, derived from Tamala Limestone, residual soil. - becoming yellow-grey from 0.4 m depth.						
52	1			D	1.3			
51	2							
	2.5	Pit discontinued at 2.5m (Collapsing conditions)						
50	3							

Dynamic Penetrometer Test (blows per 150mm)





RIG: 5 tonne excavator (800 mm wide bucket)

LOGGED: DJB

SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Geotechnics / Environment / Groundwater

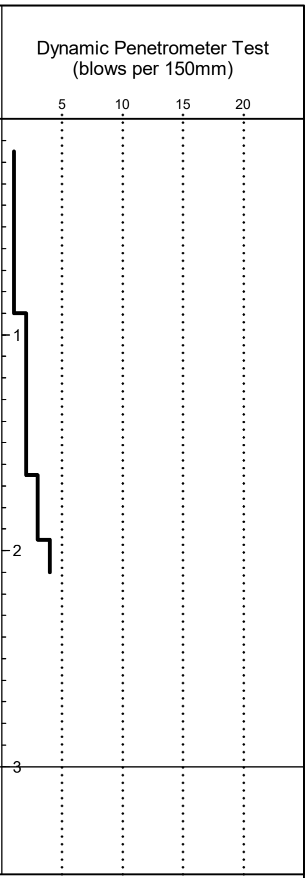
BOREHOLE LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 55.7 m AHD*
EASTING: 387257
NORTHING: 6488499
DIP/AZIMUTH: 90°/--

BORE No: 16
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
	0.1	TOPSOIL/SAND SP-SM: fine to medium grained, grey-brown, with silt, with roots, moist, topsoil.						
55		SAND SP-SM: fine to medium grained, grey-brown, with silt, moist, loose, derived from Tamala Limestone, residual soil. - becoming yellow-brown from 0.3 m depth.						
	1			D	1.0			
54	2							
53	3							
	3.0	Bore discontinued at 3.0m (Target depth)						



RIG: 110 mm hand auger **DRILLER:** YC **LOGGED:** YC **CASING:** None

TYPE OF BORING: Hand auger

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: Location coordinates are in MGA94 Zone 50 J. *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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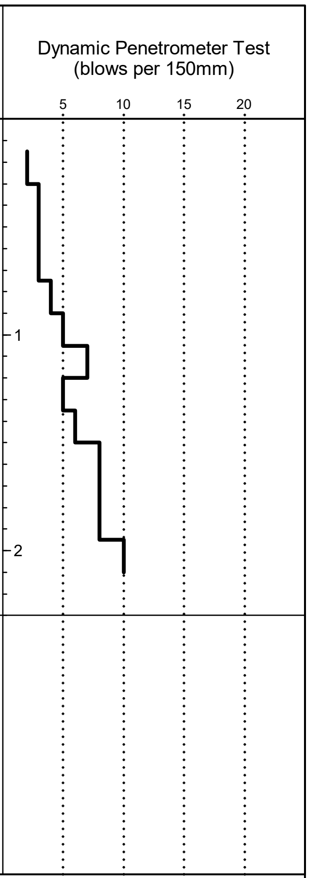
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 44.7 m AHD*
EASTING: 387552
NORTHING: 6488814

PIT No: 17
PROJECT No: 202866.01
DATE: 26/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
44.7	0.0	SAND SP: fine to medium grained, grey, trace silt, dry to moist, medium dense, Bassendean Sand. - becoming pale grey from 0.5 m depth.						
	2.3	Pit discontinued at 2.3m (Collapsing conditions)						



RIG: 5 tonne excavator (800 mm wide bucket)

LOGGED: DJB

SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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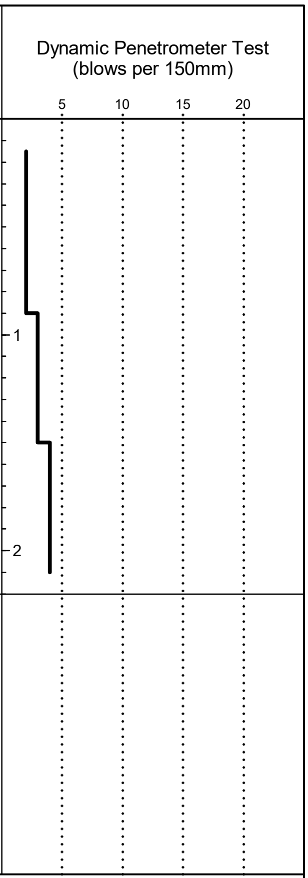
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 47.9 m AHD*
EASTING: 387660
NORTHING: 6488596

PIT No: 18
PROJECT No: 202866.01
DATE: 26/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		FILL/SAND SP: fine to medium grained, grey, trace silt, moist, medium dense, fill. - tree stump at 0.2 m to 0.4 m depth.						
	0.4	SAND SP-SM: fine to medium grained, dark-grey, with silt, moist, medium dense, Bassendean Sand.						
47	0.7	SAND SP: fine to medium grained, grey, trace silt, moist, medium dense, Bassendean Sand.						
46	2.2	Pit discontinued at 2.2m (Collapsing conditions)						
45								


Dynamic Penetrometer Test (blows per 150mm)

RIG: 5 tonne excavator (800 mm wide bucket)
LOGGED: DJB
SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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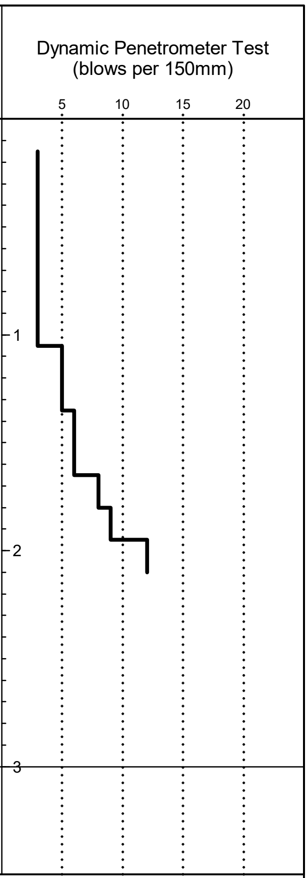
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 44.4 m AHD*
EASTING: 387903
NORTHING: 6488723

PIT No: 19
PROJECT No: 202866.01
DATE: 26/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
44		FILL/Silty SAND SM: fine to medium grained, grey and brown, trace gravel, dry to moist, medium dense, fill. PVC reticulation pipe observed at 0.3 m and 1.3 m depth. Plastic pots, bags, and straps observed through out.		D	0.45			
43	1.3	SAND SP: fine to medium grained, pale grey, trace silt, moist, medium dense, Bassendean Sand.						
42		- becoming pale grey to brown from 2.6 m depth.						
41	3.0	Pit discontinued at 3.0m (Target depth)						



RIG: 5 tonne excavator (800 mm wide bucket)

LOGGED: DJB

SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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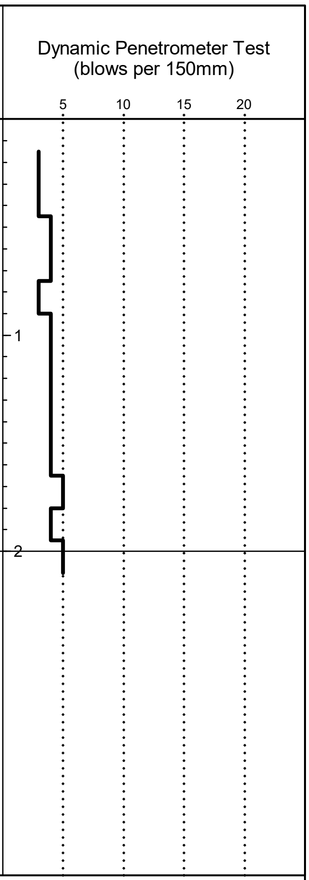
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 48.2 m AHD*
EASTING: 387936
NORTHING: 6488532

PIT No: 20
PROJECT No: 202866.01
DATE: 26/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
48	0.3	FILL/SAND SP-SM: fine to medium grained, dark grey, with silt, moist, medium dense. Fill possibly to 0.3 m depth.	⊠	D	0.1			
47	1 2.0	SAND SP: fine to medium grained, grey, trace silt, moist, medium dense, Bassendean Sand. - becoming pale-grey from 0.7 m depth.		D	1.5			
46 45	2 3	Pit discontinued at 2.0m (Collapsing conditions)						



RIG: 5 tonne excavator (800 mm wide bucket)
LOGGED: DJB
SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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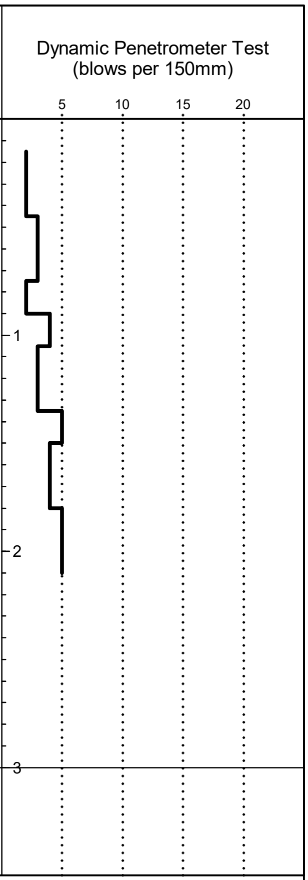
BOREHOLE LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 45.5 m AHD*
EASTING: 388262
NORTHING: 6488771
DIP/AZIMUTH: 90°/--

BORE No: 21
PROJECT No: 202866.01
DATE: 26/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Sampling & In Situ Testing Depth	Sampling & In Situ Testing Sample	Sampling & In Situ Testing Results & Comments	Water
		FILL/SAND SP: fine to medium grained, grey to dark grey, trace silt, moist, medium dense, dry, fill.						
45								
	1 1.0	SAND SP: fine to medium grained, grey, trace silt, dry to moist, medium dense, Bassendean Sand.						
44								
	2	- becoming pale-grey and trace roots observed at 2.1 m depth.						
43								
	3 3.0	Bore discontinued at 3.0m (Target depth)						



RIG: 110 mm hand auger **DRILLER:** DJB **LOGGED:** DJB **CASING:** None
TYPE OF BORING: Hand auger
WATER OBSERVATIONS: No free groundwater observed.
REMARKS: Location coordinates are in MGA94 Zone 50 J. *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

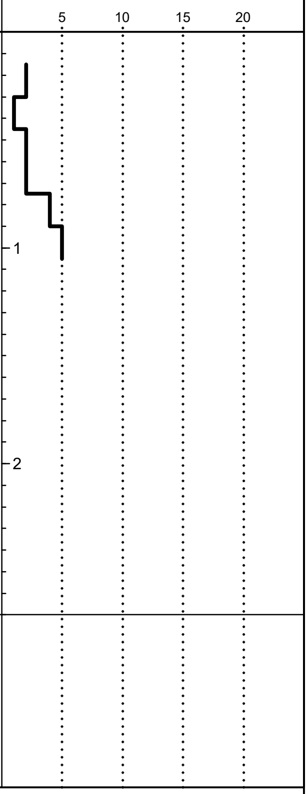
CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 44.9 m AHD*
EASTING: 388371
NORTHING: 6488917

PIT No: 22
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water
				Type	Depth	Sample	Results & Comments	
		SAND SP-SM: fine to medium grained, dark grey, with silt, medium dense, moist. - with rootlets to 0.1 m depth.						
44	0.4 1	SAND SP: fine to medium grained, pale grey, trace silt, moist, medium dense, Bassendean Sand.						
43	2							
42	2.7 3	Pit discontinued at 2.7m (Test Pit collapse)						

Dynamic Penetrometer Test (blows per 150mm)



RIG: 5 tonne excavator (800 mm wide bucket)
LOGGED: YC
SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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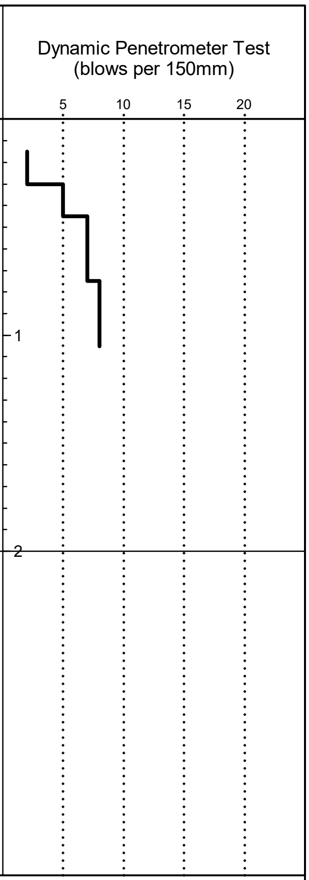
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 48.3 m AHD*
EASTING: 388438
NORTHING: 6488600

PIT No: 23
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Results & Comments	
	0.1	TOPSOIL/ SAND: fine to medium grained, dark grey-brown, with silt, moist, topsoil.					
		SAND: fine to medium grained, pale grey, trace silt, moist, medium dense, Bassendean Sand. - becoming medium dense to dense from 0.45 m depth.					
			D	1.5			
	2.0	Pit discontinued at 2.0m (Target depth)					



RIG: 5 tonne excavator (800 mm wide bucket)
LOGGED: YC
SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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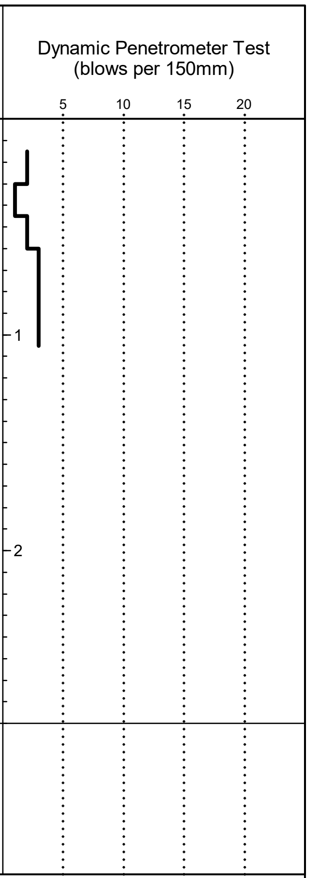
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 52.7 m AHD*
EASTING: 389342
NORTHING: 6488666

PIT No: 24
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
	0.1	TOPSOIL/ SAND: fine to medium grained, dark grey-brown, with silt, with roots, moist, topsoil.		D	0.0 0.1			
52 51 50	1 2	SAND SP-SM: fine to medium grained, yellow-brown, with silt, trace gravel, moist, medium dense, derived from Tamala Limestone, residual soil.		B	2.0			
	2.8 3	Pit discontinued at 2.8m (Test Pit collapse)						



RIG: 5 tonne excavator (800 mm wide bucket) **LOGGED:** YC **SURVEY DATUM:** MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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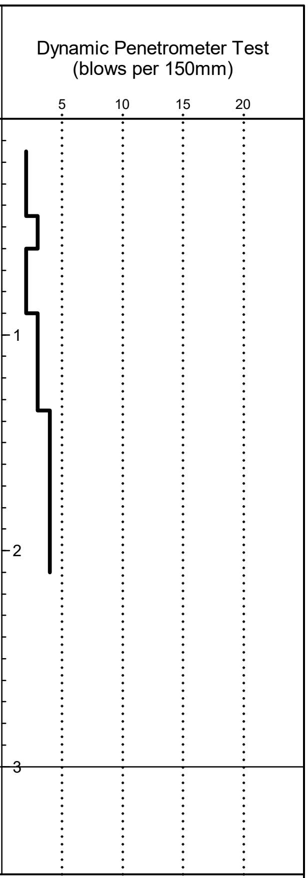
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 55.6 m AHD*
EASTING: 388955
NORTHING: 6488801

PIT No: 25
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Type	Depth	Sample	Results & Comments	Water
	0.1	SAND SP-SM: fine to medium grained, grey-brown, with silt, some rootlets, moist, derived from Tamala Limestone, residual soil.						
55 54 53	1 2	SAND SP-SM: fine to medium grained, yellow-brown, with silt, moist, medium dense, derived from Tamala Limestone, residual soil.						
	3 3.0	Pit discontinued at 3.0m (Target depth)						



RIG: 5 tonne excavator (800 mm wide bucket)
LOGGED: YC
SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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TEST PIT LOG

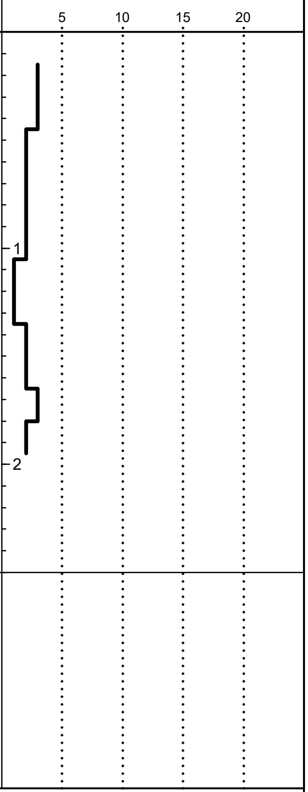
CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 56.4 m AHD*
EASTING: 388822
NORTHING: 6489258

PIT No: 26
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
	0.1	SAND SP-SM: fine to medium grained, dark grey-brown, with silt, some rootlets, moist. Possibly organic.						
56		SAND SP-SM: fine to medium grained, yellow-brown, with silt, moist, medium dense, derived from Tamala Limestone, residual soil.		D	0.3			
		- becoming loose from 0.75 m depth.			0.9		- PSP commenced at 0.9 m deep within test pit.	
	1							
55		- becoming loose to medium dense from 1.35 m depth.						
	2							
54	2.5	Pit discontinued at 2.5m (Test Pit collapse)						
	3							
53								

Dynamic Penetrometer Test (blows per 150mm)



RIG: 5 tonne excavator (800 mm wide bucket)
LOGGED: YC
SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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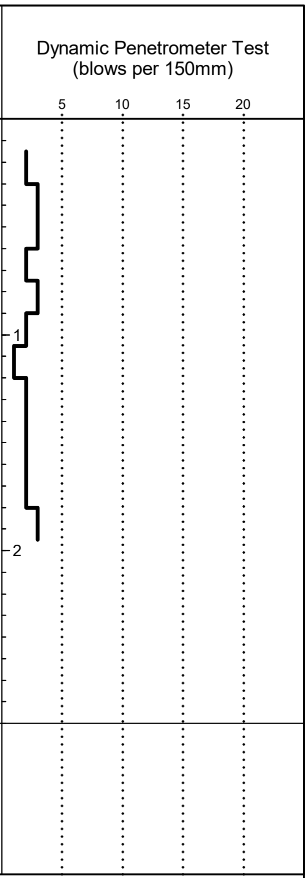
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 52.3 m AHD*
EASTING: 389022
NORTHING: 6489185

PIT No: 27
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
	0.2	SAND SP-SM: fine to medium grained, dark grey-brown, with silt, some rootlets, moist. Possibly organic.					
52		SAND SP-SM: fine to medium grained, yellow-brown, with silt, moist, medium dense, derived from Tamala Limestone, residual soil. - with roots to 0.5 m depth.					
	1			0.9		- PSP commenced at 0.9 m deep within test pit.	
51							
	2		D	2.0			
50	2.8						
	3	Pit discontinued at 2.8m (Test Pit collapse)					
49							



RIG: 5 tonne excavator (800 mm wide bucket)

LOGGED: YC

SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

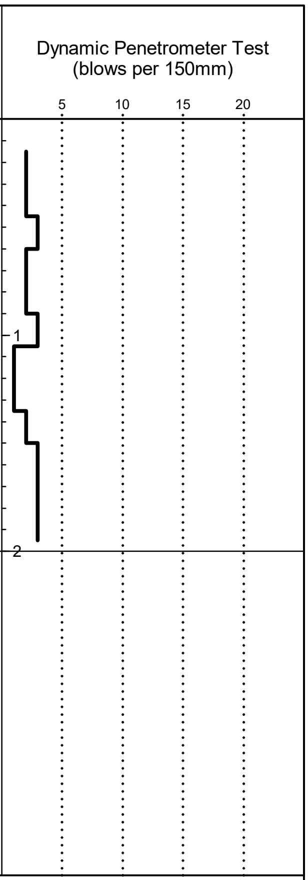
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 52.6 m AHD*
EASTING: 389465
NORTHING: 6489226

PIT No: 28
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
52 51	1	SAND SP: fine to medium grained, grey-brown, trace silt, moist, medium dense, Bassendean Sand. - becoming pale grey from 0.3 m depth. - with roots to 0.35 m depth. - loose between 1.05 m and 1.35 m depth.			0.9		- PSP commenced at 0.9 m deep within test pit.	
50	2 2.0 3	Pit discontinued at 2.0m (Test Pit collapse)						



RIG: 5 tonne excavator (800 mm wide bucket)

LOGGED: YC

SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics | Environment | Groundwater

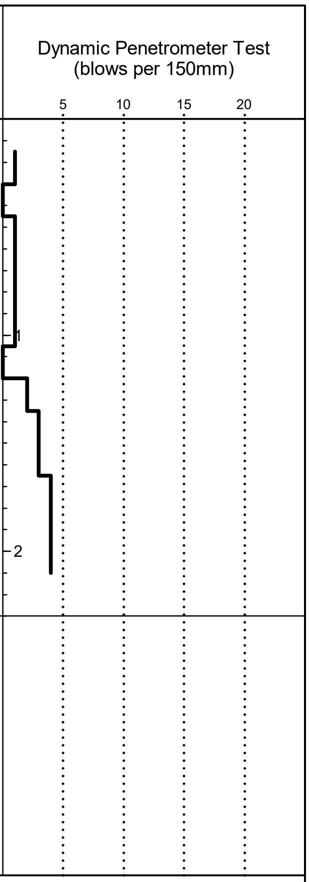
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 53.9 m AHD*
EASTING: 389379
NORTHING: 6489683

PIT No: 29
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
	0.1	TOPSOIL/SAND: fine to medium grained, grey-brown, with silt, with roots, moist, topsoil.						
53	1	SAND SP-SM: fine to medium grained, yellow-brown, with silt, moist, loose, derived from Tamala Limestone, residual soil. - with roots and rootlets observed to 0.5 m depth. - becoming medium dense from 1.35 m depth.						
52	2							
	2.3	Pit discontinued at 2.3m (Test Pit collapse)						
51	3							



RIG: 5 tonne excavator (800 mm wide bucket)
LOGGED: YC
SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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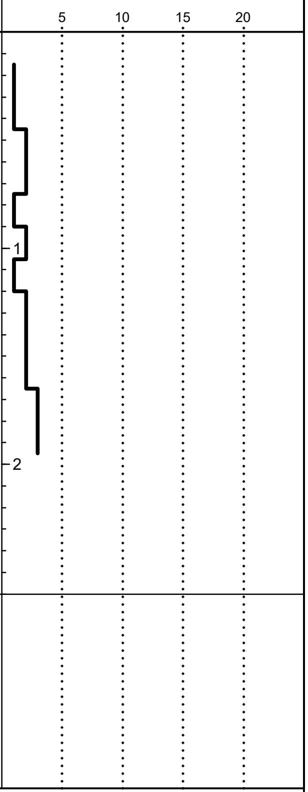
Geotechnics / Environment / Groundwater

TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 53.3 m AHD*
EASTING: 389172
NORTHING: 6489720

PIT No: 30
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Sampling & In Situ Testing: Depth	Sampling & In Situ Testing: Sample	Sampling & In Situ Testing: Results & Comments	Water	Dynamic Penetrometer Test (blows per 150mm)
	0.2	SAND SP-SM: fine to medium grained, dark grey-brown, with silt, some rootlets, moist, fill. Fill is disturbed ground.							
53 52 51	1 2 2.6	SAND SP-SM: fine to medium grained, yellow-brown, with silt, moist, loose to medium dense, derived from Tamala Limestone, residual soil. - becoming medium dense from 1.2 m depth.		 B	0.9 2.0		- PSP commenced at 0.9 m deep within test pit.		
50	3	Pit discontinued at 2.6m (Test Pit collapse)							

RIG: 5 tonne excavator (800 mm wide bucket)

LOGGED: YC

SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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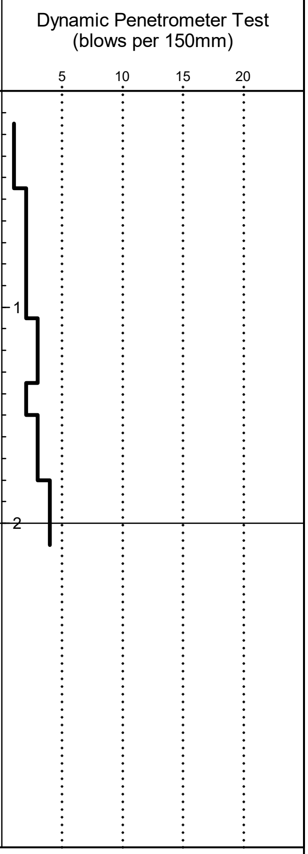
TEST PIT LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 49.5 m AHD*
EASTING: 388555
NORTHING: 6489756

PIT No: 31
PROJECT No: 202866.01
DATE: 27/5/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
	0.1	TOPSOIL/SAND: fine to medium grained, dark grey-brown, with silt, with roots, moist, topsoil.						
49 48	1	SAND SP: fine to medium grained, pale grey, trace silt, moist, loose, Bassendean Sand. - becoming loose to medium dense from 0.5 m depth. - becoming medium dense from 1.8 m depth.						
47	2 2.0	Pit discontinued at 2.0m (Test Pit collapse)						
	3							



RIG: 5 tonne excavator (800 mm wide bucket)

LOGGED: YC

SURVEY DATUM: MGA94 Zone 50 J

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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Geotechnics | Environment | Groundwater

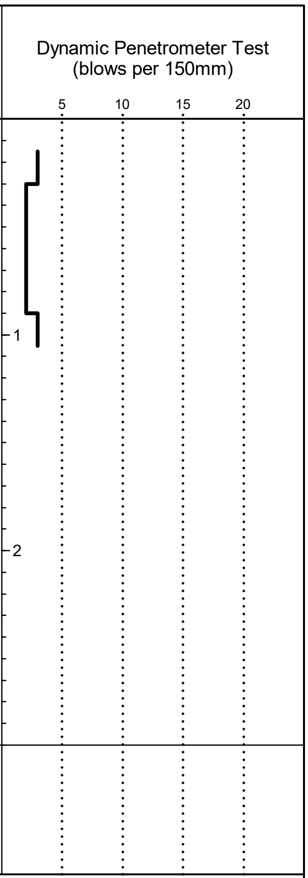
BOREHOLE LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 51.5 m AHD*
EASTING: 388960
NORTHING: 6489591
DIP/AZIMUTH: 90°/--

BORE No: 32
PROJECT No: 202866.01
DATE: 3/6/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
	0.1	FILL/TOPSOIL SP-SM: fine to medium grained, dark grey-brown, with silt and rootlets, moist, fill.	⊠					
51		FILL/SAND SP: fine to medium grained, grey-brown, trace silt, dry to moist, medium dense, fill.	⊠					
	0.6	SAND SP: fine to medium grained, yellow-brown, trace silt, medium dense, dry to moist, sand derived from Tamala Limestone.	⁘					
	1		⁘					
			⁘	D	1.2			
50			⁘					
	2		⁘					
49			⁘					
	2.9	Bore discontinued at 2.9m (Target depth)						
	3							



RIG: 110 mm hand auger **DRILLER:** BD **LOGGED:** BD **CASING:** None

TYPE OF BORING: Hand auger

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: Location coordinates are in MGA94 Zone 50 J. *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

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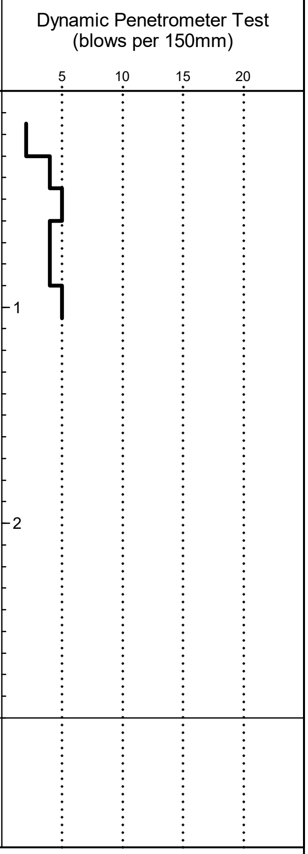
BOREHOLE LOG

CLIENT: Hesperia Projects Pty Ltd
PROJECT: East Wanneroo Precinct 7
LOCATION: Caporn Street, Mariginiup, WA

SURFACE LEVEL: 48.7 m AHD*
EASTING: 388788
NORTHING: 6489895
DIP/AZIMUTH: 90°/--

BORE No: 33
PROJECT No: 202866.01
DATE: 3/6/2021
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
	0.1	TOPSOIL SP-SM: fine to medium grained, dark grey, with silt, moist, topsoil.						
48		SAND SP: fine to medium grained, pale grey, trace silt, medium dense, moist, Bassendean Sand.						
	1			D	1.15			
47	2							
46		- becoming wet from 2.5 m depth.						
	2.9	Bore discontinued at 2.9m (Target depth)						
	3							



RIG: 110 mm hand auger **DRILLER:** BD **LOGGED:** BD **CASING:** None

TYPE OF BORING: Hand auger

WATER OBSERVATIONS: No free groundwater observed.

REMARKS: Location coordinates are in MGA94 Zone 50 J. *Surface level derived from publicly available LiDAR data.

☒ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	⊳	Water seep	S	Standard penetration test
E	Environmental sample	⯆	Water level	V	Shear vane (kPa)

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Appendix C

Laboratory Test Certificates

WESTERN
GEOTECHNICAL
& Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

TEST REPORT - ASTM D2974-14 (Test Method C)

Client:	Hesperia Projects Pty Ltd	*Ticket No.*	S3429
Client Address:	-	*Report No.*	WG21/8392-8400_1_ORG
Project:	East Wanneroo Development Area	*Sample No.*	WG21/8392-8400
Location:	Caporn Street, Mariginiup, WA	*Date Sampled:*	27-05-2021
Sample Identification:	Various - See below	*Date Tested:*	15-06-2021

TEST RESULTS - Organic Content

Sampling Method:	**Sampled by Client, Tested as Received**
Testing Completed By:	**WGLS - CO**
Furnace Temperature (^{o}C):	**440**

Sample Number	Sample Identification	Ash Content (%)	Organic Content (%)
WG21/8392	9, 0.05m	96.4	3.6
WG21/8394	12, 0.1m	98.3	1.7
WG21/8397	19, 0.45m	89.9	10.1
WG21/8398	20, 0.1m	96.9	3.1
WG21/8399	24, 0-0.1m	89.7	10.3
WG21/8400	26, 0.3m	98.4	1.6

Comments:

Approved Signatory:

Name: Erin Bullen

Date: 16-June-2021

NATA
WORLD RECOGNISED ACCREDITATION

Accreditation No. 20599
Accredited for compliance
with ISO/IEC 17025 - Testing

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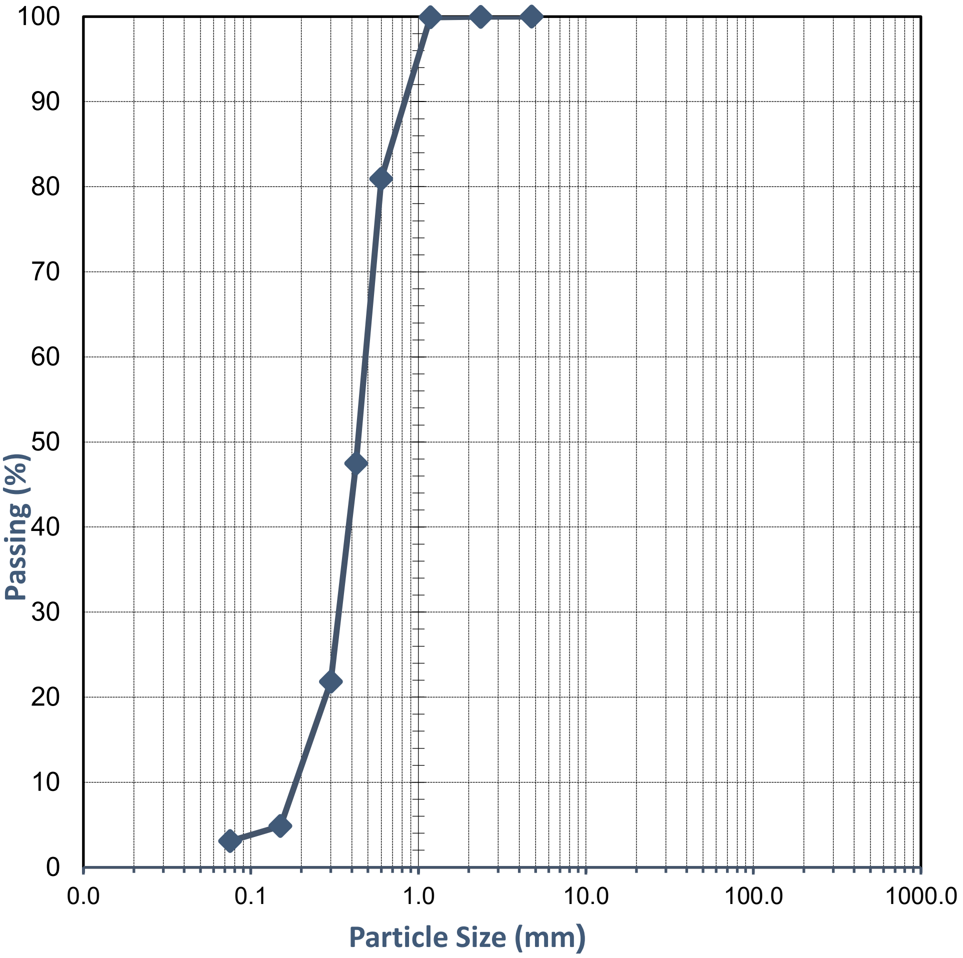
TEST REPORT - AS 1289.3.6.1

Client:	Hesperia Projects Pty Ltd	*Ticket No.*	S3429
Client Address:	-	*Report No.*	WG21/8390_1_PSD
Project:	East Wanneroo Development Area	*Sample No.*	WG21/8390
Location:	Caporn Street, Mariginiup, WA	*Date Sampled:*	27-05-2021
Sample Identification:	1, 1.0m	*Date Tested:*	15/6/21-16/6/21

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: **Sampled by Client, Tested as Received**

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	
4.75	100
2.36	100
1.18	100
0.600	81
0.425	47
0.300	22
0.150	5
0.075	3



Comments:

Approved Signatory: Coneill

Name: Cody O'Neill

Date: 16-June-2021

Accreditation No. 20599
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NATA WORLD RECOGNISED ACCREDITATION

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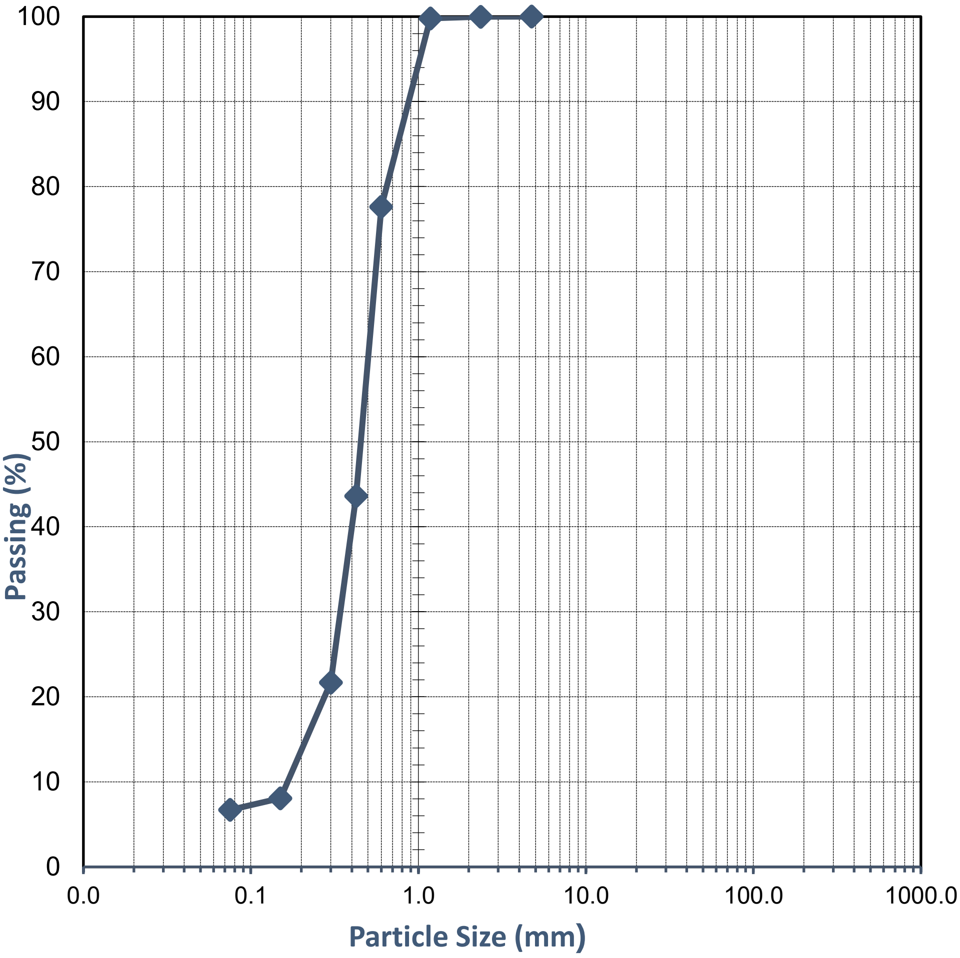
TEST REPORT - AS 1289.3.6.1

Client:	Hesperia Projects Pty Ltd	*Ticket No.*	S3429
Client Address:	-	*Report No.*	WG21/8391_1_PSD
Project:	East Wanneroo Development Area	*Sample No.*	WG21/8391
Location:	Caporn Street, Mariginiup, WA	*Date Sampled:*	27-05-2021
Sample Identification:	4, 1.0m	*Date Tested:*	15/6/21-16/6/21

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: **Sampled by Client, Tested as Received**

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	
4.75	100
2.36	100
1.18	100
0.600	78
0.425	44
0.300	22
0.150	8
0.075	7



Comments:

Approved Signatory: Coneill

Name: Cody O'Neill

Date: 16-June-2021

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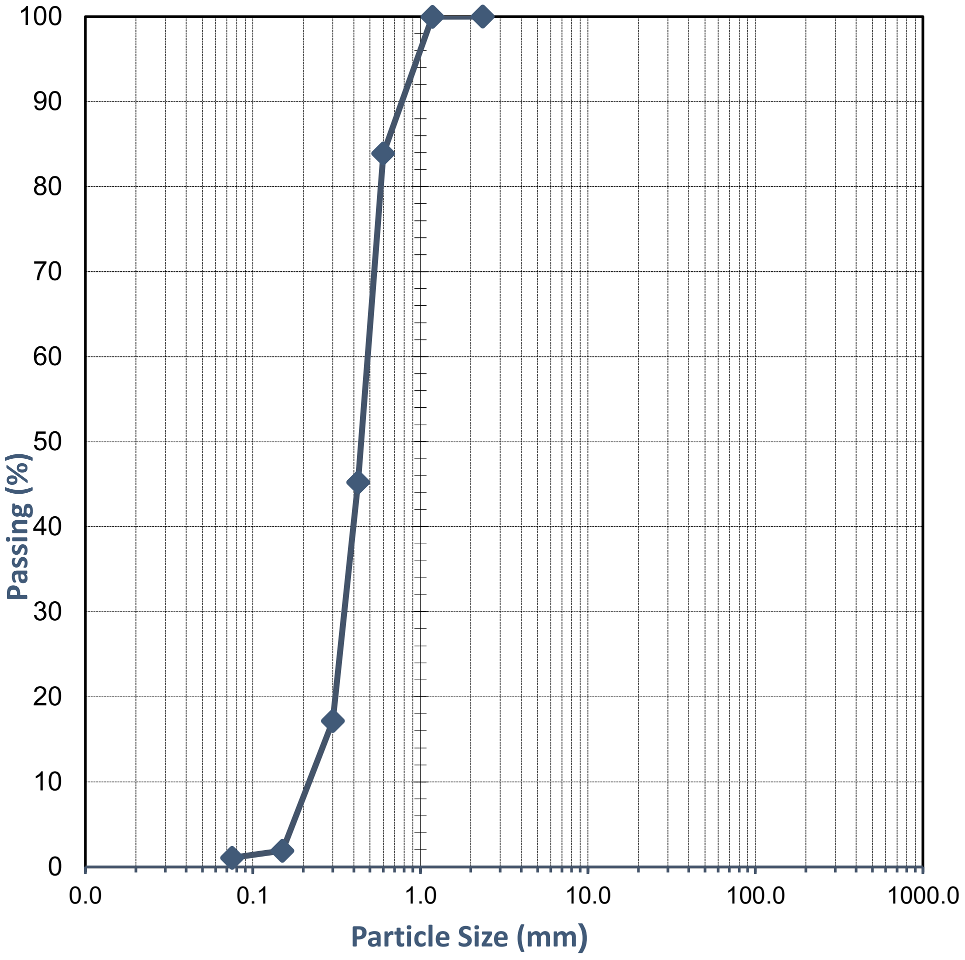
TEST REPORT - AS 1289.3.6.1

Client:	Hesperia Projects Pty Ltd	*Ticket No.*	S3429
Client Address:	-	*Report No.*	WG21/8403_1_PSD
Project:	East Wanneroo Development Area	*Sample No.*	WG21/8403
Location:	Caporn Street, Mariginiup, WA	*Date Sampled:*	27-05-2021
Sample Identification:	9, 0.9-1.2m	*Date Tested:*	15/6/21-16/6/21

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: **Sampled by Client, Tested as Received**

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	
4.75	
2.36	100
1.18	100
0.600	84
0.425	45
0.300	17
0.150	2
0.075	1



Comments:

Approved Signatory: Coneill

Name: Cody O'Neill
Date: 16-June-2021

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Accreditation No. 20599
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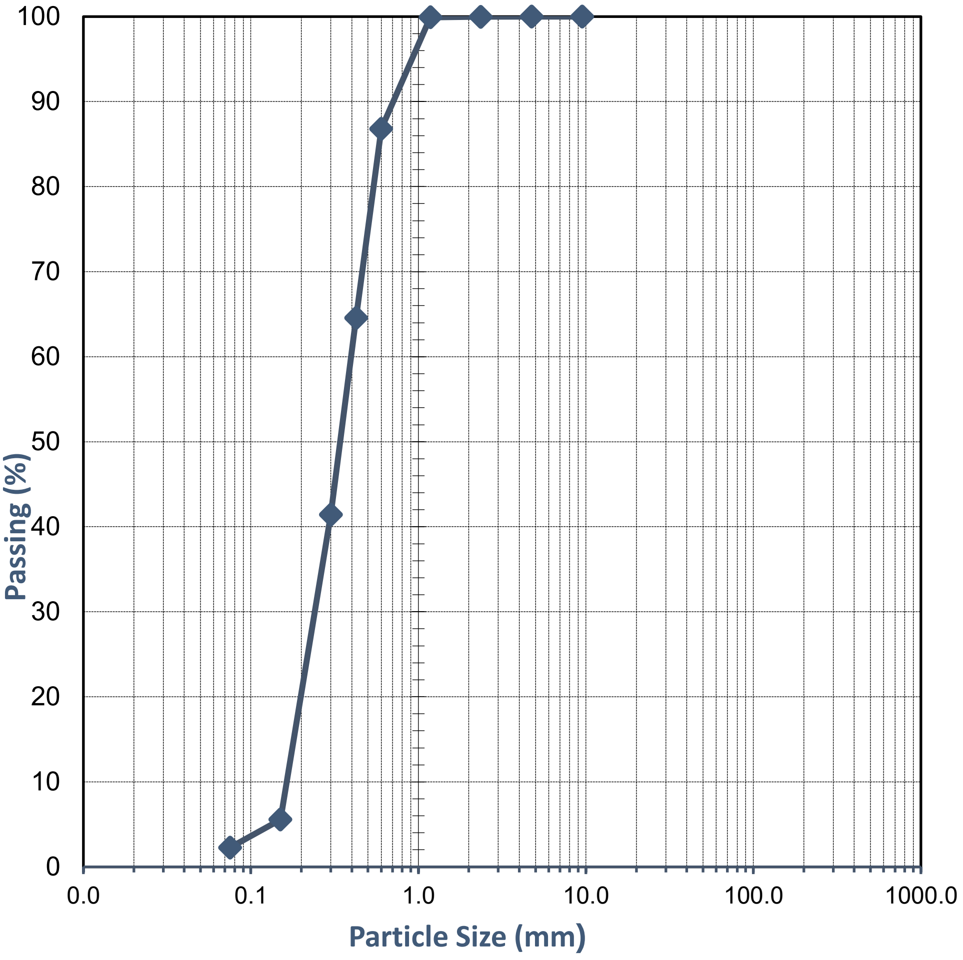
TEST REPORT - AS 1289.3.6.1

Client:	Hesperia Projects Pty Ltd	*Ticket No.*	S3429
Client Address:	-	*Report No.*	WG21/8393_1_PSD
Project:	East Wanneroo Development Area	*Sample No.*	WG21/8393
Location:	Caporn Street, Mariginiup, WA	*Date Sampled:*	27-05-2021
Sample Identification:	10, 0.6m-0.8m	*Date Tested:*	15/6/21-16/6/21

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: **Sampled by Client, Tested as Received**

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	100
4.75	100
2.36	100
1.18	100
0.600	87
0.425	65
0.300	41
0.150	6
0.075	2



Comments:

Approved Signatory: Coneill

Name: Cody O'Neill

Date: 16-June-2021

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WESTERN GEOTECHNICAL
& Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

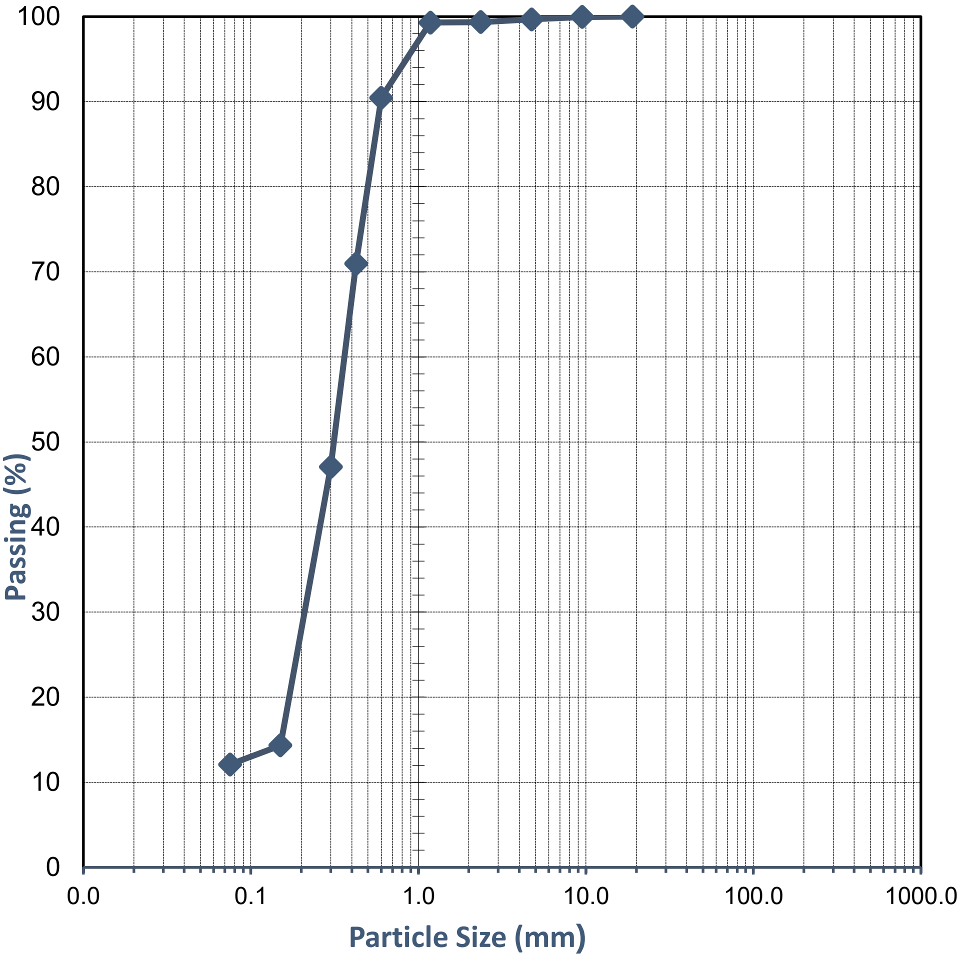
TEST REPORT - AS 1289.3.6.1

Client: Hesperia Projects Pty Ltd — ***Ticket No.*** S3429
Client Address: - — ***Report No.*** WG21/8394_1_PSD
Project: East Wanneroo Development Area — ***Sample No.*** WG21/8394
Location: Caporn Street, Mariginiup, WA — ***Date Sampled:*** 27-05-2021
Sample Identification: 12, 0.1m — ***Date Tested:*** 15/6/21-16/6/21

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: **Sampled by Client, Tested as Received**

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	100
9.5	100
4.75	100
2.36	99
1.18	99
0.600	90
0.425	71
0.300	47
0.150	14
0.075	12



Comments:

Approved Signatory:

Name: Cody O'Neill
Date: 16-June-2021

Accreditation No. 20599
Accredited for compliance
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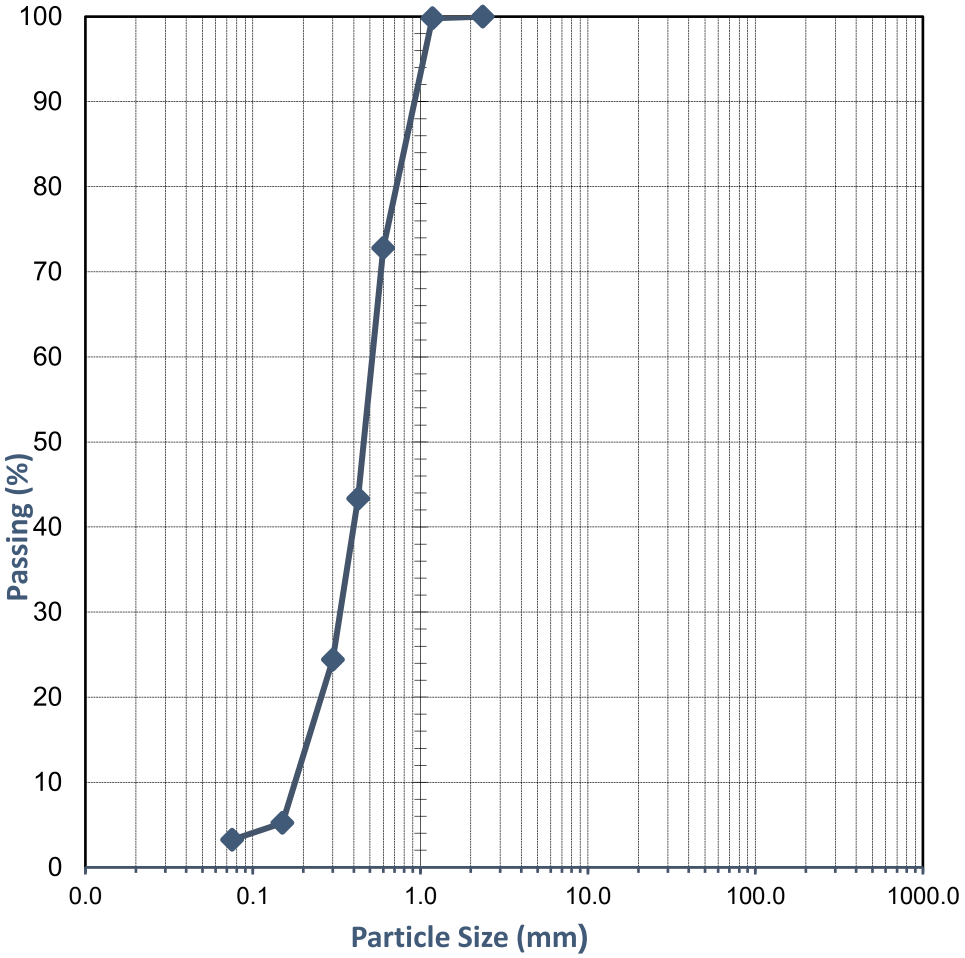
TEST REPORT - AS 1289.3.6.1

Client:	Hesperia Projects Pty Ltd	*Ticket No.*	S3429
Client Address:	-	*Report No.*	WG21/8395_1_PSD
Project:	East Wanneroo Development Area	*Sample No.*	WG21/8395
Location:	Caporn Street, Mariginiup, WA	*Date Sampled:*	27-05-2021
Sample Identification:	15, 1.3m	*Date Tested:*	15/6/21-16/6/21

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: **Sampled by Client, Tested as Received**

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	
4.75	
2.36	100
1.18	100
0.600	73
0.425	43
0.300	24
0.150	5
0.075	3



Comments:

Approved Signatory:

Name: Cody O'Neill

Date: 16-June-2021

Accreditation No. 20599
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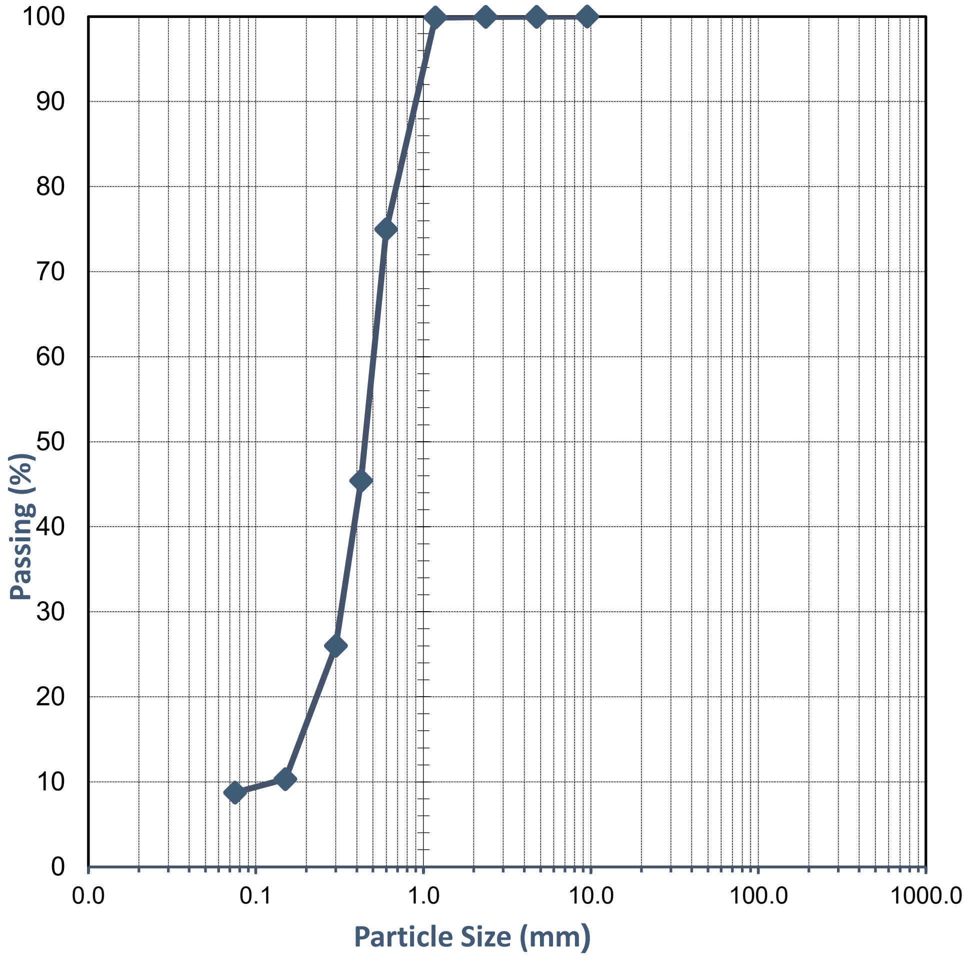
TEST REPORT - AS 1289.3.6.1

Client:	Hesperia Projects Pty Ltd	*Ticket No.*	S3429
Client Address:	-	*Report No.*	WG21/8396_1_PSD
Project:	East Wanneroo Development Area	*Sample No.*	WG21/8396
Location:	Caporn Street, Mariginiup, WA	*Date Sampled:*	27-05-2021
Sample Identification:	16, 1.0m	*Date Tested:*	15/6/21-16/6/21

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: **Sampled by Client, Tested as Received**

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	100
4.75	100
2.36	100
1.18	100
0.600	75
0.425	45
0.300	26
0.150	10
0.075	9



Comments:

Approved Signatory: Coneill

Name: Cody O'Neill

Date: 16-June-2021

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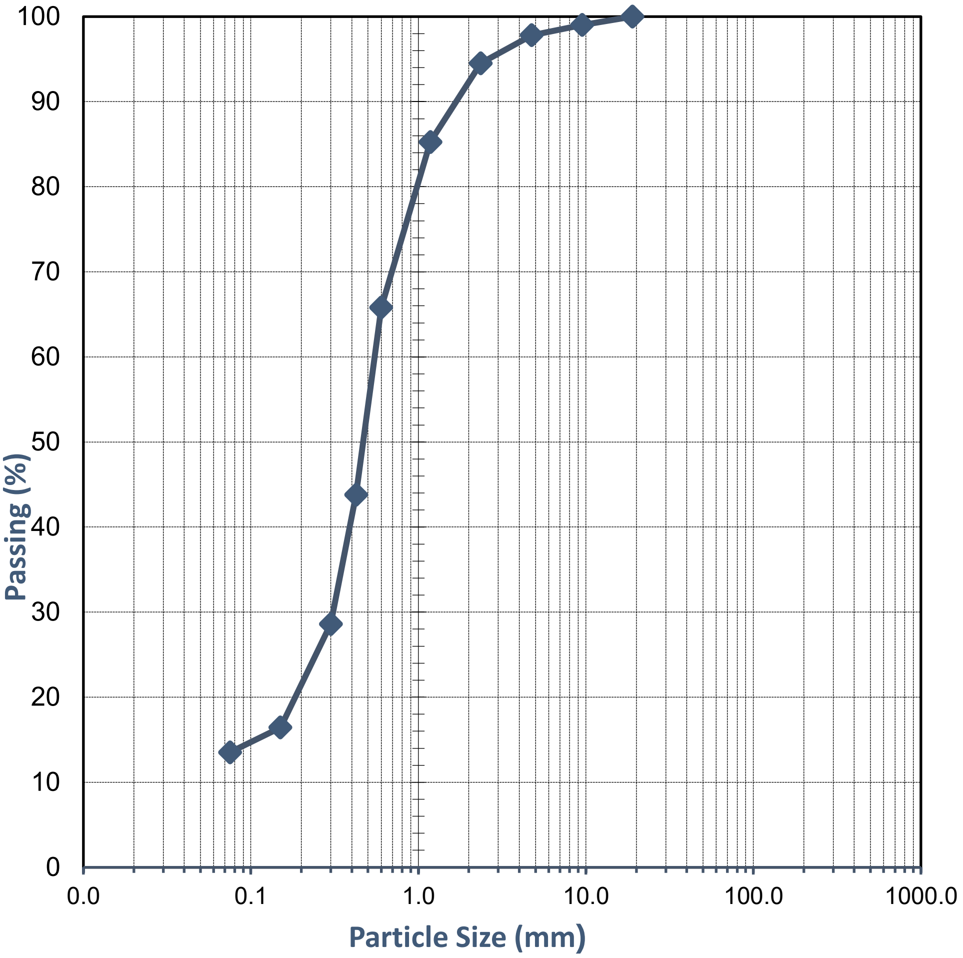
TEST REPORT - AS 1289.3.6.1

Client:	Hesperia Projects Pty Ltd	*Ticket No.*	S3429
Client Address:	-	*Report No.*	WG21/8397_1_PSD
Project:	East Wanneroo Development Area	*Sample No.*	WG21/8397
Location:	Caporn Street, Mariginiup, WA	*Date Sampled:*	27-05-2021
Sample Identification:	19, 0.45m	*Date Tested:*	15/6/21-16/6/21

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: **Sampled by Client, Tested as Received**

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	100
9.5	99
4.75	98
2.36	95
1.18	85
0.600	66
0.425	44
0.300	29
0.150	16
0.075	14



Comments:

Approved Signatory: Coneill

Name: Cody O'Neill

Date: 16-June-2021

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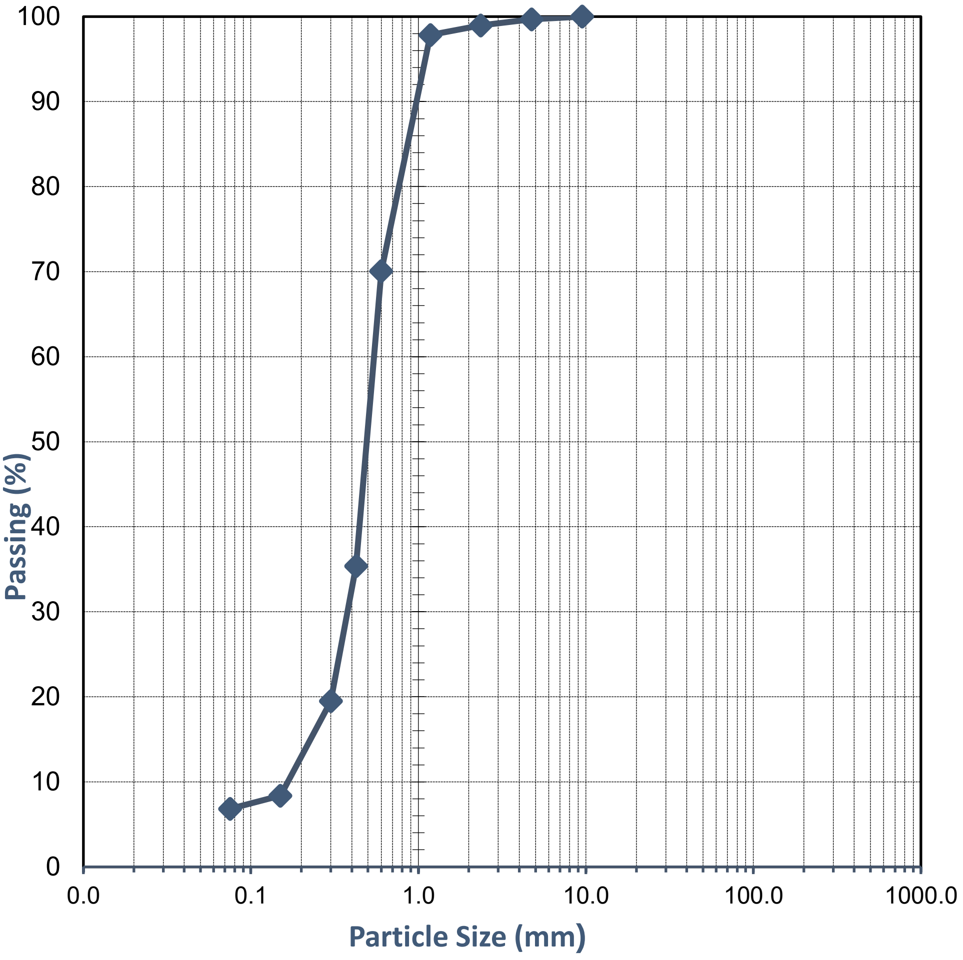
TEST REPORT - AS 1289.3.6.1

Client:	Hesperia Projects Pty Ltd	*Ticket No.*	S3429
Client Address:	-	*Report No.*	WG21/8398_1_PSD
Project:	East Wanneroo Development Area	*Sample No.*	WG21/8398
Location:	Caporn Street, Mariginiup, WA	*Date Sampled:*	27-05-2021
Sample Identification:	20, 0.1m	*Date Tested:*	15/6/21-16/6/21

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: **Sampled by Client, Tested as Received**

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	100
4.75	100
2.36	99
1.18	98
0.600	70
0.425	35
0.300	19
0.150	8
0.075	7



Comments:

Approved Signatory: Conell

Name: Cody O'Neill
Date: 16-June-2021

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WESTERN GEOTECHNICAL
& Laboratory Services

SOIL | AGGREGATE | CONCRETE | CRUSHING

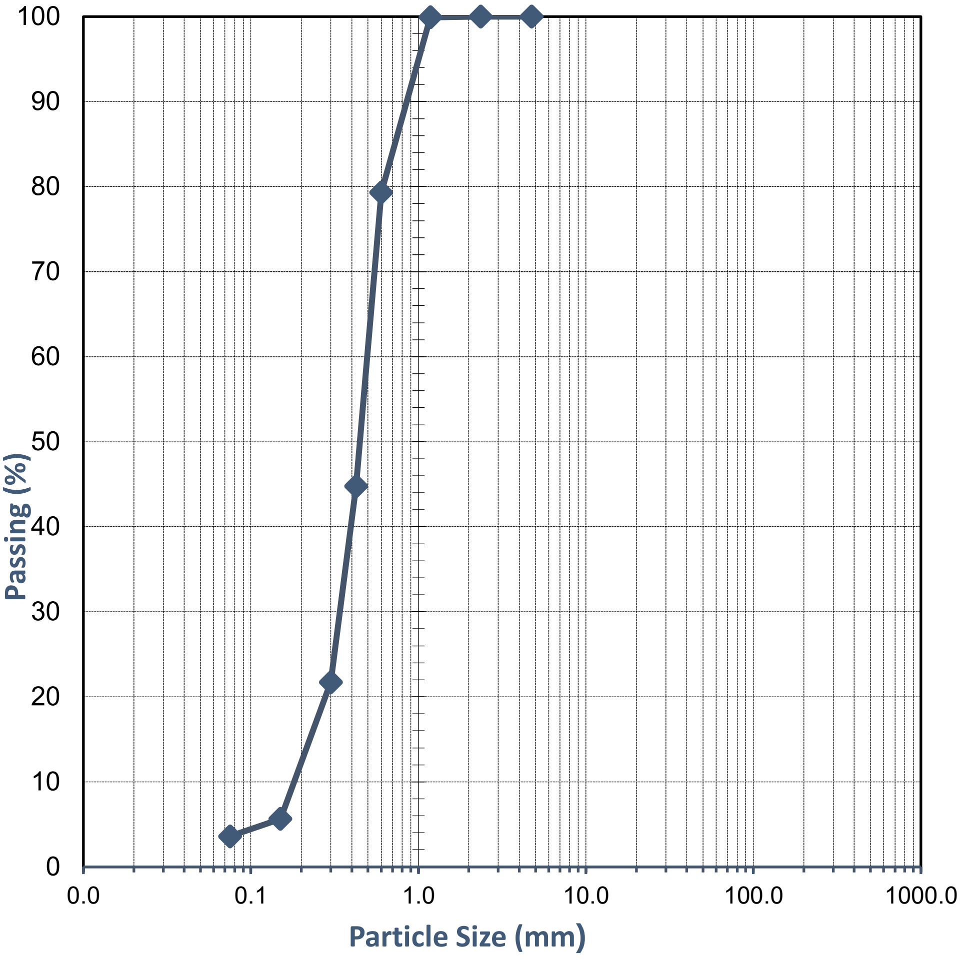
TEST REPORT - AS 1289.3.6.1

Client:	Hesperia Projects Pty Ltd	*Ticket No.*	S3429
Client Address:	-	*Report No.*	WG21/8400_1_PSD
Project:	East Wanneroo Development Area	*Sample No.*	WG21/8400
Location:	Caporn Street, Mariginiup, WA	*Date Sampled:*	27-05-2021
Sample Identification:	26, 0.3m	*Date Tested:*	15/6/21-16/6/21

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: **Sampled by Client, Tested as Received**

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	
4.75	100
2.36	100
1.18	100
0.600	79
0.425	45
0.300	22
0.150	6
0.075	4



Comments:

Approved Signatory: Conell

Name: Cody O'Neill
Date: 16-June-2021

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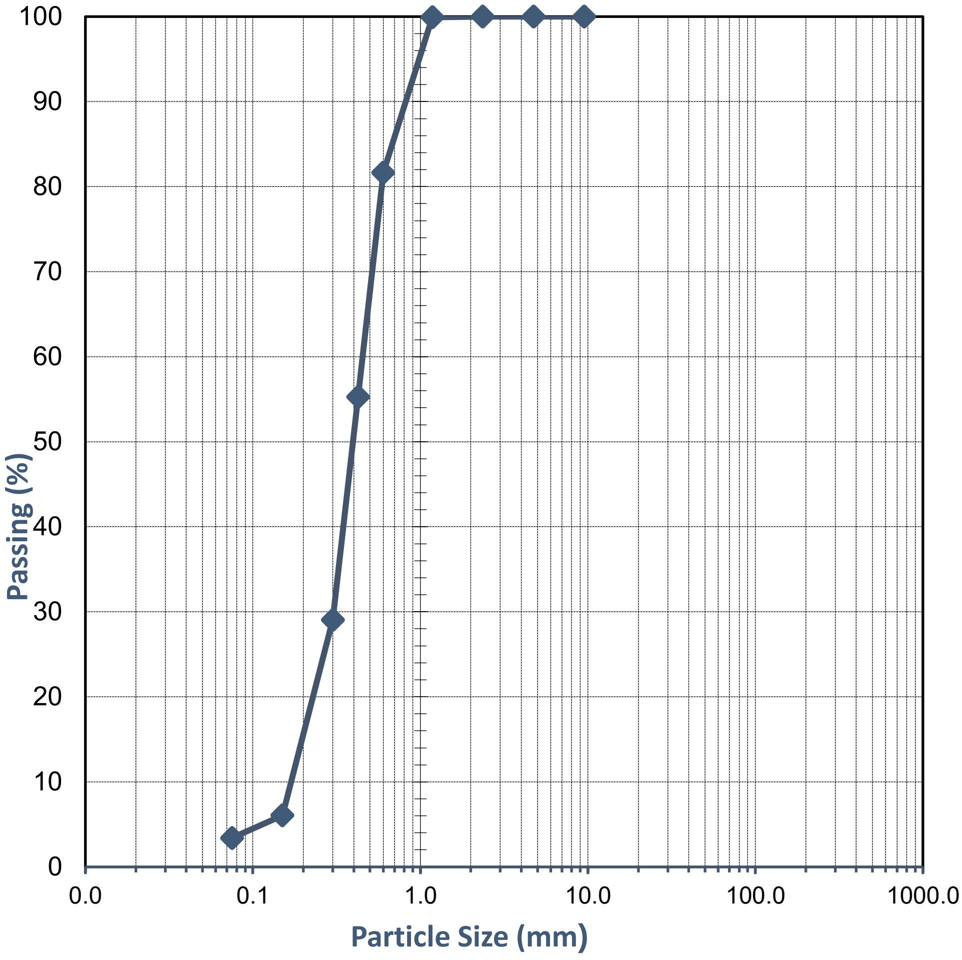
TEST REPORT - AS 1289.3.6.1

Client:	Hesperia Projects Pty Ltd	*Ticket No.*	S3429
Client Address:	-	*Report No.*	WG21/8401_1_PSD
Project:	East Wanneroo Development Area	*Sample No.*	WG21/8401
Location:	Caporn Street, Mariginiup, WA	*Date Sampled:*	27-05-2021
Sample Identification:	32, 1.2m	*Date Tested:*	15/6/21-16/6/21

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: **Sampled by Client, Tested as Received**

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	100
4.75	100
2.36	100
1.18	100
0.600	82
0.425	55
0.300	29
0.150	6
0.075	3



Comments:

Approved Signatory: Coneill

Name: Cody O'Neill

Date: 16-June-2021

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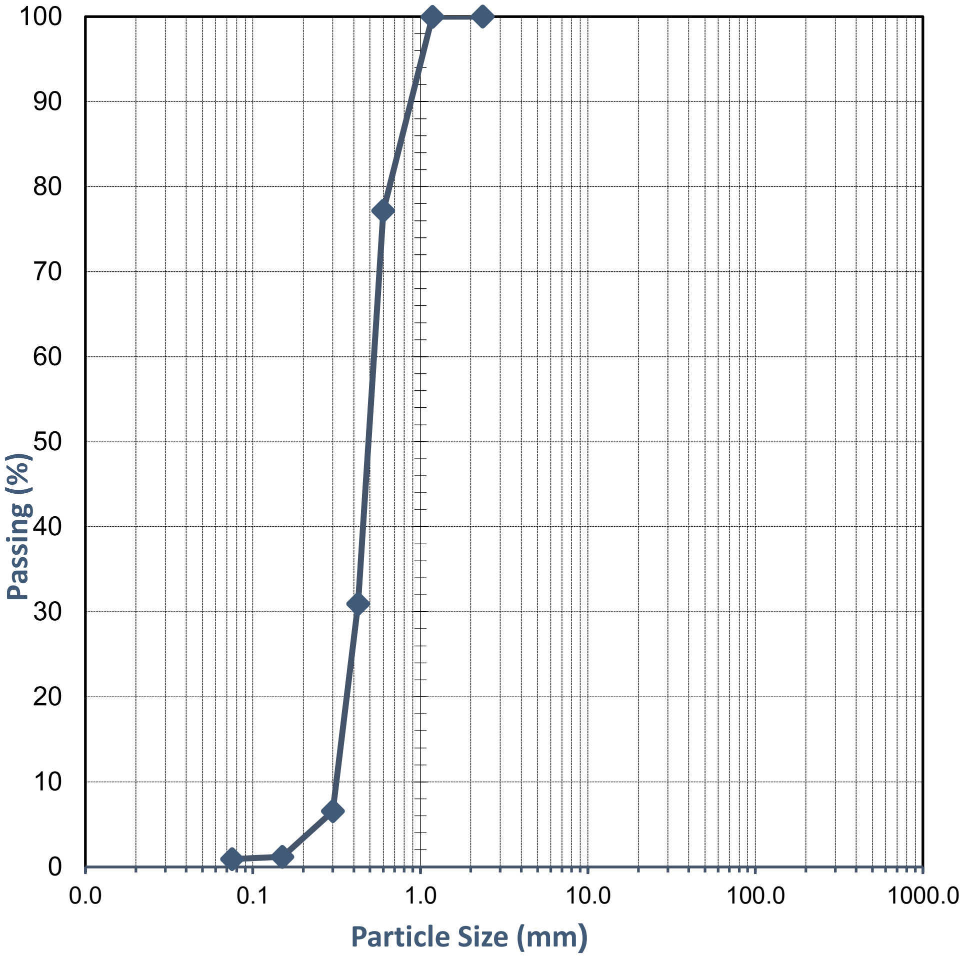
TEST REPORT - AS 1289.3.6.1

Client:	Hesperia Projects Pty Ltd	*Ticket No.*	S3429
Client Address:	-	*Report No.*	WG21/8402_1_PSD
Project:	East Wanneroo Development Area	*Sample No.*	WG21/8402
Location:	Caporn Street, Mariginiup, WA	*Date Sampled:*	27-05-2021
Sample Identification:	33, 1.15m	*Date Tested:*	15/6/21-16/6/21

TEST RESULTS - Particle Size Distribution of Soil

Sampling Method: **Sampled by Client, Tested as Received**

Sieve Size (mm)	Percent Passing Sieve (%)
150.0	
100.0	
75.0	
37.5	
19.0	
9.5	
4.75	
2.36	100
1.18	100
0.600	77
0.425	31
0.300	7
0.150	1
0.075	1



Comments:

Approved Signatory: Coneill

Name: Cody O'Neill

Date: 16-June-2021

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Appendix E Groundwater Licences

Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

SLR Project No.: 675.V64450.00000

6 December 2023

Precinct 7 Groundwater Licences

Licence Number	Licence Type	Issue Date	Expiry Date	Licence Allocation (kL)	Aquifer
108927	Groundwater Licence	02/09/2015	01/09/2025	31,150	Perth - Superfical Swan
183489	Groundwater Licence	03/02/2017	02/02/2027	31,240	Perth - Superfical Swan
152038	Groundwater Licence	17/11/2020	16/11/2022	52,300	Perth - Superfical Swan
174990	Groundwater Licence	02/10/2017	07/04/2025	55,750	Perth - Superfical Swan
87456	Groundwater Licence	21/02/2019	20/02/2029	13,950	Perth - Superfical Swan
179521	Groundwater Licence	24/10/2014	23/10/2024	28,150	Perth - Superfical Swan
78456	Groundwater Licence	14/11/2019	13/11/2029	11,500	Perth - Superfical Swan
58050	Groundwater Licence	13/10/2011	13/10/2021	17,500	Perth - Superfical Swan
58051	Groundwater Licence	08/09/2016	07/09/2026	2,450	Perth - Superfical Swan
80979	Groundwater Licence	25/07/2016	24/07/2026	25,400	Perth - Superfical Swan
84168	Groundwater Licence	04/10/2012	04/10/2022	19,500	Perth - Superfical Swan
48025	Groundwater Licence	27/11/2013	26/11/2023	30,650	Perth - Superfical Swan
106783	Groundwater Licence	15/10/2015	14/10/2025	3,350	Perth - Superfical Swan
84169	Groundwater Licence	26/06/2019	25/06/2029	9,700	Perth - Superfical Swan
58321	Groundwater Licence	05/12/2016	04/12/2026	26,150	Perth - Superfical Swan
63248	Groundwater Licence	13/04/2018	05/01/2026	12,650	Perth - Superfical Swan
200080	Groundwater Licence	20/07/2017	20/07/2022	5,000	Perth - Superfical Swan
107424	Groundwater Licence	06/11/2013	05/11/2023	8,400	Perth - Superfical Swan
106995	Groundwater Licence	01/08/2013	01/08/2023	4,150	Perth - Superfical Swan
58322	Groundwater Licence	05/01/2017	04/01/2027	6,000	Perth - Superfical Swan
181436	Groundwater Licence	24/08/2015	23/08/2025	9,450	Perth - Superfical Swan
100612	Groundwater Licence	24/07/2015	23/07/2025	5,700	Perth - Superfical Swan
55658	Groundwater Licence	09/07/2012	05/07/2022	14,900	Perth - Superfical Swan
98147	Groundwater Licence	06/08/2012	06/08/2022	10,150	Perth - Superfical Swan
150779	Groundwater Licence	27/05/2013	07/01/2023	15,750	Perth - Superfical Swan
52204	Groundwater Licence	17/12/2020	16/12/2030	77,850	Perth - Superfical Swan
49704	Groundwater Licence	01/07/2021	08/12/2025	30,750	Perth - Superfical Swan
88959	Groundwater Licence	06/08/2013	05/08/2023	13,400	Perth - Superfical Swan
106734	Groundwater Licence	19/11/2013	13/11/2023	16,900	Perth - Superfical Swan
84316	Groundwater Licence	29/07/2019	28/07/2029	23,050	Perth - Superfical Swan
75696	Groundwater Licence	09/07/2019	08/07/2029	19,500	Perth - Superfical Swan
75716	Groundwater Licence	18/06/2019	17/06/2029	3,050	Perth - Superfical Swan
108652	Groundwater Licence	11/03/2014	06/03/2024	20,150	Perth - Superfical Swan
108653	Groundwater Licence	07/09/2017	06/09/2027	11,690	Perth - Superfical Swan
75698	Groundwater Licence	18/07/2019	17/07/2029	121,500	Perth - Superfical Swan
107062	Groundwater Licence	21/02/2018	01/02/2028	50,000	Perth - Superfical Swan
156450	Groundwater Licence	14/09/2020	31/12/2022	52,850	Perth - Superfical Swan
157859	Groundwater Licence	05/01/2018	04/01/2028	13,375	Perth - Superfical Swan
75697	Groundwater Licence	14/07/2014	13/07/2024	4,850	Perth - Superfical Swan
59007	Groundwater Licence	06/05/2019	05/05/2029	30,330	Perth - Superfical Swan
205636	Groundwater Licence	12/03/2021	11/03/2031	25,050	Perth - Superfical Swan
202478	Groundwater Licence	21/02/2019	20/02/2029	30,650	Perth - Superfical Swan
153115	Groundwater Licence	13/11/2014	12/11/2024	48,650	Perth - Superfical Swan
46886	Groundwater Licence	14/06/2021	13/06/2023	16,850	Perth - Superfical Swan
97810	Groundwater Licence	24/09/2014	23/09/2024	7,400	Perth - Superfical Swan
155299	Groundwater Licence	05/10/2021	04/10/2031	18,650	Perth - Superfical Swan
63455	Groundwater Licence	20/08/2015	25/06/2025	15,300	Perth - Superfical Swan
65896	Groundwater Licence	16/07/2021	15/07/2031	10,700	Perth - Superfical Swan
46936	Groundwater Licence	13/11/2013	12/11/2023	18,604	Perth - Superfical Swan
52578	Groundwater Licence	24/11/2017	23/11/2027	12,650	Perth - Superfical Swan
200368	Groundwater Licence	16/09/2021	15/09/2031	16,800	Perth - Superfical Swan
84679	Groundwater Licence	27/06/2016	26/06/2026	6,936	Perth - Superfical Swan
50724	Groundwater Licence	23/08/2019	22/08/2029	26,900	Perth - Superfical Swan
57428	Groundwater Licence	12/07/2016	11/07/2026	37,450	Perth - Superfical Swan
178922	Groundwater Licence	24/04/2014	23/04/2024	32,700	Perth - Superfical Swan
200138	Groundwater Licence	14/03/2018	06/08/2027	27,000	Perth - Superfical Swan
166367	Groundwater Licence	11/03/2014	06/03/2024	14,700	Perth - Superfical Swan
109670	Groundwater Licence	24/04/2014	23/04/2024	13,150	Perth - Superfical Swan
162000	Groundwater Licence	21/02/2017	20/02/2027	14,350	Perth - Superfical Swan
153503	Groundwater Licence	23/04/2018	22/04/2028	7,300	Perth - Superfical Swan
156292	Groundwater Licence	11/08/2016	10/08/2026	14,700	Perth - Superfical Swan

Total	1,356,625

Groundwater Licence WRI_Number	Location	Groundwater Area	Sub-Area	Aquifer	Allocation (KL)	Location of the bore within the site
108927	Lot 5 Pinjar Rd Mariginiup	Wanneroo	Mariginiup	Perth – Superficial Swan	31150	East of Lake Mariginiup
183489	Lot 100 Pinjar Rd Mariginiup	Wanneroo	Mariginiup	Perth - Superficial Swan	31240	West
152038	Lot 7 Pinjar Rd Mariginiup	‘’	‘’	‘’	52300	‘’
78456	39, WELLS ST, MARIGINIUP	‘’	‘’	‘’	11500	South- West
179521	Lot 2 Wells St Mariginiup	‘’	‘’	‘’	28150	‘’
87456	Lot 1 Wells St Mariginiup	‘’	‘’	‘’	13950	‘’
174990	Lot 10 Caporn St Mariginiup	‘’	‘’	‘’	55750	South of Lake Mariginiup
58050		‘’	‘’	‘’	17500	‘’
84168	Lot 2 Caporn St, Mariginiup	‘’	‘’	‘’	19500	‘’
48025	Lot 3 Caporn Street Mariginiup	‘’	‘’	‘’	30650	‘’
84169	Lot 40 Caporn St Mariginiup	‘’	‘’	‘’	9700	‘’
58321	Lot 41 Caporn Street Mariginiup	‘’	‘’	‘’	26150	‘’
55658	Lot 14 Honey St Mariginiup	‘’	‘’	‘’	14900	South East of Lake Mariginiup

Groundwater Licence WRI_Number	Location	Groundwater Area	Sub-Area	Aquifer	Allocation (KL)	Location of the bore within the site
98147	Lot 13 Honey Street Mariginiup				10150	
150779	Lot 11 Caporn St, Mariginiup				15750	
52204	Lot 14 Dundebar Rd Wanneroo				77850	
100612	Lot 91 Honey St Mariginiup				5700	
49704	Lot 502 Honey St Mariginiup Lot 501 Honey St Mariginiup Lot 504 Honey St Mariginiup Lot 503 Mariginiup Rd Mariginiup LOT 101 COOGEE ROAD MARIGINIUP 6078				30750	
153561	71, HONEY ST, MARIGINIUP				9000	
60161	LOT 72 HONEY STREET MARIGINIUP 6078				28800	
84316	Lot 20 Coogee Rd, Mariginiup					

Groundwater Licence WRI_Number	Location	Groundwater Area	Sub-Area	Aquifer	Allocation (KL)	Location of the bore within the site
	Lot 51Caporn St Mariginiup					
106734	Lot 101 Mariginiup Road Mariginiup				16900	
88959	Lot 102 Mariginiup Road Mariginiup				13400	
108652	61, MARIGINIUP RD, MARIGINIUP				20150	
108653	60, ROUSSET RD, MARIGINIUP				11690	
75716	Lot 13 Rousset Rd Mariginiup				3050	
75696	14, ROUSSET RD, MARIGINIUP				19500	
178922	Lot 5 Franklin Road Jandabup				32700	
200138	LOT 8 FRANKLIN ROAD JANDABUP 6077					
166367	Lot 201 Rousset Rd Jandabup				14700	
109670	Lot 60 Rousset Road, Jandabup				13150	
162000	Lot 61 Rousset Road Jandabup				14350	

Groundwater Licence WRI_Number	Location	Groundwater Area	Sub-Area	Aquifer	Allocation (KL)	Location of the bore within the site
153503	20, ROUSSET RD, JANDABUP				7300	
156292	Lot 21 Rousset Rd Jandabup				14700	
75698	LOT 21 ON DIAGRAM 30248				121500	
107062	20, ROUSSET RD, MARIGINIUP LOT 28 MARIGINIUP ROAD MARIGINIUP 6078				50000	East of Lake Mariginiup
57028	Lot 28 Mariginiup Rd Mariginiup				52915	
156450	Lot 20 Rousset Rd Mariginiup Lot 291 Rousset Rd Mariginiup Lot 28 Mariginiup Rd Mariginiup				52850	
75697	Lot 292 Rousset Rd Mariginiup				4850	
59007	30, ROUSSET RD, MARIGINIUP				30330	
202478	LOT 22 LAKEVIEW STREET MARIGINIUP 6078				30650	

Groundwater Licence WRI_Number	Location	Groundwater Area	Sub-Area	Aquifer	Allocation (KL)	Location of the bore within the site
153115	Lot 6 Lakeview St Mariginiup				48650	
46886	Lot 5 Lakeview St Mariginiup				16850	
97810	25, LAKEVIEW ST, MARIGINIUP				7400	
155299	Lot 24 Lakeview Street Mariginiup				18650	
63455	Lot 29 Lakeview St Mariginiup				15300	
65896	30, LAKEVIEW ST, MARIGINIUP				10700	
52578	LOT 102 LAKEVIEW STREET MARIGINIUP 6078				12650	
200368	LOT 16 MARIGINIUP ROAD MARIGINIUP 6078 LOT 2287 ROUSSET ROAD MARIGINIUP 6078				13650	North East of Lake Mariginiup
84679	555, MARIGINIUP RD, MARIGINIUP				6936	
50724	Lot 14 Mariginiup Rd Mariginiup				26900	East

Groundwater Licence WRI_Number	Location	Groundwater Area	Sub-Area	Aquifer	Allocation (KL)	Location of the bore within the site
57428	13, MARIGINIUP RD, MARIGINIUP				38450	

Appendix F Preliminary Landscape Master Plans

Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

SLR Project No.: 675.V64450.00000

6 December 2023

REFER TO LOCAL STRUCTURE PLAN REPORT

APPENDIX 6:

LANDSCAPE MASTERPLAN

Appendix G Water Balance

Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

SLR Project No.: 675.V64450.00000

6 December 2023

WATER CORPORATION

DATA ANALYSIS AUSTRALIA

Introduction

Welcome to the Water Corporation's Water Balance Tool. This tool is designed to assist in profiling anticipated water use for your development. It can be used to characterise water use in Residential developments, Schools, Commercial and Industrial areas.

Simply enter information about your development into the yellow boxes in each data sheet, and the model calculates the water consumption per annum based on the figures in the Parameters & Assumptions data sheet.

To ensure that you capture all of your land, the model will check the information you enter in each sheet against the total development area you have specified, for example the total area of Residential development, and the model adds up the block sizes specified and checks if that matches the total. A warning message is displayed if it does not, however this won’t stop the model from working.

Below are some notes to assist you as you work through each of the data sheets in the model. To get started select the Water Summary data sheet and then work through each of the pages.

Water Summary

This page shows the Water Demand and Water Use summaries including the kL/person/year (Total broken down by Potable and Non-Potable) and the total kL/year metrics. It also asks for information such as the total area of the development (yellow boxes), this is then checked against each of the area totals for each subsection (which is taken from the respective page). All other information is taken from the other sheets you complete.

Summary Detail

This page summarises all of the outputs from the Residential developments, Schools, Commercial & Industrial and Other areas. This page also indicates whether the development's water consumption meets targets set in the Assumptions & Parameters page.

Water Balance

Expected water supply from alternative non-potable sources is entered here, as well as the indicative security of the supply. The Water Balance section calculates whether the supply of non-potable water meets the demand for non-potable water as entered on each of the Residential, Schools and Commercial & Industrial pages.

Total water expected water supply should be divided into supply that is generated internally (i.e. on site) and supply that comes externally to the development site.

A negative output shows that the supply from non-potable alternative water sources does not meet the demand, therefore there is a shortfall in potable water in order to meet total development demand. A positive output indicates that the supply of non-potable water in the development exceeds the estimated demand and there is excess potable water.

1. Residential

The household types, number of lots and lot sizes are entered here. The total area of the Residential component is entered at the top of the page. The model allows for up to 20 different household type/lot size combinations. For example, Traditional houses with lot sizes 400 and 450 m^2 can be entered on different lines. The Irrigation area defaults are displayed in the Parameters & Assumptions sheet, but this can be overwritten.

Your Alternative Water Supply Source is specified at the bottom of the page. Note that if a check box is not ticked then the model will ignore this source, even if a value is entered in one of the boxes.

2. Schools

The type of School and numbers of students are entered here. The total area of the School should be entered at the top of the page. Up to five schools can be entered into the model. The model requires the total number of students per school and the total area, including Irrigation area. The Irrigation area default is displayed in the Parameters and Assumptions sheet, but this can be overwritten.

Your Alternative Water Supply Source is specified at the bottom of the page. Note that if a check box is not ticked then the model will ignore this source, even if a value is entered in one of the boxes.

3. Commercial & Industrial

Commercial & Industrial types are entered here. The total area of the Commercial & Industrial component should be entered at the top of the page. Up to 15 types of Industry can be specified in the model. Depending on the type of industry, different information is required. In all cases the total land area of the industry type is required.

Your Alternative Water Supply Source is specified at the bottom of the page. Note that if a check box is not ticked then the model will ignore this source, even if a value is entered in one of the boxes.

4. POS, Roads & Verges

The total area of the POS, Roads & Verges component should be entered at the top of the page. The areas of POS are required including Bushland – which is assumed to have a zero water requirement. For Active POS, you are also asked to estimate the Water Use of Amenities associated – such as drinking water fountains, shower blocks, etc – as this is out of scope for the model.

Your Alternative Water Supply Source is specified at the bottom of the page. Note that if a check box is not ticked then the model will ignore this source, even if a value is entered in one of the boxes.

5. Other

The total area of the Other component automatically calculated at the top of the page. This data sheet is designed to capture any small areas that have not been covered and also Infrastructure Corridors. The areas specified should not be substantive (with the possible exception of Infrastructure Corridors) and should only be used as a means to ensure the total area of the development tallies.

This data sheet requires that the subsection totals have been entered otherwise the area entered here will be ignored.

Your Alternative Water Supply Source is not specified here as it is assumed the alternatives specified in the respective pages are used.

Note:

Please note that in future reference may be made to peaking factor and changes in demand, due to firefighting demand requirements, inclusion of alternative non-drinking water sources, and waterwise garden and irrigation systems.

Water Use Summary

The Water Use tool is primarily aimed at residential developments but can handle mixed deve

Developer: Hesperia

Development Name: Precinct 7 East Wanneroo

Date Of Entry:

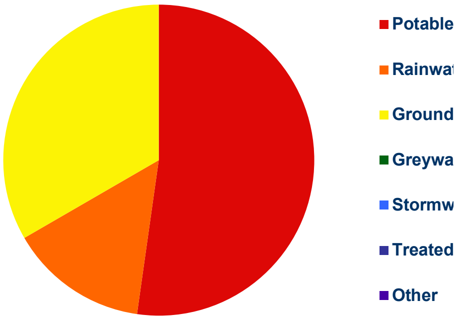
Total Area of Development (m^2): 2,402,355

Area Totals Don't Match

Water Demand

Water demand by source type in kL/year.

Potable water[1]	545,474
Rainwater	150,516
Groundwater	348,486
Greywater	0
Stormwater	0
Treated wastewater	0
Other	0



Water Use

Summa

Water use for total development and by sub-section.

	Total Water[2] (kL/person/year)	Potable Water[2] (kL/person/year)	Non-Potable Water[2] (kL/person/year)
Consumption Indicators	92	71	21

Development Summary

Click on subsection to go to page.

		Area (m^2)	Irrigation (kL/year)	Drinking[1] (kL/year)
1.	Residential	1,127,107	200,920	258,879
2.	Schools	160,172	61,506	7,570
3.	Commercial & Industrial	12,600	1,425	22,807
4.	Public Open Spaces, Roads, Footpaths & Verges	379,137	286,980	
5.	Other			
	TOTAL	1,679,016	550,831	289,256

[1] All drinking water needs are met by Potable water.

[2] These consumption indicators relate to the residential segment only.

elopments.

09-11-2021

elp/Notes (Click)

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l wastewater

y in Detail (Click)

Development Consumption (kL/year)
1,044,475

Non-Drinking (kL/year)
195,065
5,046
4,276
204,388

Water Use Summary in Detail

Total Area of Development (m^2): 2,402,355

Summary Page (Click)

Click on numbered subsection to go to page

Per Capita Summary[1]	Overall	Target Met?	1. Residential	2. Schools	3. Commercial & Industrial	4. POS, Roads & Verges	5. Other
kL/Person/Year (Total)[2,3,4]	92	✓	92	N/A	N/A	N/A	N/A
kL/Person/Year (Potable)	71	N/A	71	N/A	N/A	N/A	N/A
kL/Person/Year (potable in-house)[5]	N/A	N/A	41	N/A	N/A	N/A	N/A
kL/Person/Year (potable ex-house)	N/A	N/A	30	N/A	N/A	N/A	N/A
kL/Person/Year (Non-Potable)	21	N/A	21	N/A	N/A	N/A	N/A
kL/Year (non-potable in-house)	N/A	N/A	14	N/A	N/A	N/A	N/A
kL/Year (non-potable ex-house)	N/A	N/A	7	N/A	N/A	N/A	N/A
Per Year Summary							
kL/Year (Total)[2]	1,044,475	N/A	654,864	74,122	28,509	286,980	0
kL/Year (Irrigation)	550,831	N/A	200,920	61,506	1,425	286,980	0
kL/Year (Drinking)	289,256	N/A	258,879	7,570	22,807	0	0
kL/Year (Non-Drinking)	204,388	N/A	195,065	5,046	4,276	0	0
kL/ha/Year (Irrigation)[6]	14,323	✗	1,783	3,840	1,131	7,569	0
kL/Year (Potable)	545,474	N/A	504,349	12,616	28,509	0	0
kL/Year (potable in-house)	N/A	N/A	290,600	N/A	N/A	N/A	N/A
kL/Year (potable ex-house)	N/A	N/A	213,749	N/A	N/A	N/A	N/A
kL/Year (Non-Potable)	499,002	N/A	150,516	61,506	0	286,980	0
kL/Year (non-potable in-house)	N/A	N/A	98,514	N/A	N/A	N/A	N/A
kL/Year (non-potable ex-house)	N/A	N/A	52,002	N/A	N/A	N/A	N/A

Targets

[3] Within Metropolitan Residential Average

[4] Above Development Estate Average

[6] Exceeds Dept of Water Irrigation Allowance

[1] The Per Capita Summary is only applicable to Residential

[2] Total refers to both Potable & Non-Potable Water

[5] See Parameter & Assumptions for in- & ex-house definitions

Water Balance

Please enter water supply and security of supply into the yellow boxes.

Water Supply

Summary Page (Click)

Water supply by source type in kL/year. Total water supply should be divided into:
1. Supply from within the development site; and
2. Supply that is external to the site.

	Internal to Site	External to Site	Security of Supply
Rainwater	151,507		
Groundwater	1,300,000		10 years
Greywater			
Stormwater			
Treated wastewater			
Other			

Water Demand

Summary Page (Click)

Water demand by source type in kL/year. From the Water Summary page.

Potable water	545,474
Rainwater	150,516
Groundwater	348,486
Greywater	0
Stormwater	0
Treated wastewater	0
Other	0
Total	1,044,476

Water Balance

Water balance by source type is the Water Demand less the Water Supply in kL/year.
A negative balance indicates a shortfall in supply. A positive balance indicates a surplus of supply.

	Shortfall in Supply	Excess in Supply
Rainwater		991
Groundwater		951,514
Greywater		
Stormwater		
Treated wastewater		
Other		

Additional Potable Water Required (kL/year) 0

1. Residential

Please Enter Total Residential Area

Total Area (m²): 1,127,107

Area Running Total (m²): 1,127,107 **Area Totals Match**

Total Residential Water Use

Summary Page (Click)

Per Capita Summary

kL/Person/Year (Total)[1]	92
kL/Person/Year (Potable)	71
kL/Person/Year (in-house)[2]	41
kL/Person/Year (ex-house)	30
kL/Person/Year (Non-Potable)	21
kL/Person/Year (in-house)	14
kL/Person/Year (ex-house)	7

Per Year Summary

kL/Year (Total)[1]	654,864
kL/Year (Irrigation)	200,920
kL/Year (Drinking)	258,879
kL/Year (Non-Drinking)	195,065
kL/ha/Year (Irrigation)	1,783
kL/Year (Potable)	504,349
kL/Year (in-house)	290,600
kL/Year (ex-house)	213,749
kL/Year (Non-Potable)	150,516
kL/Year (in-house)	98,514
kL/Year (ex-house)	52,002

[1] Total refers to Potable & Non-Potable Water

[2] See Parameter & Assumptions for in- & ex-house definitions

Residential Information

Summary Page (Click)

Multiple residency types are possible.

Help/Notes (Click)

Household Type	Lots	Households (per Lot)	Area (m²/Lot)	Irrigation Area (m²/Lot)
Traditional	141	1	555	139
Traditional	501	1	450	113
Traditional	1,052	1	375	94
Cottage	1,077	1	314	79
Apartment	343	1	265	58

Water Sources

Summary Page (Click)

Select possible water sources and their contribution to Irrigation or Non-Drinking water use.

Model only uses water source when check box is ticked.

Source	Select Source(s)	Source Contribution (%)	
		Irrigation	Non-Drinking
Potable water		74	49
Rainwater*	☑	26	51
Groundwater	☐		
Greywater	☐		
Stormwater	☐		
Treated wastewater	☐		
Other	☐		
TOTAL ALTERNATE		26	51

Apply Rainwater to:
☑ Irrigation
☑ Non-drinking

* Rainwater proportion calculated automatically and split between Irrigation and Non-drinking

2. Schools

Please Enter Total School Area

Total Area (m^2): 160,172

Area Running Total (m^2): 160,172 Area Totals Match

Total Schools Water Use

Summary Page (Click)

Per Year Summary

kL/Year (Total)[1]	74,122
kL/Year (Irrigation)	61,506
kL/Year (Drinking)	7,570
kL/Year (Non-Drinking)	5,046
kL/ha/Year (Irrigation)	3,840
kL/Year (Potable)	12,616
kL/Year (Non-Potable)	61,506

[1] Total refers to Potable & Non-Potable Water

School Information

Summary Page (Click)

Multiple school sizes are possible.

Help/Notes (Click)

School Type	Students	Area (m^2/School)	Irrigation Area (m^2/School)
High School	800	80,014	32,006
Primary School	400	40,000	16,000
Primary School	400	40,158	16,063

Water Sources

Summary Page (Click)

Select possible water sources and their contribution to Irrigation or Non-Drinking water use.

Model only uses water source when check box is ticked.

Source	Select Source(s)	Source Contribution (%) Irrigation	Non-Drinking
Potable water		0	100
Rainwater*	☐	0	0
Groundwater	☑	100	0
Greywater	☐		
Stormwater	☐		
Treated wastewater	☐		
Other	☐		
TOTAL ALTERNATE		100	0

Apply Rainwater to:
☑ Irrigation
☑ Non-drinking

* Rainwater proportion calculated automatically and split between Irrigation and Non-drinking

3. Commercial & Industrial

Please Enter Total Commercial & Industrial Area

Total Area (m^2): 12,600

Area Running Total (m^2): 12,600 Area Totals Match

Total Commercial & Industrial Water Use

Summary Page (Click)

Per Year Summary

kL/Year (Total)	28,509
kL/Year (Irrigation)	1,425
kL/Year (Drinking)	22,807
kL/Year (Non-Drinking)	4,276
kL/ha/Year (Irrigation)	1,131
kL/Year (Potable)	28,509
kL/Year (Non-Potable)	0

[1]Total refers to Potable & Non-Potable Water

Commercial & Industrial Information

Summary Page (Click)

Multiple types of Hotel, Nursing Home and Hospital are possible.

Help/Notes (Click)

Use the check boxes at the end of each line to indicate the use of alternative water sources.

Industry Type	Gross Area (m^2)	Gross Lettable Area[1] (m^2)	Number of Units[2]	Unit Type	
Hospitality	12,600		50	ENTITIES	☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐
					☐

[1] For Commercial/Office spaces, Retail Centres and Light Industrial/General Purpose only.

[2] For Aquatic Centres, Other Sporting Facilities, Commercial Laundries, Hospitality and Manufacturing only.

Water Sources

Summary Page (Click)

Select possible water sources and their contribution to Irrigation or Non-Drinking water use.

Model only uses water source when check box is ticked.

Source	Select Source(s)	Source Contribution (%) Irrigation	Non-Drinking
Potable water		100	100
Rainwater*	☐	0	0
Groundwater	☐		
Greywater	☐		
Stormwater	☐		
Treated wastewater	☐		
Other	☐		
TOTAL ALTERNATE		0	0

Apply Rainwater to:
☑ Irrigation
☑ Non-drinking

* Rainwater proportion calculated automatically and split between Irrigation and Non-drinking

4. POS, Roads & Verges

Please Enter Total POS, Roads & Verges Area

Total Area (m^2): 379,137

Area Running Total (m^2): 379,137 Area Totals Match

Total POS, Roads & Verges Water Use

Summary Page (Click)

Per Year Summary

kL/Year (Total)	286,980
kL/Year (Irrigation)	286,980
kL/Year (Drinking)	0
kL/Year (Non-Drinking)	0
kL/ha/Year (Irrigation)	7,569
kL/Year (Potable)	0
kL/Year (Non-Potable)	286,980

[1]Total refers to Potable & Non-Potable Water

POS, Roads & Verges Information

Summary Page (Click)

Help/Notes (Click)

For Active POS, please estimate the total water use by amenities.
E.g. water fountains and shower cubicles.

Public Open Space	Area (m^2)	Amenities (kL/Year)
Active	69,269	
Passive	309,868	
Bushland/Non-Irrigated Areas		
Roads & Paths		
Verges		
Street Scaping		

Water Sources

Summary Page (Click)

Select possible water sources and their contribution to Irrigation or Non-Drinking water use.

Model only uses water source when check box is ticked.

Source	Select Source(s)	Source Contribution (%) Irrigation	Source Contribution (%) Non-Drinking[1]
Potable water		0	100
Rainwater[2]	☐	0	0
Groundwater	☑	100	0
Greywater	☐		
Stormwater	☐		
Treated wastewater	☐		
Other	☐		
TOTAL ALTERNATE		100	0

Apply Rainwater to:
☑ Irrigation
☑ Non-drinking

[1] Non-Drinking water use for POS amenities.

[2] Rainwater proportion calculated automatically and split between Irrigation and Non-drinking

5. Other

Please Enter Total Other Area

Total Area (m^2): 0

Area Running Total (m^2): Area Totals Don't Match

Total Other Water Use

Summary Page (Click)

Per Year Summary

kL/Year (Total)	0
kL/Year (Irrigation)	0
kL/Year (Drinking)	0
kL/Year (Non-Drinking)	0
kL/ha/Year (Irrigation)	0
kL/Year (Potable)	0
kL/Year (Non-Potable)	0

[1] Total refers to Potable & Non-Potable Water

Other Information

Summary Page (Click)

Total Areas on each subsection must have been completed for this to function.

Help/Notes (Click)

The comments section is optional.

Area Type	Area (m^2)	Comments
Residential		
Schools		
Commercial & Industrial		
POS, Roads & Verges		
Infrastructure Corridor		

Appendix H Stormwater Modelling Report

Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

SLR Project No.: 675.V64450.00000

6 December 2023

PENTIUM
WATER

Memo

Date: 29th November 2023
To: John Hunt
From: Dan Williams
Pages: 7 pages
Regarding: East Wanneroo Precinct 7 - Stormwater Modelling

The following provides an overview of the stormwater modelling undertaken by Pentium Water to inform the Precinct 7 Local Water Management Strategy. This memo is intended to document the methodology and outputs of the stormwater modelling, and to inform the structure planning and preliminary civil and landscape design process in terms of stormwater management basin locations and sizes.

Summary of tasks completed:

1. Review design earthworks contours against latest district-scale Controlled Groundwater Levels and consider (at a high level) potential subsoil drainage requirements and design levels.
2. Review design contours and stormwater catchments as provided by Tabec Civil Engineering Consultants. Undertake drainage catchment calculations to provide breakdown of land uses for stormwater modelling based on Structure Plan Map (HES MAR 03-05f-02).
3. Undertake sizing calculations for bioretention basins, based on assessment of direct connected impervious area, for all catchments adjacent to Lake Mariginiup or Lake Jandabup.
4. XPSWMM hydrological and hydraulic modelling to determine 1% AEP basin volume and area requirements, based on hydrologic routing and adopted loss parameters for catchments that do not outfall to Lake Mariginiup or Lake Jandabup.

Subsoil requirements

Figure 1 below provides an assessment of the preliminary design levels against the district-scale Controlled Groundwater Levels (determined in the DWMS (Urbaqua, 2021)) which indicates that there is generally approximately 3 m or more separation to the controlled groundwater level, with the minimum separation being 2.5 m along a section of the perimeter road along the south-east part of the lake. Given the separation between the design surface and the proposed controlled groundwater level, it is not anticipated that subsoil drainage is a significant design constraint for Precinct 7. However, subsoils may be installed beneath parts of the project area as a contingency against rising groundwater levels.

The minimum level at which those subsoil drains can be set has been determined as the Controlled Groundwater Level (GGL) in the District Water Management Strategy (Urbaqua, 2021), which was established as the 1986-1995 average annual maximum groundwater level. However, elevations of some areas of subsoil drainage are likely to not be practically installed at CGL given the significant depth to that level. In this instance, if it is considered necessary to install subsoil drains to control groundwater level rise, they will be installed at a more practical level (eg. 1.5m below road pavement level).

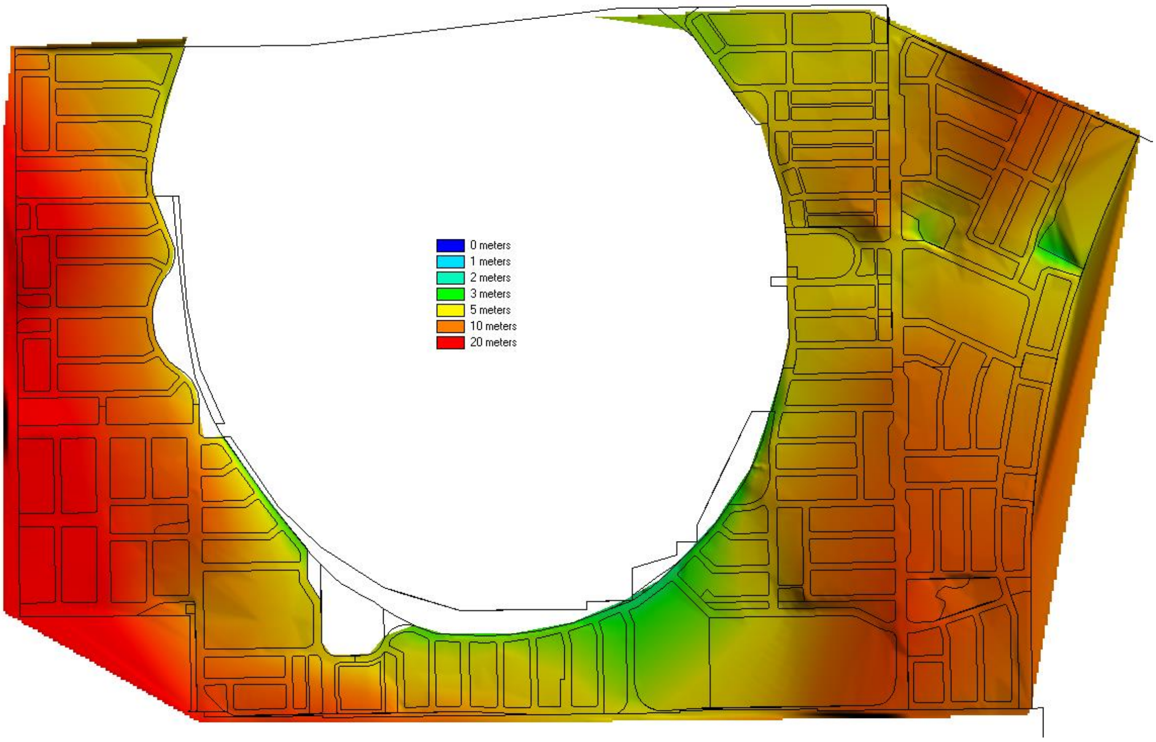

Figure 1: Approximate depth from design surface to Controlled Groundwater Level

Groundwater modelling undertaken by RPS (2021) estimated post-development groundwater levels across Precinct 7 in the scenario that the entire EWDSP area was developed and there was no district-scale groundwater level management to control the groundwater level rise that would otherwise result from the change in land use and associated increased recharge and decreased abstraction. The RPS assessment then identified areas where the separation from this post-development groundwater level to the preliminary design earthworks levels across Precinct 7 was less than 3 metres. These areas were nominated as potential subsoil drainage areas to control post-development groundwater level in Precinct 7, by discharging intercepted groundwater to Lake Mariginiup. The areas identified by RPS (2021) comprised a relatively small portion of Precinct 7 abutting the eastern and southern sides of the lake.

It is understood that a district-scale groundwater / lake water level management system will be implemented to facilitate development of the broader EWDSP area. Therefore, the preliminary assessment by RPS described above is not considered to reflect the likely post-development groundwater levels or the extent of subsoil drainage that will actually be required in Precinct 7.

The minimum design earthworks level along the eastern and southern sides of Lake Mariginiup is approximately 45.5 mAHD (and only in very minor areas, with design levels typically being much higher than this). A 2020 review into the water level thresholds for the management of Gnangara Mound wetlands in accordance with Ministerial Statement No. 819 (Kavazos et al., 2020) proposes a maximum water level threshold for Lake Mariginiup of 42.6 mAHD. This is, therefore, the maximum level at which the district-scale groundwater level control system would maintain water levels in Lake Mariginiup (other than, potentially, for short periods following large or successive rainfall events).

Whilst more significant groundwater rise / mounding beneath the Precinct 7 development area is possible, it is considered unlikely that subsoil drainage will be required in Precinct 7, with the possible exception of some localised areas fringing Lake Mariginiup. Based on the preliminary design levels described above (ie. minimum 45.5 mAHD), any such subsoil drainage will be able to outlet well above the maximum / controlled water level in Lake Mariginiup for treatment prior to discharge to the lake.

It is understood that subsoil drainage will be required to be treated outside of wetland buffers and then overland flow into the lake, with no or minimal alteration of natural surface levels through wetland buffer areas. This design outcome is achievable based on the preliminary design levels, and it is noted that there also exists opportunity to locally adjust (ie. lift) the design earthworks levels at the detailed design stage if required in any locations to facilitate subsoil drainage treatment and outlet level requirements.

It is anticipated that specific locations requiring subsoil drainage will be defined at the subdivision stage and documented in future Urban Water Management Plans, once the district-scale groundwater management system and associated groundwater modelling is further progressed.

Stormwater catchments

Figure 2 below provides the post-development stormwater catchments. The stormwater management strategy is described in the LWMS and broadly comprises:

- For catchments that drain to locations adjacent to Lake Mariginiup or Lake Jandabup: retention, treatment and infiltration of runoff generated from constructed impervious surfaces during the first 15mm of rainfall, with larger events allowed to overtop the bioretention basins and flow (as overland flow through vegetated areas) towards the lakes for flood storage.
- For catchments that drain to low points not associated with either of the lakes: treatment of the first 15mm event and flood storage (via retention and infiltration) of larger events up to 1% AEP within landscaped drainage basins in POS areas.

It is noted that Catchments P and U grade eastwards towards Lake Jandabup and stormwater from these catchments will be managed in the relatively low-lying area on the eastern boundary of Precinct 7 adjoining WAPC-owned land which is zoned ‘Parks and Recreation’ in the MRS and is associated with the Lake Jandabup foreshore. These catchments will retain, treat, and infiltrate the 15 mm event within the POS proposed along the eastern boundary of Precinct 7 prior to discharging as overland flow towards Lake Jandabup. This is consistent with the principles of the DWMS which shows this eastern portion of Precinct 7 as ultimately discharging to Lake Jandabup.

It is also noted that there is some external catchment area to the south of Precinct 7 which will contribute stormwater flows into Precinct 7. No specific assessment or modelling of the catchment area to the south of the Precinct 7 LSP has been undertaken as it is assumed that the drainage design for the (external) Precinct 6 area will involve treating the first 15mm within its own LSP area and larger events simply being conveyed through Precinct 7 to discharge to Lake Mariginiup. Figure 2 shows the two locations of external catchment inflows along the southern boundary of Precinct 7, as per the DWMS (Urbaqua, 2021). Also noted on the figure is the peak 1% AEP flow estimates provided in the DWMS. The DWMS flags these flow paths as potentially being overland flow through a large conveyance swale. The Precinct 7 structure plan has considered and responded to these flow paths with provision for open channel conveyance along Caporn Street (within the High School site) and through POS 5 towards Lake Mariginiup.

Pentium Water considers that the DWMS flow estimates may be very conservative, given the sandy site conditions, and opportunity for infiltration and detention of flows higher in the catchment (thus reducing the magnitude of flows and size of drainage infrastructure through Precincts 6 and 7). However, no further assessment has been made on this given the flows will be generated outside of Precinct 7 and the planning, earthworks and drainage details for that external catchment area (Precinct 6) are unknown. Therefore, Pentium Water considers that in the absence of more refined drainage design for Precinct 6, the LWMS for Precinct 7 should accommodate the external flow rates identified in the DWMS. There is the potential for any land take associated with drainage corridors for these external flows to be recouped at a later date should the future planning and water management for Precinct 6 result in significantly smaller inflows to Precinct 7.

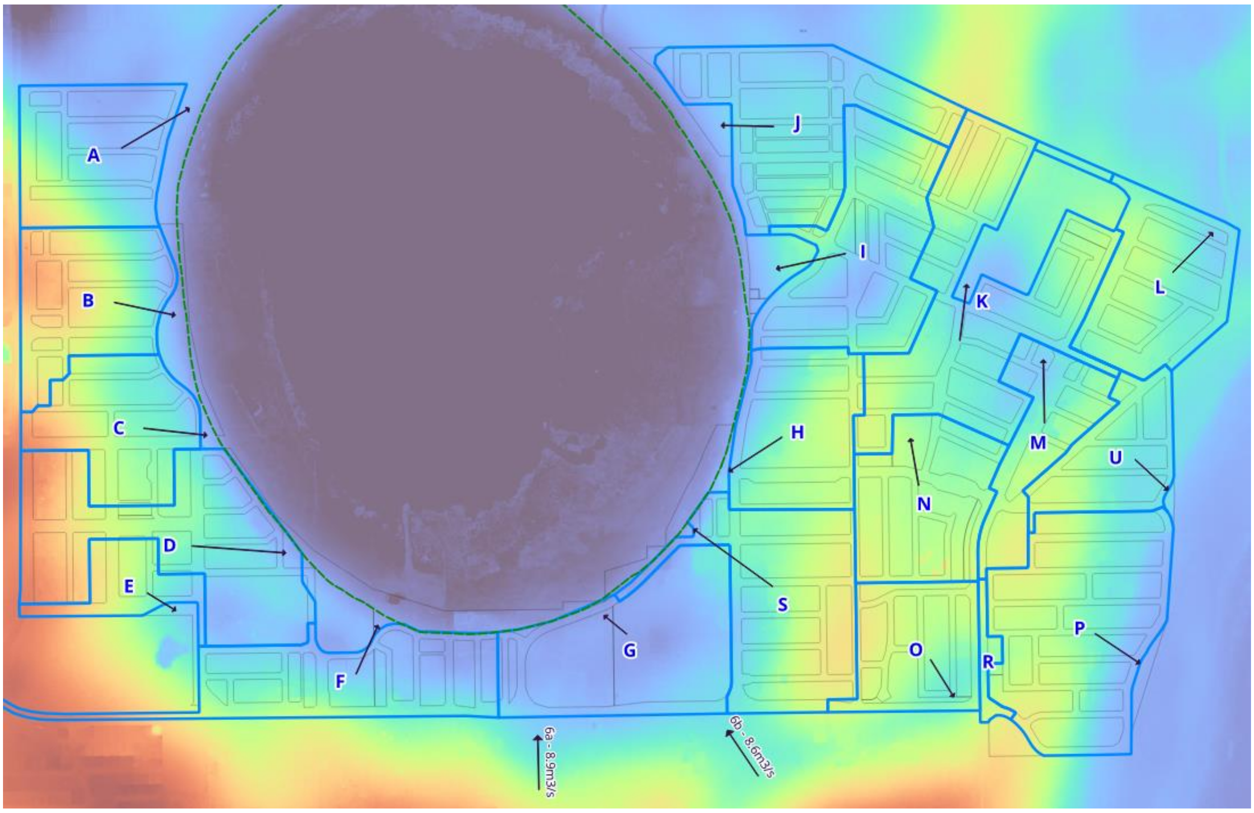

Figure 2: *Stormwater catchments (colour shading shows existing topography)*

A detailed breakdown of land uses within each stormwater catchment (according to Structure Plan Map HES MAR 03-05f-02) is provided in Table 1 below.

Table 1: *Catchment area breakdown*

CATCHMENT	TOTAL	ROAD	R30	R40	SPECIAL USE	POS	SCHOOL
A	11.722	5.308	0.000	3.786	0.000	2.628	0.000
B	11.565	7.283	0.000	4.282	0.000	0.000	0.000
C	10.442	6.967	0.000	3.475	0.000	0.000	0.000
D	18.683	7.914	0.000	5.097	0.000	1.701	3.971
E	4.360	1.976	0.000	2.299	0.000	0.085	0.000
F	13.749	5.950	0.000	6.495	1.260	0.044	0.000
G	16.336	0.418	0.000	2.709	0.000	4.141	9.068
H	10.871	3.408	0.000	3.455	0.000	0.000	4.008
I	15.547	9.146	0.095	5.940	0.000	0.366	0.000
J	16.360	1.413	8.815	6.132	0.000	0.000	0.000
K	22.141	13.826	0.000	8.273	0.000	0.042	0.000
L	12.762	6.296	0.000	5.947	0.000	0.519	0.000
M	9.734	3.143	0.000	5.141	0.000	1.450	0.000
N	11.946	6.446	0.000	4.166	0.000	1.334	0.000
O	9.739	3.998	0.000	4.144	0.000	1.597	0.000
P	20.032	13.530	0.000	6.390	0.000	0.112	0.000
R	1.840	0.000	0.000	1.617	0.000	0.223	0.000
S	15.606	9.875	0.000	5.719	0.000	0.009	0.003
U	7.664	4.407	0.000	3.257	0.000	0.000	0.000
TOTAL	241.099	111.304	8.910	88.324	1.260	14.251	17.050

Modelling approach / assumptions

Stormwater drainage modelling has been undertaken in XPSWMM as a 1D hydrological and hydraulic model, with the following parameters and assumptions:

- Catchment breakdown per Table 1 above
- Hydrologic modelling methodology is based on Australian Rainfall and Runoff 2019 including the use of design rainfall intensity-frequency-duration data derived using the ARR 2019 methodology and the simulation of the full range of design rainfall event durations and temporal pattern ensembles in order to identify the critical duration. Results reported herein are based on the median temporal pattern result.
- Catchment types each modelled with specific initial and proportional losses described below in Table 2, based on the following assumptions:
    - All residential (ie. including smaller, R40 zoned lots) will be required to utilise soakwells to contain all stormwater on-site, however a small runoff assumption has been included to account for potential runoff from driveway areas, overflow from soakwells etc. Therefore, these catchment areas have been modelled with a 0.90 proportional loss (ie. a 0.10 volumetric runoff coefficient). No initial losses applied to this catchment type given the high proportional loss and the logic that the 0.10 effective runoff coefficient is applicable in part to impervious driveway areas etc which will have minimal initial loss.
    - Special use areas assumed to comprise high density / highly impervious use (eg. town centre). This area assumed to retain the first 15mm on site and therefore has been excluded from bioretention basin sizing, however for the purpose of modelling major event discharge rates to Lake Mariginiup a low proportional loss (ie. large runoff coefficient) has been adopted.
    - Road reserves modelled with a 1.5mm initial loss which is appropriate for the impervious portion of the catchment (ie. carriageways and foot paths) and conservative for the pervious portions (ie. verges). A proportional loss of 0.20 applied which represents the expected infiltration losses through verge areas (and potentially through the piped system if measures such as bottomless pits are used).
- Hydraulic modelling of basin sizes adopted the following infiltration rates:
    - 3 m/d for bioretention basins, including the lower (bioretention) portion of flood storage areas. This rate is based on ideal hydraulic conductivity for treatment media as well as potential long-term clogging.
    - 5 m/d for flood storage areas E, K, L, M, N, O & R where estimated groundwater separation is at least 6 m.
    - Slightly reduced rate of 4 m/d for flood storage area K where estimated groundwater separation is only ~3m and may impede infiltration during major events given large basin size.

Table 2: Model loss parameters

Catchment type	Initial loss (mm)	Proportional loss
Residential	0	0.90
Road reserves	1.5	0.20
Special use	15	0.20

Bioretention basin sizes

Table 3 below provides sizing details for bioretention basins. Basins E, K, L, M, N, O & R have been omitted as these are sized through the XPSWMM modelling to contain the 1:100yr event (details provided further below). The bioretention basin sizing assumes 0.5m deep basins, with 1:6 batters and a design infiltration rate of 3 m/d.

Table 3: Bioretention basin sizing

Catchment	Base area	Top area	Depth	Volume
A	490 m^2	792 m^2	0.5 m	318 m^3
B	564 m^2	885 m^2	0.5 m	359 m^3
C	444 m^2	733 m^2	0.5 m	291 m^3
D	686 m^2	1036 m^2	0.5 m	428 m^3
F	898 m^2	1294 m^2	0.5 m	545 m^3
G	333 m^2	588 m^2	0.5 m	227 m^3
H	441 m^2	729 m^2	0.5 m	290 m^3
I	814 m^2	1193 m^2	0.5 m	499 m^3
J	842 m^2	1227 m^2	0.5 m	514 m^3
P	882 m^2	1275 m^2	0.5 m	536 m^3
S	780 m^2	1151 m^2	0.5 m	480 m^3
U	583 m^2	909 m^2	0.5 m	370 m^3

Flood storage basin sizes

The modelled sizing details for basins which are not adjacent to the lake and thus provide a flood storage function (ie. Basins E, K, L, M, N, O & R) are provided in Table 4. These basins have been modelled with 1:6 batter slopes and a maximum storage depth of 1.2 m for the 1% AEP event.

Table 4: Basin sizing details for 1% AEP retention basins

Catch-ment	Base area (m2)	15mm event			20% AEP			1% AEP		
		Depth (m)	Top area	Volume (m3)	Depth (m)	Top area	Volume (m3)	Depth (m)	Top area	Volume (m3)
E	440	0.55	760	324	0.72	880	467	1.18	1250	945
K	2620	0.40	3140	1143	0.59	3400	1757	1.19	4300	4083
L	1520	0.47	1990	831	0.66	2200	1232	1.19	2850	2560
M	1190	0.49	1630	690	0.68	1820	1019	1.20	2390	2106
N	1020	0.49	1440	598	0.68	1610	892	1.19	2150	1853
O	960	0.50	1370	576	0.69	1540	850	1.19	2060	1750
R	210	0.59	470	195	0.76	560	285	1.19	840	583

1% AEP discharge rates

The XPSWMM model was also used to estimate the peak discharge rates and total discharge volumes to Lake Mariginiup and Lake Jandabup during major (1% AEP) events. Table 5 below reports these parameters. The peak discharge rate is reported for the critical duration (typically 1 hour event) whilst the total discharge volume is reported for a longer duration / higher rainfall depth events (24 hours and 168 hours hours). Discharge volumes are reported to inform any potential district-scale assessment of surface water flow volumes to lakes and corresponding potential flood rise in the lakes.

Based on only the discharge volumes reported below in Table 5, the corresponding flood rise in Lake Mariginiup (based on stage-storage calculations from LiDAR) is estimated as ~0.14 m. However, it is noted that the Precinct 7 catchments detailed herein do not represent the entire catchment area discharging to Lake Mariginiup. Furthermore, it is acknowledged that this very high-level assessment does not take into account any other potential inflows or outflows such as subsoil drainage discharge to the lake or pumped outflow from the lake as part of the district water level management system. Nonetheless, this basic assessment demonstrates that the potential for significant flood rise in Lake Mariginiup is low given the very large size and storage capacity of the water body.

Table 5: Discharges to Lake Mariginiup

Catchment	1% AEP peak discharge	1% AEP discharge volume [1] (24-hour event)	1% AEP discharge volume [1] (168-hour event)
A	0.69 m^3/s	9.01 ML	12.70 ML
B	0.40 m^3/s	10.47 ML	14.53 ML
C	0.68 m^3/s	8.72 ML	12.04 ML
D	0.90 m^3/s	12.29 ML	17.25 ML
F	1.26 m^3/s	17.43 ML	24.83 ML
G	0.45 m^3/s	5.78 ML	8.53 ML
H	0.63 m^3/s	7.94 ML	11.27 ML
I	0.80 m^3/s	14.36 ML	19.77 ML
J	0.86 m^3/s	15.96 ML	21.17 ML
S	1.02 m^3/s	14.00 ML	19.50 ML
Total	-	115.96 ML	161.59 ML
Flood rise [2]	-	0.09 m	0.12 m

1. Discharge volume taken as full runoff volume reporting to bioretention basin (ie. excluding infiltration losses in basins) on the assumption that water infiltrated at basins migrates to lake as sub-surface flow or via subsoil drains.
2. Refer to commentary above regarding the limitations of this high-level assessment of flood rise in Lake Mariginiup associated with discharge from the adjacent bioretention basins.

Dan Williams

Principal Hydrologist

dwilliams@pentiumwater.com.au

08 6182 1790

Appendix I Engineering and Earthworks Plans

Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

SLR Project No.: 675.V64450.00000

6 December 2023

LEGEND

—46—	FINISHED SURFACE CONTOURS (1.0m INTERVAL)
46	EXISTING SURFACE CONTOURS (1.0m INTERVAL)
▬	PROPOSED CATCHMENT BOUNDARY
▬	EXTERNAL CATCHMENT BOUNDARY
—42—	MAXIMUM GROUNDWATER CONTOUR (1986 TO 1995)
←	FLOW PATH
←	EXTERNAL CATCHMENT FLOW PATH
●	POTENTIAL BREEDING TREES
▬	WETLAND BUFFER

PRELIMINARY

WAPC No.

A1

No.	DATE	DRAWN	APPROVED	AMENDMENT	No.	DATE	DRAWN	APPROVED	AMENDMENT
A	29.11.23	KS	JS	OPTION D PRELIMINARY ISSUE					

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PROJECT EAST WANNEROO

TITLE PRELIMINARY DRAINAGE CATCHMENT PLAN
OPTION D

DRAWING NUMBER 2449-SK-003D

ISSUE A

Plotted By kshanland Plot Date: 29/11/23 - 14:49 Cad File: C:\12d5\data\TB-120\2449 - East Wanneroo_30\CADD\CAD\2449-SK\2449-SK-003C Drainage Catchment Plan Option D.dwg

LEGEND

—·—46—·—·—	FINISHED SURFACE CONTOURS (1.0m INTERVAL)
46	EXISTING SURFACE CONTOURS (1.0m INTERVAL)
●	POTENTIAL BREEDING TREES

CUT AND FILL LEGEND

🟥	Above 5.00m CUT	🟩	Above 5.00m FILL
🟥	4.50m – 5.00m CUT	🟩	4.50m – 5.00m FILL
🟥	4.00m – 4.50m CUT	🟩	4.00m – 4.50m FILL
🟪	3.50m – 4.00m CUT	🟩	3.50m – 4.00m FILL
🟪	3.00m – 3.50m CUT	🟩	3.00m – 3.50m FILL
🟪	2.50m – 3.00m CUT	🟩	2.50m – 3.00m FILL
🟪	2.00m – 2.50m CUT	🟩	2.00m – 2.50m FILL
🟪	1.50m – 2.00m CUT	🟩	1.50m – 2.00m FILL
🟦	1.00m – 1.50m CUT	🟩	1.00m – 1.50m FILL
🟦	0.50m – 1.00m CUT	🟩	0.50m – 1.00m FILL
🟦	0.00m – 0.50m CUT	🟨	0.00m – 0.50m FILL

CUT: -1,317,900m^3
FILL: 1,051,200m^3 x 1.2
= 1,261,440m^3
BALANCE: -56,460m^3

PRELIMINARY

WAPC No.

A1

No.	DATE	DRAWN	APPROVED	AMENDMENT	No.	DATE	DRAWN	APPROVED	AMENDMENT
A	29.11.23	KS	JS	OPTION D PRELIMINARY ISSUE					

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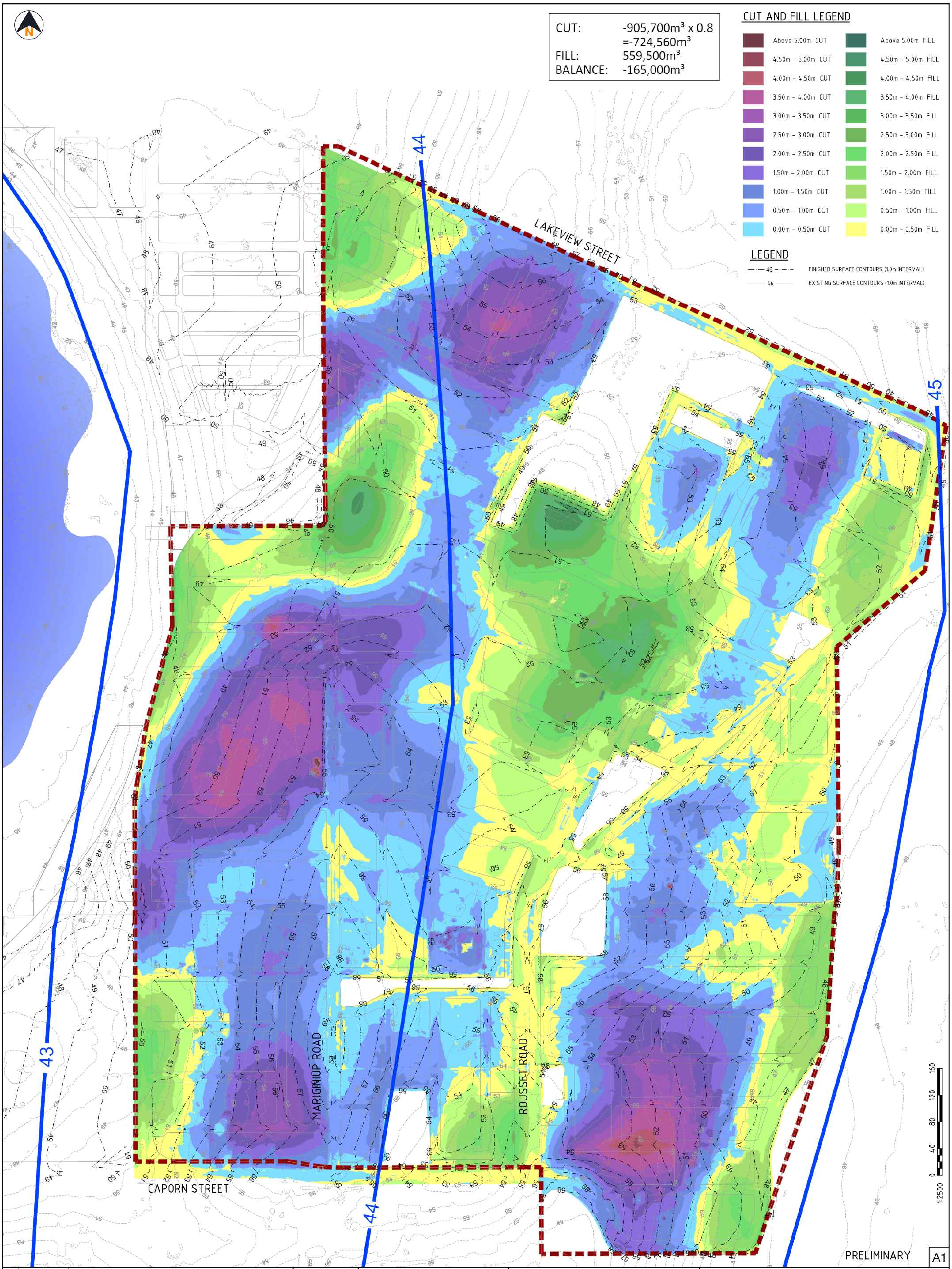
PROJECT EAST WANNEROO

TITLE CUT TO FILL PLAN
OPTION D

DRAWING NUMBER 2449-SK-004D

ISSUE A

Plotted By: ksharland Plot Date: 29/11/23 - 15:18 Cad File: C:\12d5\data\TB-12D\2449 - East Wanneroo_3D\CADD\CAD\2449-SK\2449-SK-004D Cut and Fill Plan Option D.dwg



CUT: -905,700m^3 x 0.8
=-724,560m^3
FILL: 559,500m^3
BALANCE: -165,000m^3

CUT AND FILL LEGEND

🟥	Above 5.00m CUT	🟩	Above 5.00m FILL
🟥	4.50m - 5.00m CUT	🟩	4.50m - 5.00m FILL
🟥	4.00m - 4.50m CUT	🟩	4.00m - 4.50m FILL
🟪	3.50m - 4.00m CUT	🟩	3.50m - 4.00m FILL
🟪	3.00m - 3.50m CUT	🟩	3.00m - 3.50m FILL
🟪	2.50m - 3.00m CUT	🟩	2.50m - 3.00m FILL
🟪	2.00m - 2.50m CUT	🟩	2.00m - 2.50m FILL
🟪	1.50m - 2.00m CUT	🟩	1.50m - 2.00m FILL
🟦	1.00m - 1.50m CUT	🟩	1.00m - 1.50m FILL
🟦	0.50m - 1.00m CUT	🟩	0.50m - 1.00m FILL
🟦	0.00m - 0.50m CUT	🟨	0.00m - 0.50m FILL

LEGEND

—·— 46 —·—	FINISHED SURFACE CONTOURS (1.0m INTERVAL)
······ 46 ······	EXISTING SURFACE CONTOURS (1.0m INTERVAL)

No.	DATE	DRAWN	APPROVED	AMENDMENT
C	29.11.23	KS	JS	REVISED LAYOUT, DESIGN UPDATED
B	08.11.23	KS	JS	REVISED LAYOUT, DESIGN UPDATED
A	26.10.23	KS	JS	PRELIMINARY ISSUE

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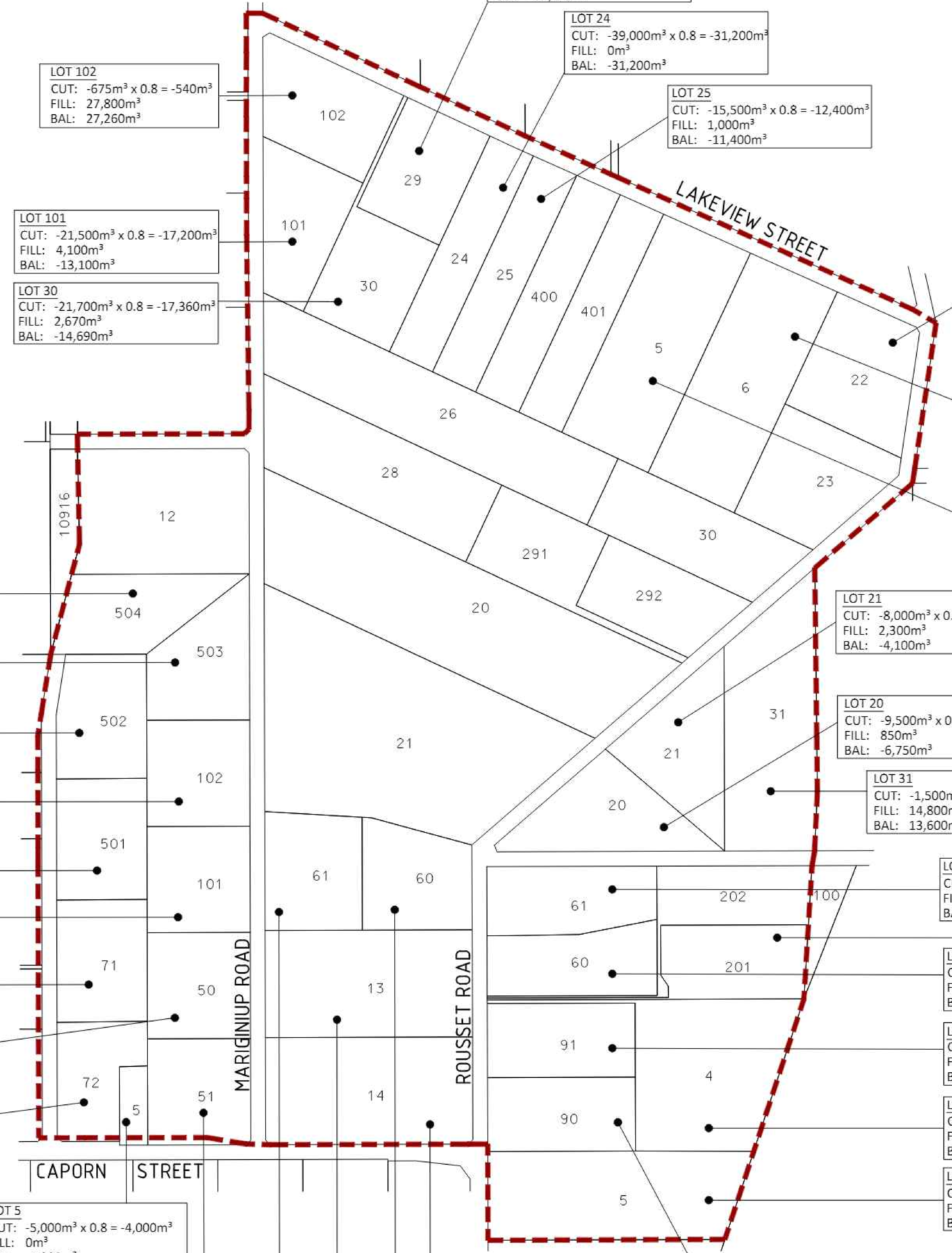
PROJECT EAST WANNEROO

TITLE CUT TO FILL PLAN

DRAWING NUMBER 2449-SK-022

ISSUE C



LOT 29
CUT: -39,300m³ x 0.8 = -31,360m³
FILL: 0m³
BAL: -31,440m³

LOT 24
CUT: -39,000m³ x 0.8 = -31,200m³
FILL: 0m³
BAL: -31,200m³

LOT 25
CUT: -15,500m³ x 0.8 = -12,400m³
FILL: 1,000m³
BAL: -11,400m³

LOT 102
CUT: -675m³ x 0.8 = -540m³
FILL: 27,800m³
BAL: 27,260m³

LOT 101
CUT: -21,500m³ x 0.8 = -17,200m³
FILL: 4,100m³
BAL: -13,100m³

LOT 30
CUT: -21,700m³ x 0.8 = -17,360m³
FILL: 2,670m³
BAL: -14,690m³

LOT 504
CUT: -28,800m³ x 0.8 = -23,040m³
FILL: 5,000m³
BAL: -18,040m³

LOT 503
CUT: -63,150m³ x 0.8 = -50,520m³
FILL: 0m³
BAL: -50,520m³

LOT 502
CUT: -49,250m³ x 0.8 = -39,400m³
FILL: 0m³
BAL: -39,400m³

LOT 102
CUT: -27,000m³ x 0.8 = -21,600m³
FILL: 0m³
BAL: -21,600m³

LOT 501
CUT: -22,500m³ x 0.8 = -18,000m³
FILL: 0m³
BAL: -18,000m³

LOT 101
CUT: -21,600m³ x 0.8 = -17,280m³
FILL: 0m³
BAL: -17,280m³

LOT 71
CUT: -5,000m³ x 0.8 = -4,000m³
FILL: 8,300m³
BAL: 4,300m³

LOT 50
CUT: -25,300m³ x 0.8 = -20,240m³
FILL: 0m³
BAL: -20,240m³

LOTS 72
CUT: -4,500m³ x 0.8 = -3,600m³
FILL: 6,700m³
BAL: 3,100m³

LOT 22
CUT: -6,800m³ x 0.8 = -5,440m³
FILL: 11,000m³
BAL: 5,560m³

LOT 6
CUT: -30,400m³ x 0.8 = -24,320m³
FILL: 1,500m³
BAL: -22,820m³

LOT 5
CUT: -8,600m³ x 0.8 = -6,800m³
FILL: 4,850m³
BAL: -2,030m³

LOT 21
CUT: -8,000m³ x 0.8 = -6,400m³
FILL: 2,300m³
BAL: -4,100m³

LOT 20
CUT: -9,500m³ x 0.8 = -7,600m³
FILL: 850m³
BAL: -6,750m³

LOT 31
CUT: -1,500m³ x 0.8 = -1,200m³
FILL: 14,800m³
BAL: 13,600m³

LOT 61
CUT: -8,800m³ x 0.8 = -7,000m³
FILL: 970m³
BAL: -6,030m³

LOT 201
CUT: -8,200m³ x 0.8 = -6,560m³
FILL: 12,000m³
BAL: 5,440m³

LOT 60
CUT: -23,300m³ x 0.8 = -18,640m³
FILL: 760m³
BAL: -17,880m³

LOT 91
CUT: -33,300m³ x 0.8 = -26,640m³
FILL: 470m³
BAL: -26,170m³

LOT 4
CUT: -40,550m³ x 0.8 = -32,440m³
FILL: 11,800m³
BAL: -20,640m³

LOT 5
CUT: -29,570m³ x 0.8 = -23,656m³
FILL: 17,200m³
BAL: -6,456m³

LOT 5
CUT: -5,000m³ x 0.8 = -4,000m³
FILL: 0m³
BAL: -4,000m³

LOTS 51
CUT: -42,700m³ x 0.8 = -34,160m³
FILL: 0m³
BAL: -34,160m³

LOT 61
CUT: -4,650m³ x 0.8 = -3,720m³
FILL: 1,590m³
BAL: -2,130m³

LOTS 14
CUT: -10,500m³ x 0.8 = -8,400m³
FILL: 22,500m³
BAL: 14,100m³

LOT 60
CUT: -9,560m³ x 0.8 = -7,650m³
FILL: 1,480m³
BAL: -6,168m³

LOT 90
CUT: -53,000m³ x 0.8 = -42,400m³
FILL: 255m³
BAL: -42,145m³

LOTS 13
CUT: -10,900m³ x 0.8 = -8,720m³
FILL: 2,650m³
BAL: -6,070m³

CUT AND FILL LEGEND

■	Above 5.00m CUT	■	Above 5.00m FILL
■	4.50m - 5.00m CUT	■	4.50m - 5.00m FILL
■	4.00m - 4.50m CUT	■	4.00m - 4.50m FILL
■	3.50m - 4.00m CUT	■	3.50m - 4.00m FILL
■	3.00m - 3.50m CUT	■	3.00m - 3.50m FILL
■	2.50m - 3.00m CUT	■	2.50m - 3.00m FILL
■	2.00m - 2.50m CUT	■	2.00m - 2.50m FILL
■	1.50m - 2.00m CUT	■	1.50m - 2.00m FILL
■	1.00m - 1.50m CUT	■	1.00m - 1.50m FILL
■	0.50m - 1.00m CUT	■	0.50m - 1.00m FILL
■	0.00m - 0.50m CUT	■	0.00m - 0.50m FILL

OVERALL
CUT: -905,700m³ x 0.8
=724,560m³
FILL: 559,500m³
BALANCE: -165,000m³

SCALE 1:4000
0 50 100 200 250

PRELIMINARY

WAPC No.

A1

No.	DATE	DRAWN	APPROVED	AMENDMENT
E	29.11.23	KS	JS	REVISED LAYOUT, DESIGN UPDATED
D	09.11.23	KS	JS	VOLUMES UPDATED TO INCLUDE BALANCE
C	08.11.23	KS	JS	REVISED LAYOUT, DESIGN UPDATED
B	02.11.23	KS	JS	LOT 5 VOLUME ADDED
A	24.10.23	KS	JS	PRELIMINARY ISSUE

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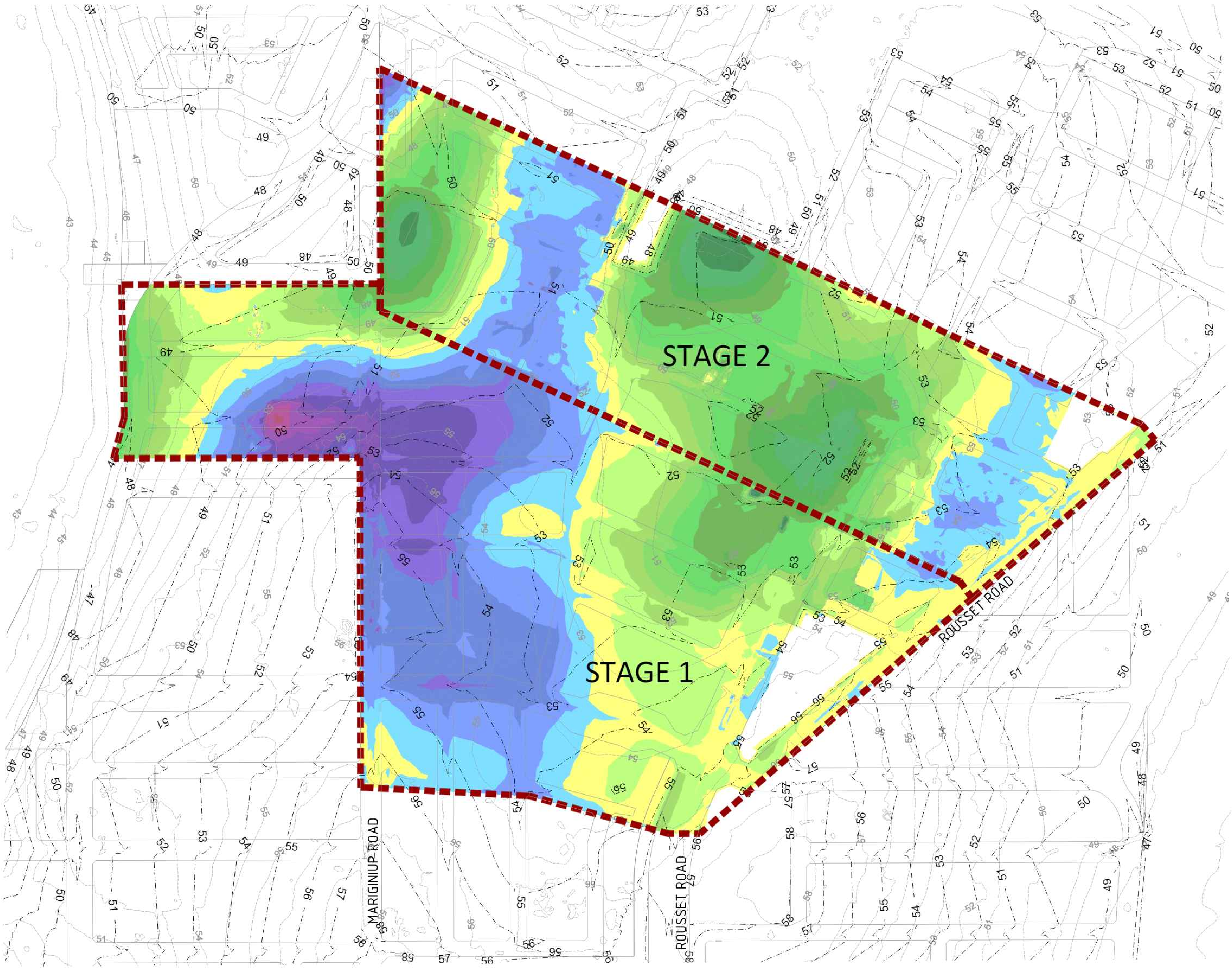
PROJECT EAST WANNEROO
TITLE CUT TO FILL PLAN OVER EXISTING LOTS
DRAWING NUMBER 2449-SK-023
ISSUE E

Plotted By: ksharland Plot Date: 29/11/23 - 11:56 Cad File: C:\12d5\data\TB-12D\2449 - East Wanneroo _30\CADD\CAD\2449-SK\2449-SK-023 Cut and Fill Plan over Existing Lots.dwg



CUT AND FILL LEGEND

▇	Above 5.00m CUT	▇	Above 5.00m FILL
▇	4.50m - 5.00m CUT	▇	4.50m - 5.00m FILL
▇	4.00m - 4.50m CUT	▇	4.00m - 4.50m FILL
▇	3.50m - 4.00m CUT	▇	3.50m - 4.00m FILL
▇	3.00m - 3.50m CUT	▇	3.00m - 3.50m FILL
▇	2.50m - 3.00m CUT	▇	2.50m - 3.00m FILL
▇	2.00m - 2.50m CUT	▇	2.00m - 2.50m FILL
▇	1.50m - 2.00m CUT	▇	1.50m - 2.00m FILL
▇	1.00m - 1.50m CUT	▇	1.00m - 1.50m FILL
▇	0.50m - 1.00m CUT	▇	0.50m - 1.00m FILL
▇	0.00m - 0.50m CUT	▇	0.00m - 0.50m FILL

LEGEND

— · — 46 — · —	FINISHED SURFACE CONTOURS (1.0m INTERVAL)
······ 46 ······	EXISTING SURFACE CONTOURS (1.0m INTERVAL)

STAGE 1

CUT: $-117,000\text{m}^3 \times 0.8$
$= 93,600\text{m}^3$

FILL: $104,500\text{m}^3$

BALANCE: $10,900\text{m}^3$

STAGE 2

CUT: $-19,100\text{m}^3 \times 0.8$
$= 15,280\text{m}^3$

FILL: $209,500\text{m}^3$

BALANCE: $194,200\text{m}^3$

PRELIMINARY

WAPC No.

SCALE

A1

No.	DATE	DRAWN	APPROVED	AMENDMENT	No.	DATE	DRAWN	APPROVED	AMENDMENT
C	29.11.23	KS	JS	REVISED LAYOUT, DESIGN UPDATED					
B	08.11.23	KS	JS	REVISED LAYOUT, DESIGN UPDATED					
A	24.10.23	KS	JS	PRELIMINARY ISSUE					

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PROJECT EAST WANNEROO
TITLE CUT TO FILL PLAN
STAGE 1 AND 2
DRAWING NUMBER 2449-SK-024
ISSUE C

Plotted By: ksharland Plot Date: 29/11/23 - 11:46 Cad File: C:\12dS\data\TB-12D\2449 - East Wanneroo_30\CADD\CAD\2449-SK\2449-SK-024 Cut and Fill Plan Stage 1.dwg

PRELIMINARY

WAPC No.

A1

No.	DATE	DRAWN	APPROVED	AMENDMENT	No.	DATE	DRAWN	APPROVED	AMENDMENT
C	29.11.23	KS	JS	LAYOUT REVISED, DESIGN UPDATED					
B	09.11.23	KS	JS	LAYOUT REVISED, DESIGN UPDATED					
A	24.10.23	KS	JS	PRELIMINARY ISSUE					

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DRAWN	CHECKED	DATE

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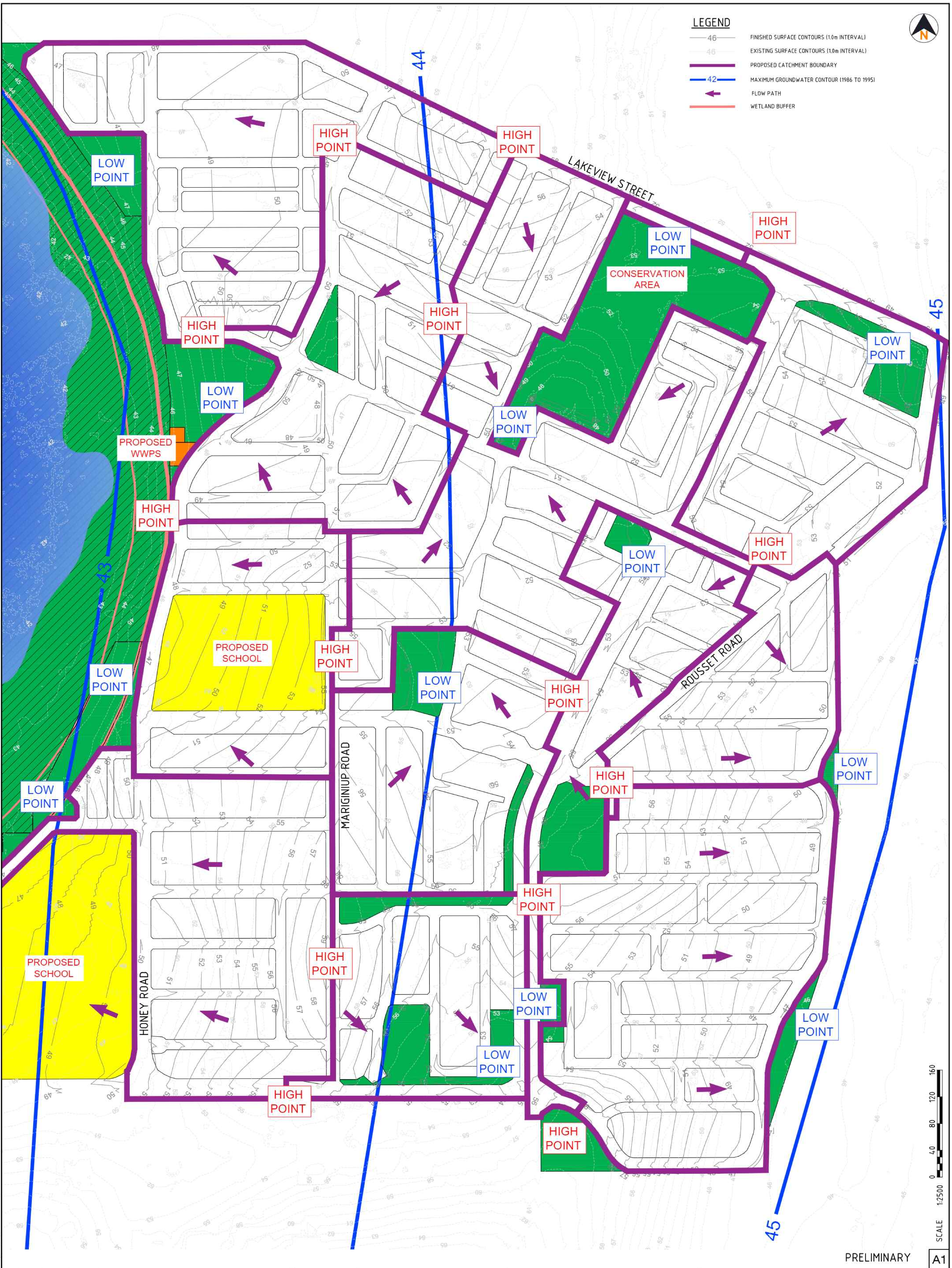
PROJECT EAST WANNEROO

TITLE PRELIMINARY SEWER PLAN

DRAWING NUMBER 2449-SK-025

ISSUE C

Plotted By: ksharland Plot Date: 29/11/23 - 11:37 Cad File: C:\12dS\data\TB-12D\2449 - East Wanneroo_30\CADD\CAD\2449-SK\2449-SK-025 Sewer Plan.dwg



Z:\lib\general\A1_TABEC_VERT.dwg 04/02/20 12:59:33 pkeenan

PRELIMINARY

A1

No.	DATE	DRAWN	APPROVED	AMENDMENT
C	29.11.23	KS	JS	REVISED LAYOUT, DESIGN UPDATED
B	09.11.23	KS	JS	REVISED LAYOUT, DESIGN UPDATED
A	26.10.23	KS	JS	PRELIMINARY ISSUE

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DRAWN ...... CHECKED ...... DATE ......

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PROJECT EAST WANNEROO

TITLE DRAINAGE CATCHMENT PLAN

DRAWING NUMBER 2449-SK-026

ISSUE C

Appendix J Groundwater Modelling Report

Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

SLR Project No.: 675.V64450.00000

6 December 2023

GROUNDWATER MODELLING REPORT

Precinct 7, East Wanneroo District Structure Plan

AU213001891.001
Rev 0
24 November 2021

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
Rev 0	Final for issue	SteWat	CasTur	ShaMcS	22/11/2021

Approval for issue

S. McSweeney	Shane McSweeney	24 November 2021

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1 INTRODUCTION

Hesperia Property Pty Ltd holds development lots within Precinct 7 (the "site") of the East Wanneroo District Structure Plan (EWDSP). The EWDSP (Figure 1) was endorsed by the Western Australian Planning Commission in late 2020 and provides a long-term vision for urban development covering more than 8,000 ha of land divided into 28 precincts. In accordance with *Better urban water management* (WAPC 2008), a District Water Management Strategy (DWMS) was prepared by Urbaqua (2021) to outline the surface water and groundwater management strategies to be implemented for development within the EWDSP area.

The EWDSP DWMS (Urbaqua, 2021) identified groundwater level rise as a key risk to development. Rising groundwater can increase lake and groundwater levels, causing excessive depths and durations of inundation and/or waterlogging of wetlands and vegetation. Key risks to the development include:

- Water logging 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
- Increased prevalence of mosquitoes and other nuisance insects
- Sterilisation of land for development due to unfeasible costs of earthworks and imported sand.

As Precinct 7 encompasses lower lying areas surrounding Lake Mariginiup and is down-gradient of Lake Jandabup, rising groundwater levels may impact some areas of the development. Subsoil drainage systems are well understood and are a practical and cost-effective option for protecting property and infrastructure from the risk of rising groundwater levels.

A Local Water Management Strategy (LWMS) is currently being developed by 360 Environmental to support a Local Structure Plan (LSP) submission for the residential development of Precinct 7. RPS has been engaged by Hesperia Property Pty Ltd to develop a groundwater model to assess groundwater level rise across Precinct 7 to support the LWMS.

The objectives of the groundwater modelling are twofold:

1. Estimate post-development groundwater level changes across the LSP area, including at the key environmental locations of Lake Jandabup and Lake Mariginiup, to estimate areas of the LSP that would require subsoil drainage.
2. Estimate subsoil drainage volumes that require management, to inform the design of the groundwater management system.

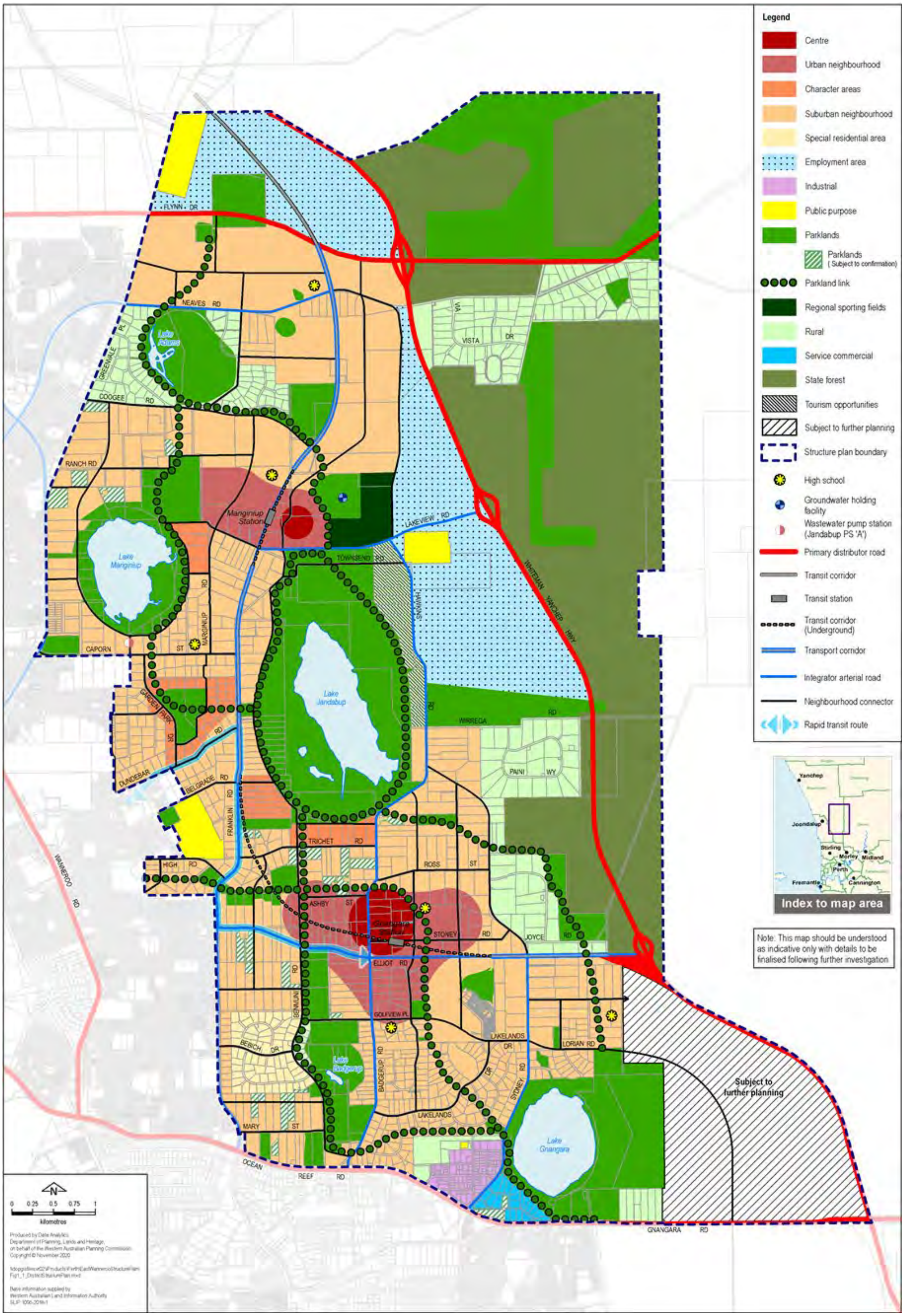

Figure 1: **East Wanneroo District Structure Plan (WAPC, 2020)**

2 BACKGROUND

2.1 Site description

2.1.1 Location and land uses

The EWDSP area is located approximately 2 km east of the Wanneroo townsite, 6 km east of Joondalup and 25 km north of the Perth CBD. It covers an area of ~8,500 ha, extending from north of Neaves Road to Gnangara Road in the south, to Centre Way to the east and as far west as Pinjar Road.

Precinct 7 is located on the western side of the EWDSP area, as shown on Figure 2, encompassing much of Lake Mariginiup. The south-eastern corner of Precinct 7 is adjacent to Lake Jandabup.

Current land uses across Precinct 7 include:

- Irrigated horticulture and market gardens
- Rural residential
- Native bushland.

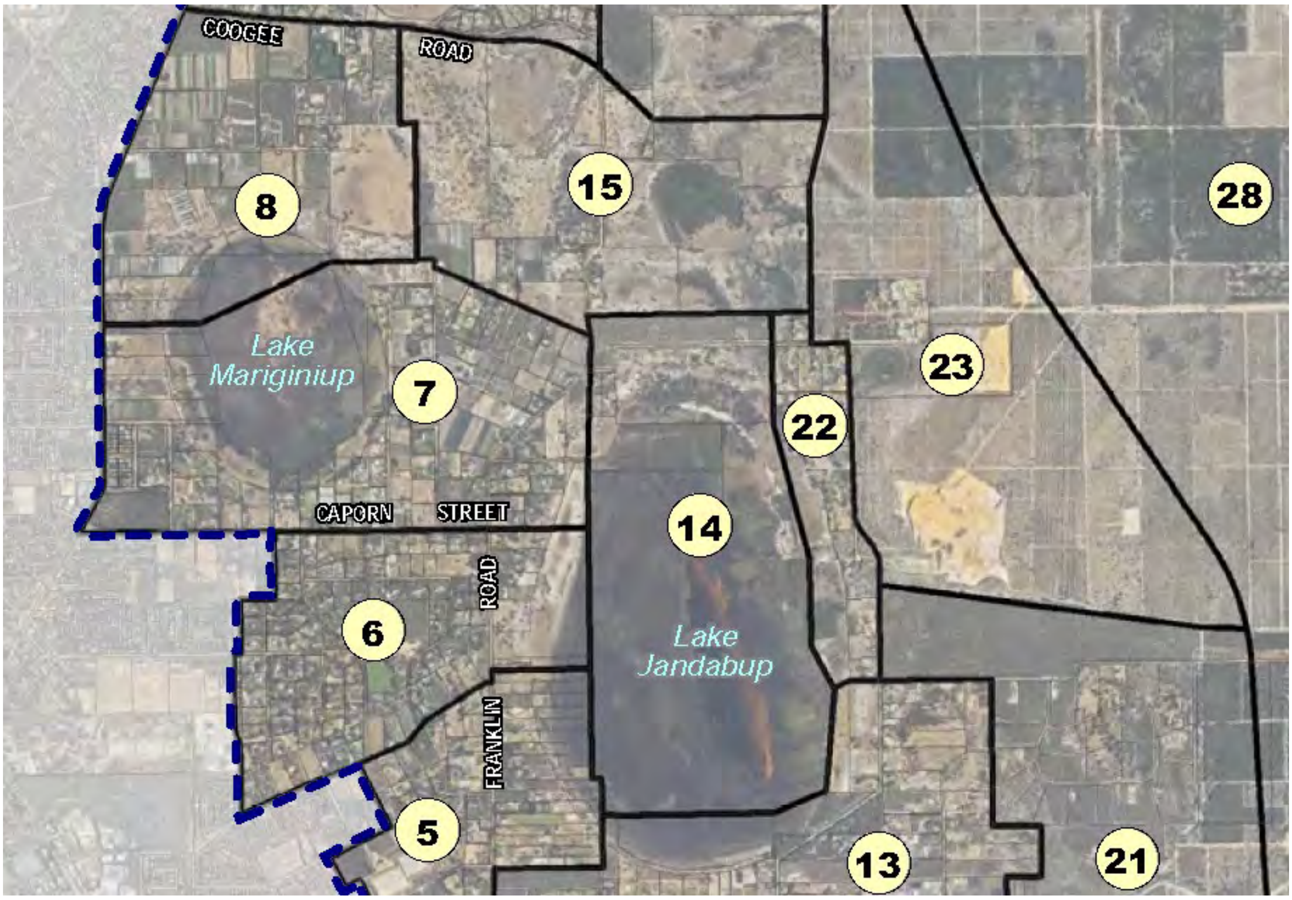

Figure 2: Precinct 7 and surrounding precincts within the EWDSP area (modified from WAPC, 2021)

2.1.2 Topography

2.1.2.1 Regional topography

The EWDSP area is comprised of undulating Spearwood sand dunes to the west and low Bassendean sand dune systems to the east. A chain of low-lying wetlands has formed along a generally north–south alignment through the inter-dunal swale between the Bassendean and Spearwood dune systems.

Surface elevations across the EWDSP area range from 40 to 45 m AHD (Australian Height Datum) in the low-lying wetlands up to about 98 m AHD at a high point on the western boundary.

2.1.2.2 Precinct 7 topography

Surface elevations across Precinct 7 range from 40.5 m AHD at the base of Lake Mariginiup up to ~66 m AHD at the western boundary. The topography across Precinct 7 is shown in Figure 3.

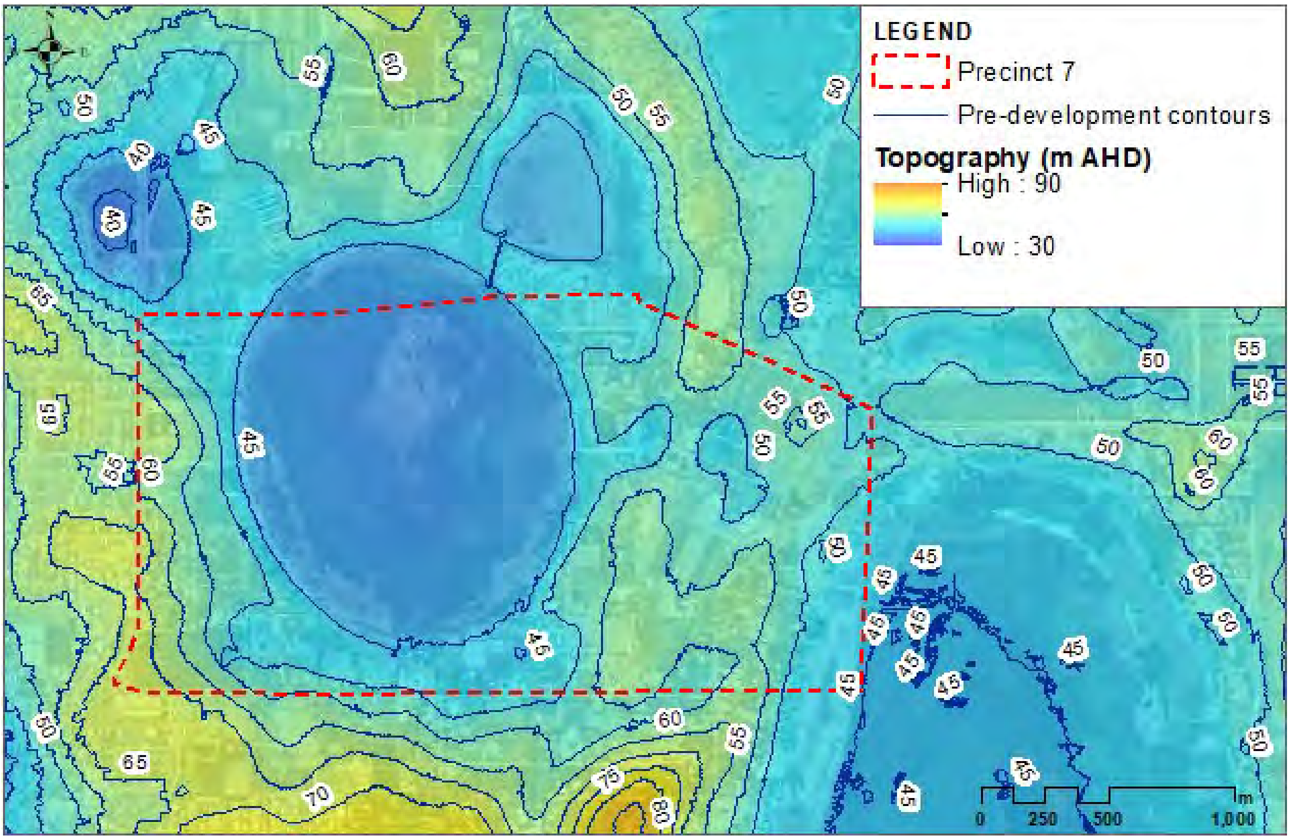

Figure 3: Topography across Precinct 7

2.2 Climate and rainfall

The EWDSP area experiences a temperate climate, characterised by a distinctly hot, dry summer and a cold, wet winter.

2.2.1 Pre-development

Climate data between September 2014 and June 2021 was used for the calibration of the pre-development model. Climate data was obtained from the SILO database, which provides spatially and temporally complete climate datasets across a gridded raster by post-processing raw observational data and interpolating between stations (Queensland Government 2021). SILO data was obtained for a grid point about 3 km north-east of the site. Annual rainfall over the model calibration period (between 2014 and 2020) ranged from 557 mm in 2019 to 807 mm in 2017, and the average annual rainfall over this period was 666 mm.

2.2.2 Post-development

The Department of Water (now DWER) has developed future climate predictions for Western Australia (DoW, 2015). These are reported using monthly anomalies, which are the projected differences compared to a baseline period. The baseline period is 1961–1990, while the future climate scenarios are wet, medium and dry for 2030, 2050, 2070 and 2100. Baseline rainfall data (from 1961 to 1990) was adjusted to a Wet 2050 future climate scenario for the post-development simulations that ran from 2021 to 2050.

Annual rainfall for the future Wet 2050 climate scenario ranged from 521 mm to 1,208 mm with an annual average of 744 mm. The future annual average rainfall used for the post-development model simulations is about 4% less than the baseline annual average rainfall (779 mm between 1961 and 1990) and about 6% higher than the average annual rainfall over the last 20 years (704 mm between 2001 and 2020).

Short crop evapotranspiration and Morton Lake evaporation data extracted from SILO over the baseline period was adjusted using monthly climate anomalies for the Wet 2050 future climate scenario.

Average monthly rainfall and short crop evaporation rates for the future climate simulations (i.e. baseline adjusted by monthly anomalies) are shown in Figure 4.

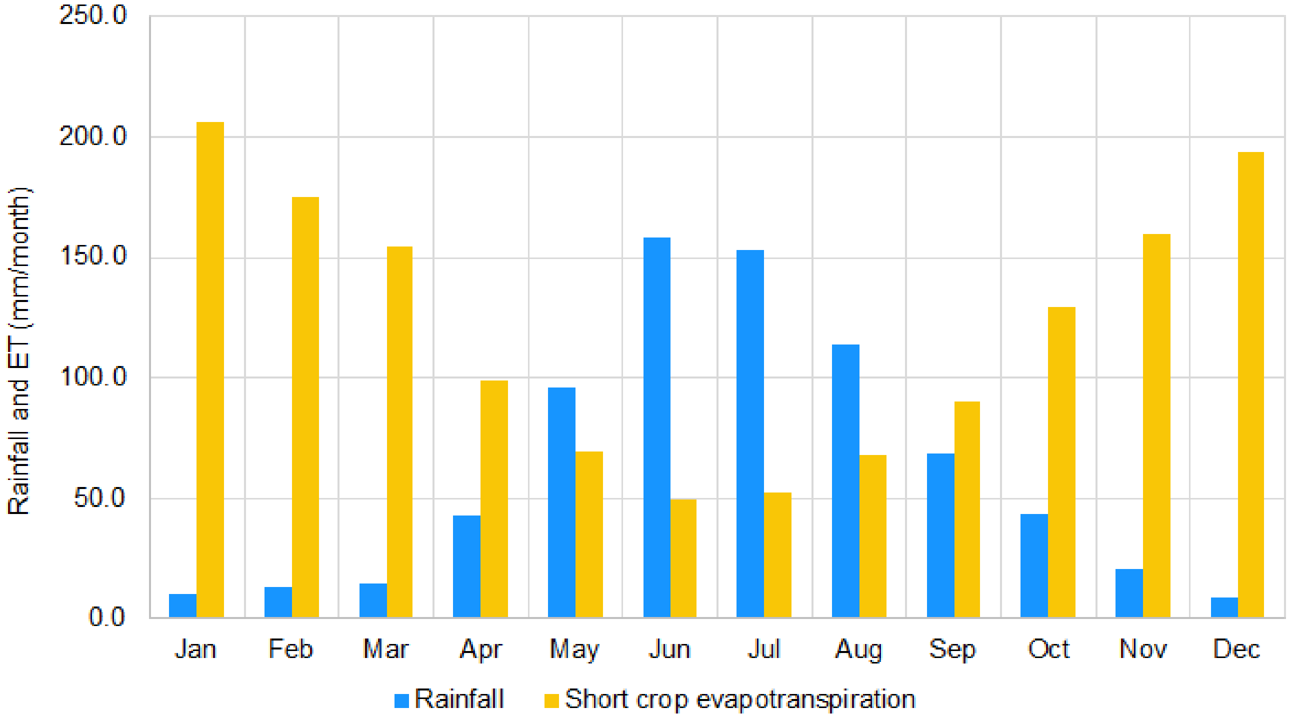

Figure 4: Future climate rainfall and evapotranspiration (short crop)

2.3 Geology

2.3.1 Superficial formations

The 1:50,000 Environmental geology series maps for Perth and Muchea (Geological Survey of Western Australia & Western Australia Department of Mines, 1986) predominantly show Bassendean Sand (S8, S10), a light grey, medium grained sand, to the east of the interdunal swale across the EWDSP area (Figure 5). The surficial geology to the west of the interdunal swale consists of sand derived from the Tamala Limestone (S7). This sand unit, referred to as the Spearwood Sand, is yellow–orange, medium to coarse grained. Peaty clay deposits (Cps), dark grey and black with variable sand content, are typically found near wetland depressions. These units are known as the superficial formations and create the Superficial aquifer. The surficial geology across Precinct 7 is predominantly Spearwood Sand with some peaty clay.

The Perth Groundwater Map (DWER 2020) indicates the base of the Superficial aquifer slopes down from east to west across the model domain from about 0 m AHD on the eastern side of the model to -20 m AHD to the west. The thickness of the Superficial aquifer in the EWDSP area is approximately 50 to 60 m.

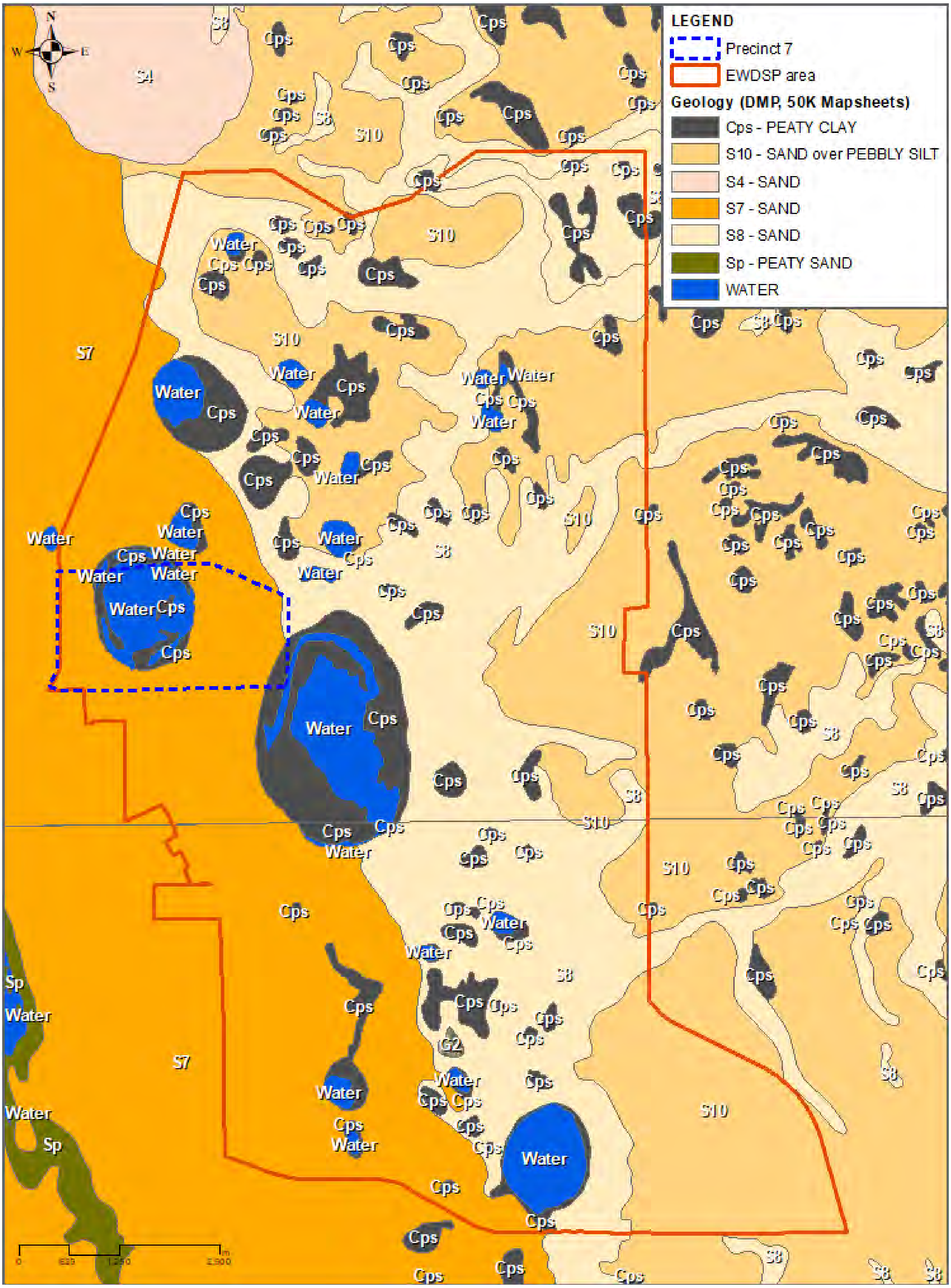

Figure 5: **Surface geology mapping (1:50,000 Environmental geology series maps for Perth and Muchea)**

2.3.2 Mesozoic formations

Davidson (1995) indicates the superficial formations across the northern third of the model domain overlie the Wanneroo Member of the Leederville Formation, whereas the central and southern parts of the model predominantly overlie the Poison Hill Greensand and the Mirrabooka Member of the Osborne Formation. There is some contact with Kardinya Shale through parts of the model and some contact with the Henley Sandstone Member of the Osborne Formation and the Molecap Greensand in areas to the west (Figure 6).

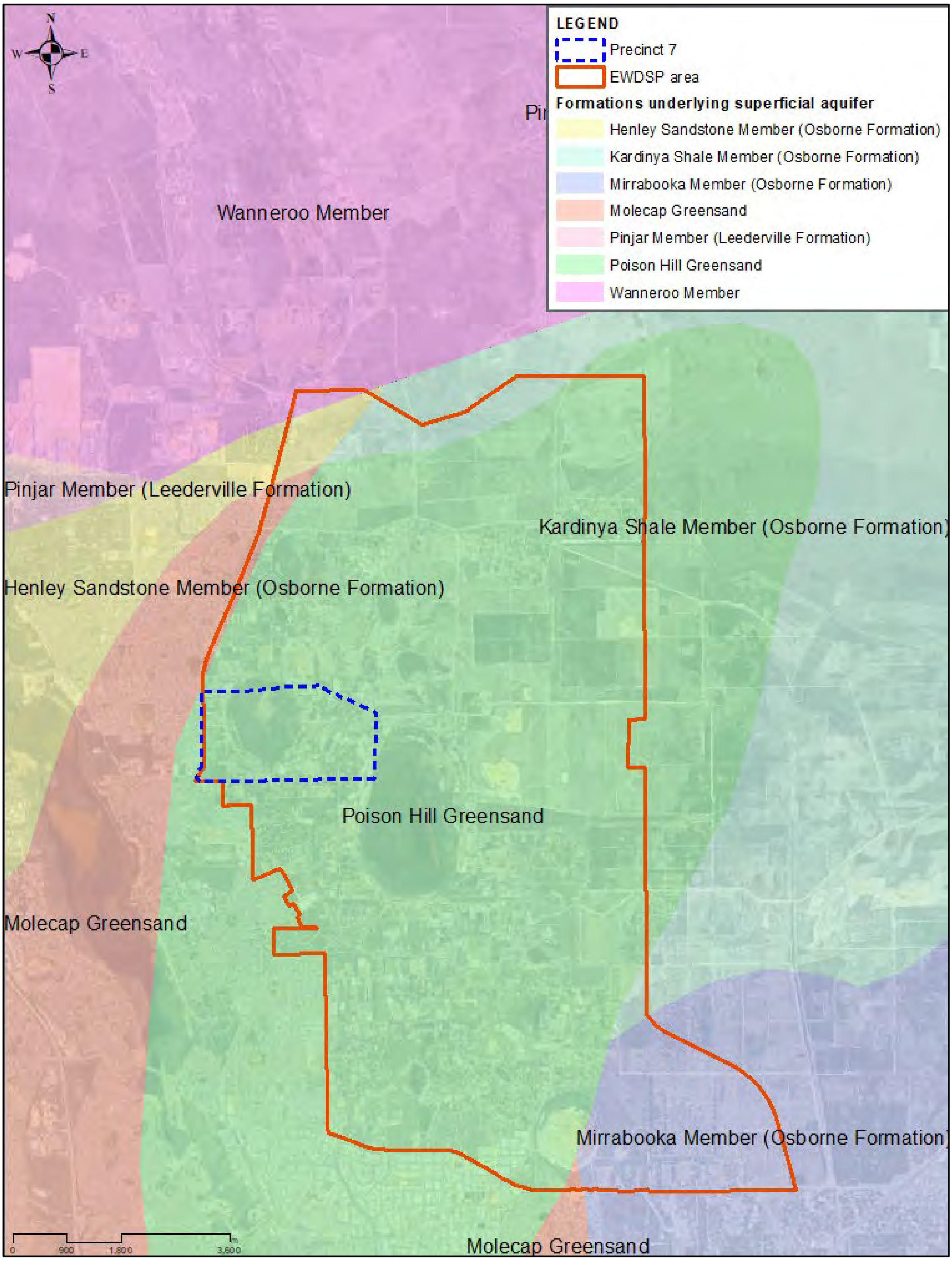

Figure 6: Mesozoic formations underlying the Superficial aquifer (after Davidson (1995) (Plate 49))

2.4 Hydrogeology

2.4.1 Superficial aquifer groundwater flow

Historical maximum groundwater contours (Figure 7) show groundwater flows in a west-south-westerly direction across the EWDSP area with the maximum groundwater elevation ranging from ~67 m AHD in the north-eastern corner to ~39 m AHD along parts of the western boundary. Across the EWDSP area the hydraulic gradient is ~ 0.0025 to 0.003, which corresponds to a 1 m fall in water table elevation across a distance of 330 m to 400 m.

Lake Joondalup is located about 2.5 km west of Lake Mariginiup. To the west of Lake Mariginiup and immediately east of Lake Joondalup the hydraulic gradient is very steep (with the groundwater dropping about 14 m over a distance of about 700 m. Davidson (1995) suggests the hydraulic gradient steepening may be the result of low conductivity material in this area.

According to Davidson (1995) there is some downward leakage from the Superficial aquifer to the Leederville aquifer and both downward and upward leakage to the Mirrabooka aquifer.

2.4.2 Site hydrogeology

Historical maximum groundwater contours indicate groundwater flows in a west to south-westerly direction across Precinct 7, and Lake Mariginiup is a flow-through wetland (Figure 7) with groundwater discharging to the lake on the up-gradient (eastern) side and recharging from the lake on the downgradient (western) side. Over the model calibration period (September 2014 to June 2021), groundwater levels varied from ~43.6 m AHD to ~45.0 m AHD near the eastern precinct boundary (bore 61610745). Near the south-western corner of the precinct (bore 61610684), groundwater levels varied from 38.2 m AHD to 39.2 m AHD over the calibration period, which indicates the hydraulic gradient across the precinct is about 0.002.

2.4.3 Groundwater area and protection zones

Precinct 7 is located within the Wanneroo groundwater area and the Mariginiup groundwater subarea of the Superficial aquifer.

Although Precinct 7 is not within a Public Drinking Water Supply Area (PDWSA), it is located between the Gnangara Underground Water Pollution Control Area (UWPCA) approximately 1 km to the east and the Perth Coastal and Gwelup UWPCA (~2 km to west). Public water supply bores within the EWDSP area are located in the Gnangara UWPCA to the east of Precinct 7.

2.4.4 Controlled groundwater level

The East Wanneroo DWMS (Urbaqua 2021) proposes the 1986 to 1995 Average Annual Maximum Groundwater Level (AAMGL) as the controlled groundwater level for the East Wanneroo DSP area.

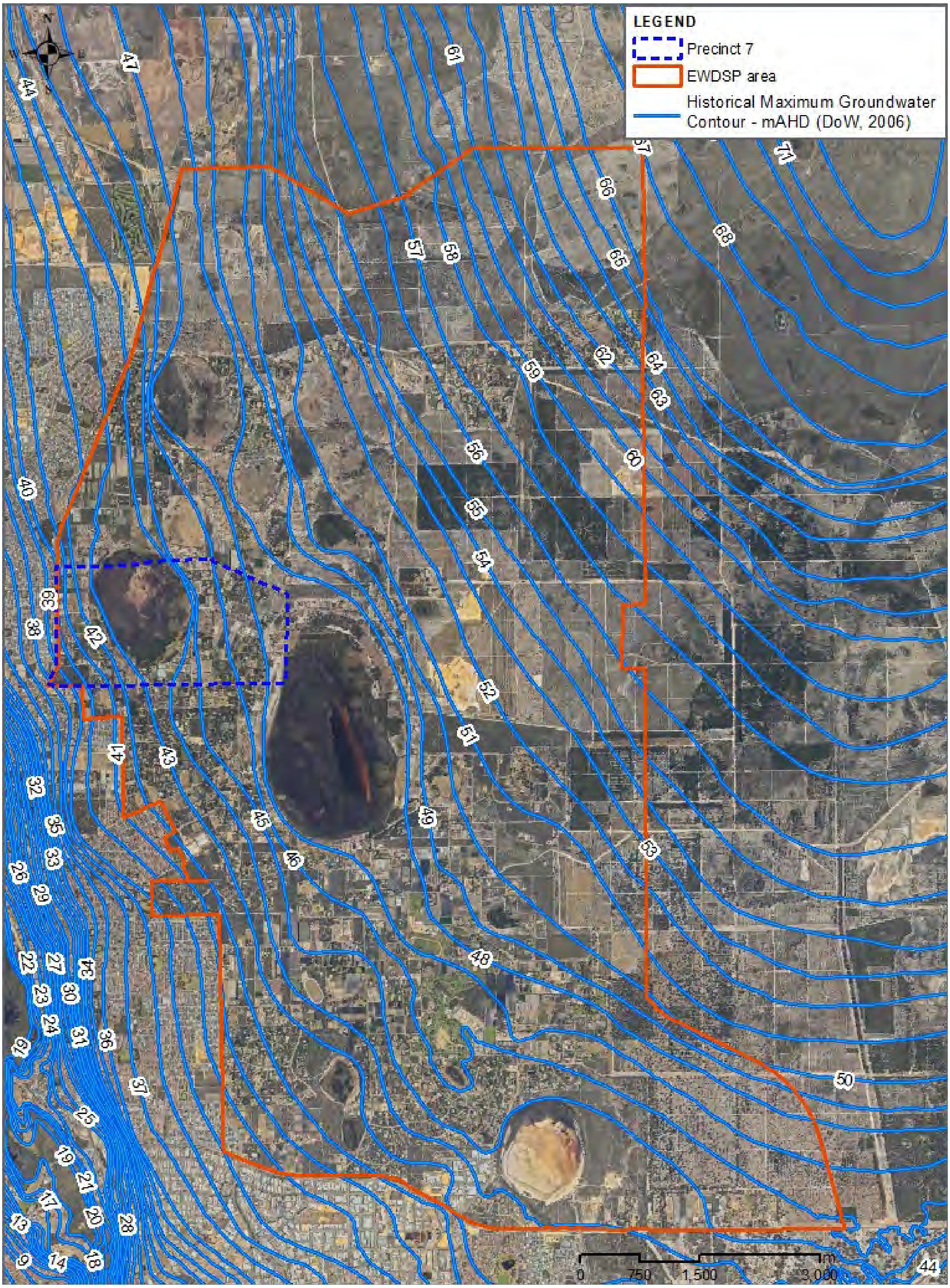

Figure 7: Historical maximum groundwater contours

2.5 Lake Mariginiup and Lake Jandabup

Lake Mariginiup and Lake Jandabup are flow-through lakes, receiving groundwater from the east and discharging to the west. The lake and water table levels vary in phase; however the lake levels respond more readily to high rainfall and evaporation periods than the groundwater level (Hall 1983, Allen 1979).

Precinct 7 surrounds most of Lake Mariginiup. Groundwater flows into the lake via upward flow from the upper section of the Superficial aquifer on the eastern side of the lake, while outflow to the groundwater in the Superficial aquifer is by downward flow from the western side of the lake (Hall 1983). Monitoring data and minimum groundwater contours indicate a head drop of about 1 m between the eastern and western side of Lake Mariginiup. The DWMS indicates the invert level of Lake Mariginiup is 40.5 m (Urbaqua 2021).

2.6 Wetlands

The East Wanneroo DSP area contains several large wetlands and numerous smaller wetlands (Urbaqua, 2021). Lake Mariginiup is a Conservation Category (CC) wetland within Precinct 7. Although Lake Jandabup is mapped as a CC wetland, the western edge of Lake Jandabup near the Precinct 7 boundary is mapped as Multiple Use (MU) wetland (Figure 8).

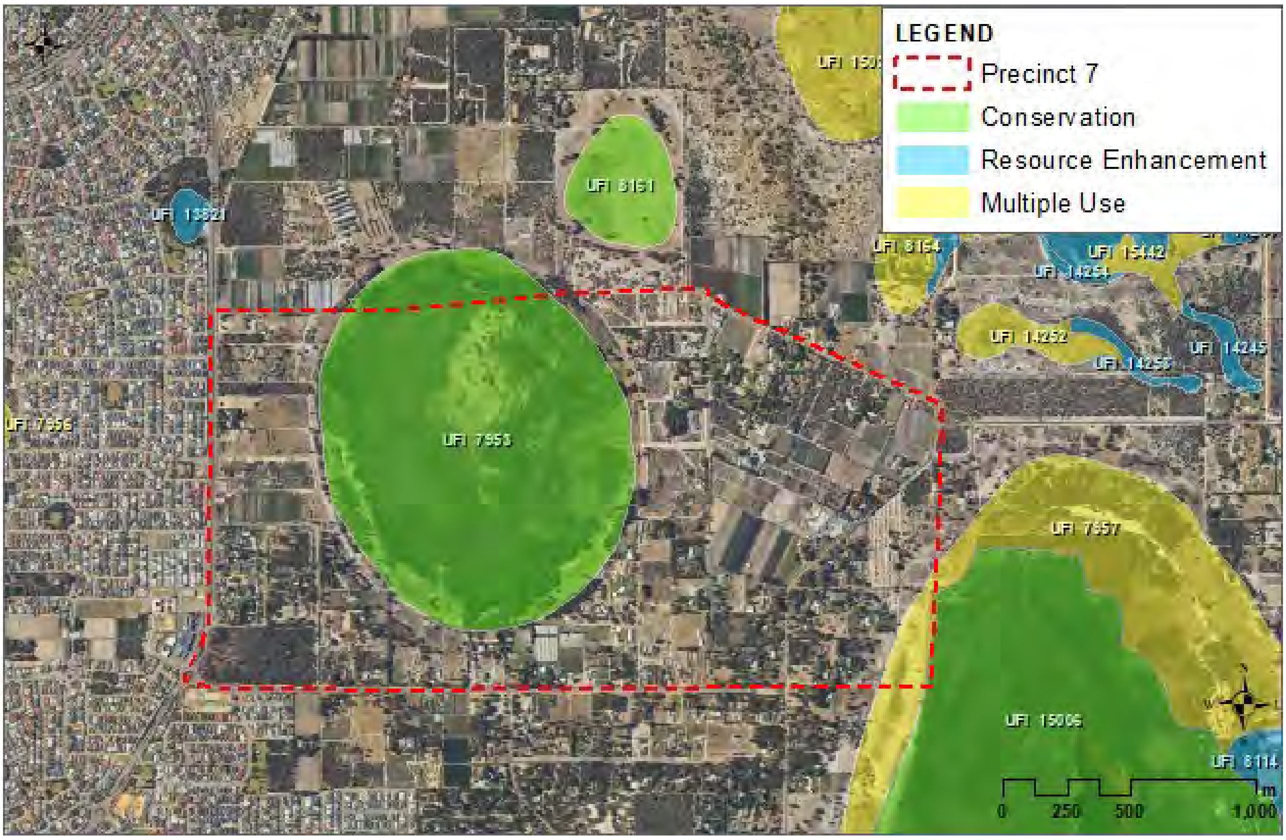

Figure 8: Geomorphic wetland mapping

3 GROUNDWATER MODEL DEVELOPMENT

3.1 Objective and scope

The primary objectives of the groundwater modelling at this stage of planning are to:

1. Estimate post-development groundwater level changes across the LSP area, including at the key environmental locations of Lake Jandabup and Lake Mariginiup, to estimate areas of the LSP that would require subsoil drainage.
2. Estimate subsoil drainage volumes that require management, to inform the design of the groundwater management system.

3.2 Conceptual hydrogeology

The numerical model is based on the conceptual hydrogeological model illustrated in Figure 9. Water enters the model inflow from the eastern boundary, rainfall recharge and some upward leakage from underlying aquifers. Groundwater flows out of the model to the west, with groundwater losses due to evaporation and evapotranspiration, public and private abstraction, and some downward leakage to underlying aquifer system.

The Superficial aquifer is predominantly a sand aquifer across the model domain, with Bassendean Sand to the east and Spearwood Sand to the west. A steep hydraulic gradient is evident between Lake Mariginiup and Lake Joondalup, which Davidson (1995) indicates is partly due to the marginally lower hydraulic conductivity of finer grained sand at the eastern margin of the Tamala limestone.

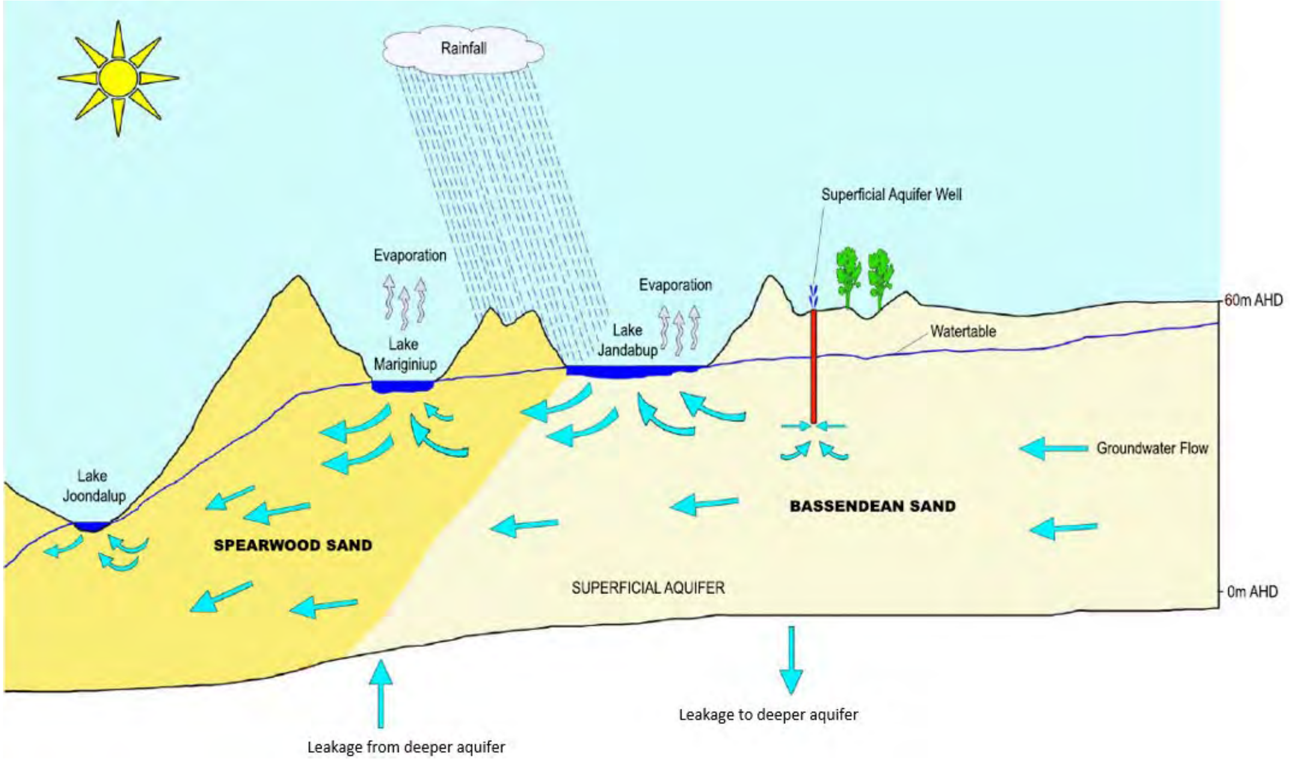

Figure 9: Conceptual hydrogeological model (after RPS 2009)

3.3 Model design

The simulation program used to model the groundwater flow field was MODFLOW-USG (Panday et al. 2017). Pre- and post-processing of the MODFLOW files was carried out using GMS software package (version 10.5) (Aquaveo, 2021). The focus area of the model was the Precinct 7 area including Lake Mariginiup and Lake Jandabup.

3.3.1 Model grid

The groundwater model was developed covering an area with dimensions approximately 22 km (north-south) by 12 km (east-west). The focus area of the groundwater model was the Precinct 7 area and the nearby lake areas (Lake Mariginiup and Lake Jandabup) to simulate surface water groundwater interactions in the nearby surface water bodies. The model grid had a cell size of 40 m across focus area, with the cell size increasing to 160 m beyond the area of refinement (Figure 10).

The model was developed with five layers representing the Superficial aquifer. The model layering did not represent different lithologies (i.e. it was assumed that aquifer properties did not vary vertically) rather layering was specified to facilitate the simulation of leakage from and to the underlying aquifers, abstraction from public and private wells, and to provide adequate vertical discretisation beneath the lakes.

Figure 10: Model grid refinement across Precinct 7 and surrounds

3.3.2 Boundary conditions

The groundwater model was developed with the following boundary conditions:

- Northern and eastern boundary – no flow parallel to groundwater flow (i.e. perpendicular to the historical minimum groundwater contours)
- North-eastern corner – aligned along the 67 mAHD minimum historical groundwater contour, with a transient specified head based on nearby bore observation data
- Western and southern boundary – aligned along the 34 mAHD historical minimum groundwater contour, with a transient specified head based on nearby bore observation data
- Recharge and evapotranspiration were specified across the top of the model (specified flow conditions)
- Specified flows were included in the base layer of the model to simulate upward leakage from and downward leakage to underlying aquifers, as indicated by Davidson (1995).

3.4 Modelling period and initial conditions

For calibration purposes, the model was run as a transient simulation with monthly stress periods from September 2014 to June 2021 (~7 years). This time period was chosen as it was after much of the pine clearing had occurred within the East Wanneroo regional area and is deemed sufficient to establish modelled groundwater trends and fluctuations. Four time-steps were used within each stress period. Observation data from bores across the model domain between August 2014 and October 2014 were used to generate the initial head boundary condition within the model.

For the future climate scenarios, the model was run with monthly stress periods for a duration of 30 years, from January 2021 to December 2050, using baseline climate data adjusted for the future climate anomalies. The calibrated model January 2021 groundwater surface was used as the initial head condition for the future climate scenario simulations.

3.5 Aquifer parameters

3.5.1 Hydraulic conductivity

The estimated horizontal hydraulic conductivities (K) of the main geological units shown in Figure 5, are as follows:

- Bassendean Sand (S8, S10) – the K value is estimated to range between 10 m/day to 50 m/day. Calibration of the PRAMS model indicated K values for Bassendean Sand ranging from ~8 to 15 m/day in the Superficial aquifer within the EWDSP area (CyMod Systems, 2009).
- Spearwood Sand (S7) – the K values for the Spearwood Sand are estimated to range from approximately 10 to 50 m/day, but calibration of the PRAMS model indicated K values ranging from about 3 to 10 m/day within the EWDSP area (PRAMS, CyMod Systems, 2009).
- Low hydraulic conductivity (K) zone (within S7) – part of the apparent low hydraulic conductivity zone between Lake Mariginiup and Lake Joondalup lies within the western edge of the model domain. This zone is not well understood, but Davidson (1995) indicates it is partly due to the marginally lower hydraulic conductivity of finer grained sand in the Spearwood Sand at the eastern margin of the Tamala limestone. A low hydraulic conductivity zone has been observed between the Bassendean and Spearwood dune systems at a number of locations north and south of Perth. A calibrated hydraulic conductivity of 0.8 m/day was applied by McFarlane (2015) to simulate the low hydraulic conductivity zone observed between the Bassendean Sand and Spearwood Sand down gradient of the Spectacles wetland (south of Perth).
- Vertical anisotropy (K_h/K_v) was assumed to be 3.0 in the sand formations, and 6.0 in the lower permeability deposits associated with the lakes.

Aquifer parameters were assumed to not vary in the vertical direction.

3.5.2 Specific yield and specific storage

- Specific yield (Sy) is the amount of water that will be drained by gravity from a material. The estimated specific yield for both Bassendean Sand and Spearwood Sand is 0.25 (CyMod Systems, 2009). These values are similar to those used for the East Wanneroo integrated groundwater-lake flow modelling study (Bourke, 2009).
- Specific storage (Ss) is the amount of water released from storage per unit volume of the aquifer per unit decline in hydraulic head. Although the Superficial aquifer at the model domain is not confined, the Ss is required for multilayer MODFLOW models. The Ss value is very small, and a value of 5×10^{-4} m^{-1} was applied to the model, which is consistent with the storage values used for the East Wanneroo integrated groundwater-lake flow modelling study (Bourke, 2009).

3.6 Groundwater recharge

Recharge was applied across the model domain on a monthly basis according to different land uses identified from aerial imagery. Recharge rates were estimated using a recharge factor applied to monthly rainfall rates. The recharge factors were consistent with the estimated annual recharge rates documented for the PRAMS model development (Xu et al. 2009), and the recharge rates applied for the East Wanneroo integrated groundwater lake modelling (Bourke 2009). The pre-development recharge rates used for the model development are given in Table 1.

Table 1: Recharge rates applied to each land use area within the model domain

Land use	Recharge factor (% of annual rainfall)
Pines	8*
Cleared pines (low density)	25
Banksia (medium density)	28*
Banksia (high density)	10
Special rural	40
Market garden / pasture	40
Low lying naturally vegetated areas	30
Urban	50
Industrial	63
Lake	100

* Reduced by subtracting 5% of potential evapotranspiration

3.7 Evapotranspiration

Evapotranspiration (ET) is an important process, particularly with shallow water tables and vegetated areas. For the MODFLOW ET Package, a user defined ET rate and elevation is applied, with the rate decreasing linearly to a specified extinction depth, at which depth ET is considered zero.

Short crop evapotranspiration rates provided in the SILO climate data and an extinction depth of 1.5 m were applied across the model in the land use areas that had shallow groundwater levels and shallow rooted crops.

To account for evapotranspiration from the deeper-rooted pines and banksias, an evaporative loss of 5% of pan evaporation was incorporated into the recharge rate calculations resulting in negative recharge rates (corresponding to evapotranspiration losses) during the drier summer months where the depth to groundwater was generally less than 20 m for pine areas and 10 m for banksia woodland areas. ET was not applied in these areas, as it had been included in the applied recharge rates

Evaporative losses across the urban and industrial land use area were assumed to be negligible and therefore not simulated in the model.

3.8 Groundwater abstraction

Groundwater is abstracted from the Superficial aquifer via private bores and public bores. Based on DWER records, there are approximately 840 private bores in the Superficial aquifer within the model domain. The abstraction rates were estimated at 90% of the licensed allocation to allow for irrigation recharge, with averages applied where more than one bore is abstracting from a single licence. Private abstraction was divided into monthly periods in the transient modelling simulation, with more abstraction in the drier months when irrigation rates are higher.

Monthly abstraction rates were obtained from the Water Corporation for the public abstraction bores abstracting groundwater from the Superficial aquifer within the model domain.

3.9 Leakage between aquifers

Leakage between the Superficial aquifer and the underlying units has been included in the model based on the leakage rates provided in Davidson (1995). The leakage was applied as a specified flux either into or out of the base layer of the model (layer 5), depending on whether there was upward leakage from the Mirrabooka aquifer or downward leakage into the Mirrabooka or Leederville aquifers. The leakage was applied across the areas shown on Plate 54 in Davidson (1995).

3.10 Lake (LAK) package

The Lake (LAK) package (Merrit and Konikow, 2000) was used to simulated lake–aquifer interactions within the groundwater flow model, and to estimate the stage in Lake Mariginiup. With this package, the lake stages are computed from the water budget, which includes the following:

- Inflow from and outflow to groundwater
- Lake evaporation and rainfall - monthly rainfall rates (100%) and Morton Lake evaporation rates based on SILO climate data were applied within the LAK package
- Run-off to and withdrawal from the lake – no stormwater run-off or withdrawals were incorporated into the modelling, but Lake Jandabup supplementation was included (as a run-off rate) based on data provided in the DWMS

Lake bathymetry was based on data that has previously been provided to RPS by the Department of Water.

3.11 Model calibration

3.11.1 Groundwater elevations

The groundwater flow model was calibrated manually under transient conditions by varying the horizontal hydraulic conductivity of the main geological units and comparing computed groundwater heads with measured groundwater heads from 67 observation wells in the Superficial aquifer.

The calibrated model produced groundwater contours that resembled the measured values across much of the domain, particularly through the western parts of the model in the vicinity of the site. The mean absolute residual head (MARH) difference across the model domain is 0.66 m, which is 2.1% of the measured hydraulic head drop across the model domain (of 32 m). The root mean square (RMS) residual head difference is 1.0 m, or a scaled root mean squared residual head (SRMS) of 3.2% of the measured hydraulic head drop across the model domain.

Simulated groundwater contours across Precinct 7 for September 2021 (at the end of winter towards the end of the model calibration) are shown in Figure 11. Pre-development groundwater contours indicate the groundwater elevation sloped down in a westerly direction across the precinct from 45 mAHD at the eastern boundary to 40 mAHD near the south-western corner. The model is generally well calibrated in the vicinity of Precinct 7 (Figure 12) which is the focus area for the modelling investigation. There was poorer agreement between simulated and observed groundwater elevations on the eastern side of the model in areas where there have been changes in land use, particularly pine clearing.

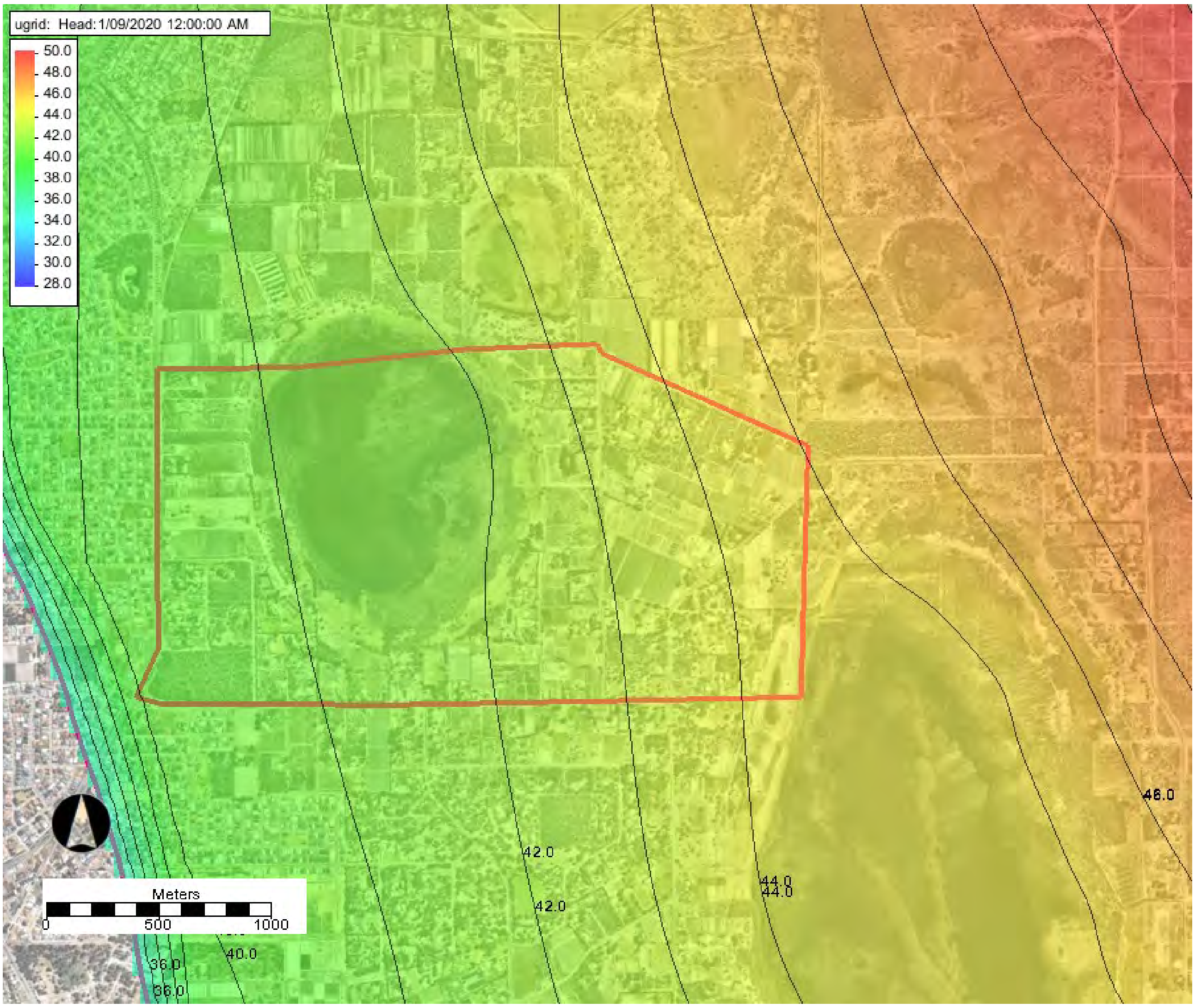

Figure 11: **Simulated groundwater contours across Precinct 7 towards the end of the calibration periods (September 2020)**

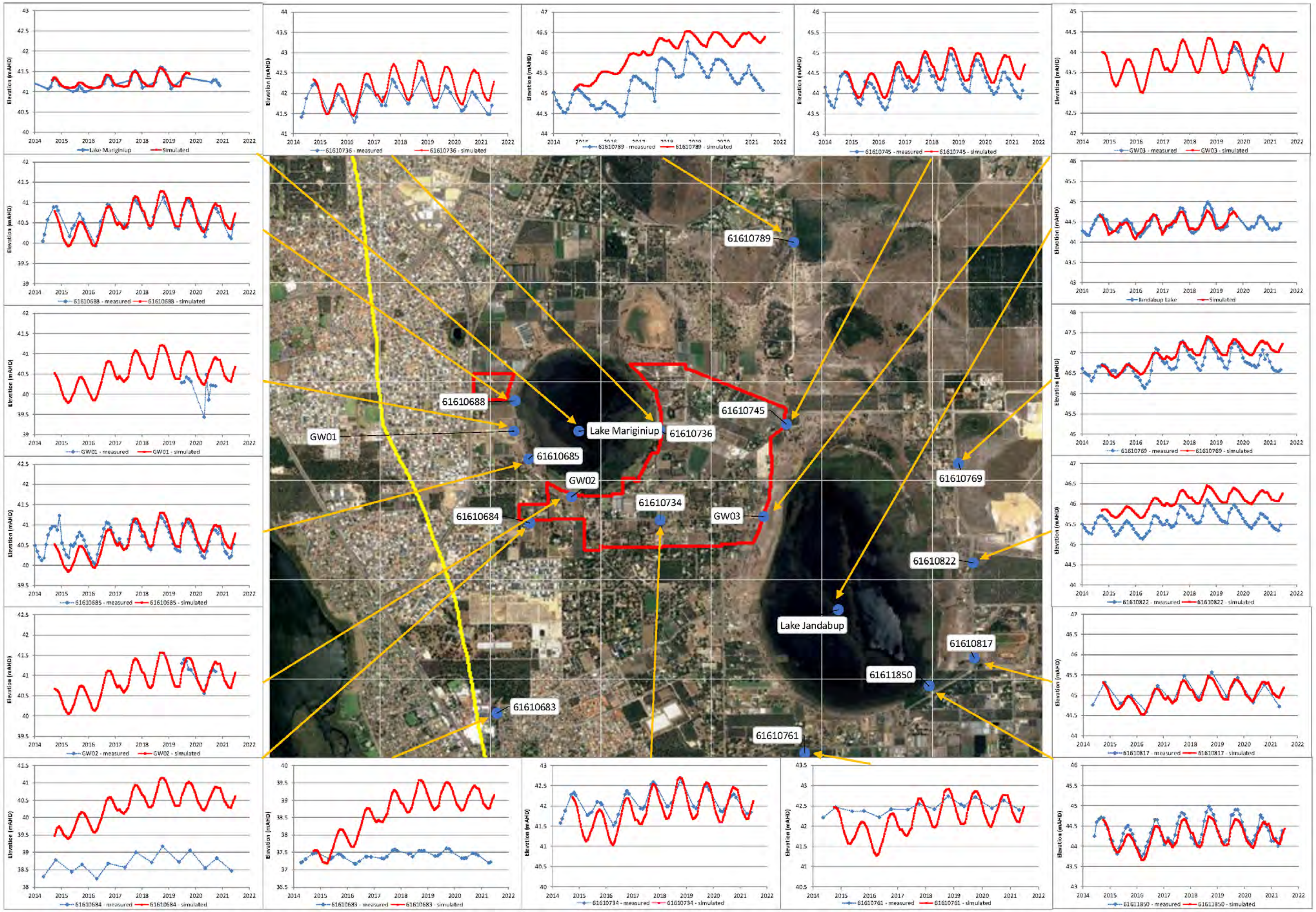

Figure 12: **Model calibration graphs in the vicinity of Precinct 7**

3.11.2 Calibrated aquifer parameter values

The calibrated aquifer parameter values are shown in Table 2. These values are reasonable with respect to literature values (CyMod Systems 2009) and previous modelling investigations in the area (Bourke, SA 2009). The adjusted hydraulic conductivity for the low K zone of 0.8 m/day is consistent with the hydraulic conductivity assumed by McFarlane 2015 for the simulation of a low hydraulic conductivity zone observed between the Bassendean Sand and Spearwood Sand downgradient of the Spectacles wetland (south of Perth) (McFarlane 2015).

Table 2: Calibrated aquifer parameters

Geological unit	Estimated range (m/day)*	Calibrated value
Bassendean Sand	10–50	12
Spearwood Sand	8–15	10
Low K Zone	<8	0.8

* Estimated range presented by CyMod Systems (2009)

3.12 Water balance

The water balance for the calibrated pre-development model, for all stress periods, is given in Table 3.

Table 3: Pre-development model water balance

Water balance parameter	Volume (m^3)	Per cent of water balance (with storage) (%)	Per cent of water balance (without storage) (%)	Per cent of rainfall (%)
Water IN				
Storage	199,971,802	35.4		
Constant head	49,678,243	8.8	13.6	
Wells*	3,164,840	0.6	0.9	
ET	0	0.0	0.0	
Recharge	304,564,269	53.9	83.5	29.3
Lake seepage	7,380,021	1.3	2.0	
Total IN	564,759,174	100.0	100.0	
Water OUT				
Storage	222,761,345	39.4		
Constant head	92,995,461	16.5	27.2	
Wells	173,770,494	30.8	50.8	
ET	52,045,468	9.2	15.2	
Recharge†	17,676,724	3.1	5.2	
Lake seepage	5,553,699	1.0	1.6	
Total out	564,803,191			
IN - OUT	-44017			
Error (%)	-0.01			

* Well inflows refers to the upward leakage into the Superficial aquifer from the Mirrabooka aquifer due to the specified flux boundary condition

† Recharge loss due to the inclusion of evapotranspiration within the recharge rates for deeper rooted vegetation

The water entering the system is via rainfall recharge (85% of total), groundwater inflow (14%), lake seepage into the groundwater (2%) and upward seepage from underlying aquifer systems (0.9%). Water exits the system by abstraction (51%), ET (20%), groundwater outflow (27%) and groundwater upflow into the lake (1.6%).

The water balance error for the entire model domain is -0.013%, which is less than 0.1%, the error specified by Konikow (1978) that is considered ideal.

4 POST-DEVELOPMENT GROUNDWATER MODELLING

The DWMS identifies groundwater level rise as a key risk to development due to higher recharge rates in urban areas and reduced abstraction with changing land use. The pre-development calibrated (transient) model was used as the starting point for model forecasting to:

- Assess the extent of subsoil drainage required to control groundwater rise (Scenario 1)
- Estimate subsoil flow rates in the Precinct 7 subsoil drainage system following development of the EWDSP area (Scenario 2a)
- Assess the impact of discharge of the subsoil drainage water into Lake Mariginiup (Scenario 2b).

The Wet 2050 future climate was used for the model forecasting, and the model was run for a period of 30 years (nominally 2021 to 2050, inclusive) using the calibrated January 2021 groundwater surface as the initial head condition across the model domain. This section outlines the changes that were made to the calibrated model for each forecast scenario and summarises the modelling results.

4.1 Scenario 1 – no subsoil drainage

For the forecast simulations, full build-out of the EWDSP area was assumed to determine the areas across the DSP area that will require subsoil drainage to control rising groundwater levels.

Key changes to the model to carry out the forecasting with no subsoil drainage are summarised below:

- Recharge rates and evapotranspiration rates were adjusted based on the land uses proposed in the EWDSP (Figure 1). In particular, across the DSP area recharge rates of 60% and 63% were applied to proposed urban and industrial or commercial land use areas, respectively, which is reasonable with respect to the VFM (Xu et al. 2009).
- Public abstraction was assumed to occur from the existing water supply bores at monthly rates equal to the average monthly abstraction rate between 2014 and 2021.
- Private groundwater abstraction currently occurring within the EWDSP area was removed from the model in areas of urban or industrial land use.
- Post-development public open space (POS) irrigation was included across the DSP area.
- The topographic surface was adjusted to include post-development ground elevations across Precinct 7.

Peak groundwater levels occurred after the eighth simulated winter (October 2028). The peak groundwater contours across Precinct 7 are shown in Figure 13.

4.1.1 Subsoil drainage area

The peak groundwater contours shown in Figure 13 were used to determine the depth to maximum future groundwater level below the ground surface (post-development ground elevations across Precinct 7). Areas requiring subsoil drainage were identified as those areas where the depth to the maximum groundwater level (without subsoil drainage) was less than 3 m. The areas requiring subsoil drainage across Precinct 7 and its surrounds are shown in Figure 14.

Subsoil drainage was not included immediately down gradient of the lakes in areas where the CGL is within 3 m of the ground level as this would potentially drain lake water into the subsoil drainage system. Subsoil drainage down gradient of Lake Mariginiup is not required if the lake water level does not exceed the absolute maximum lake level recommended in the DWMS.

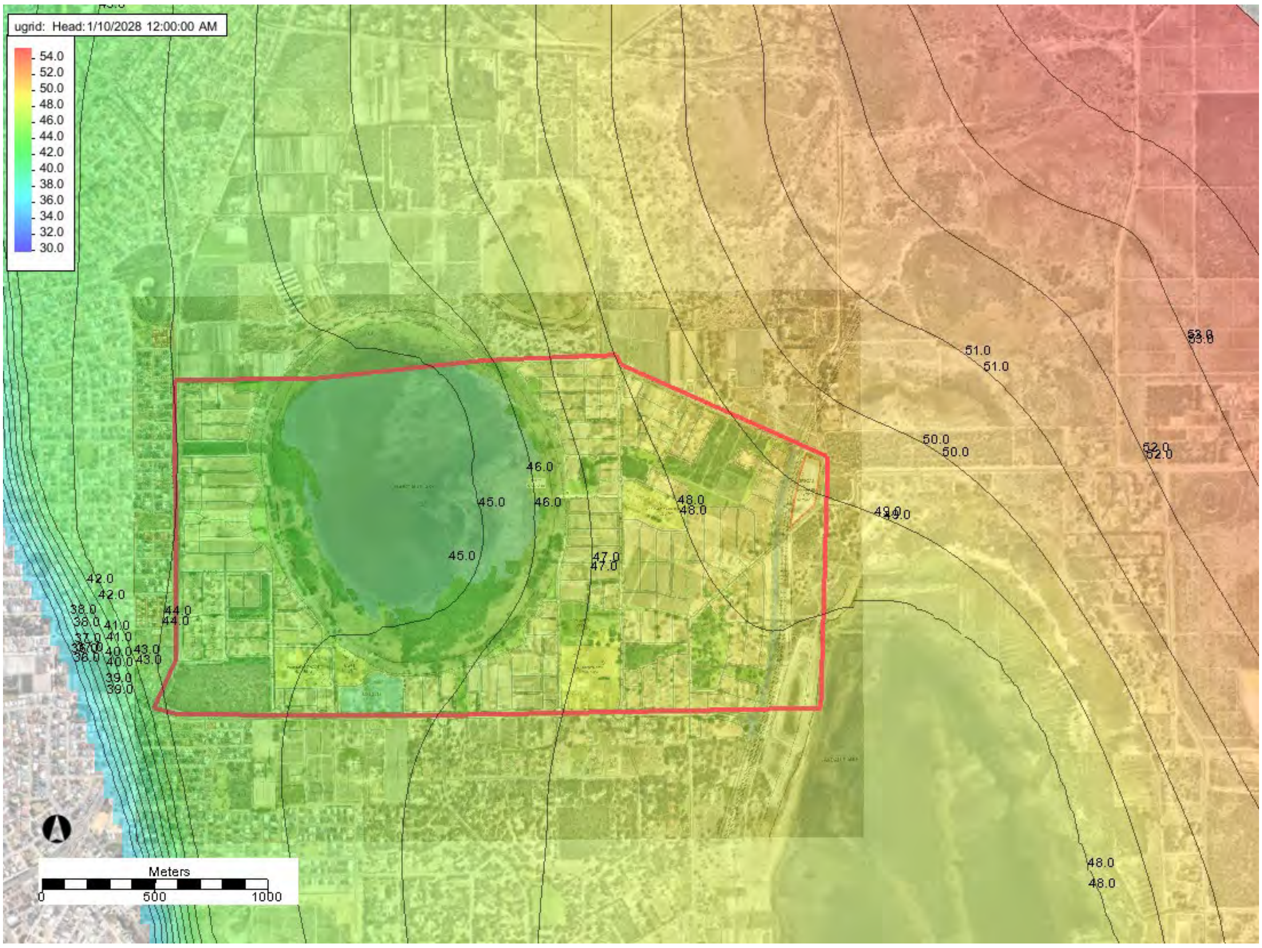

Figure 13: Peak post-development groundwater contours across Precinct 7 with no subsoil drainage

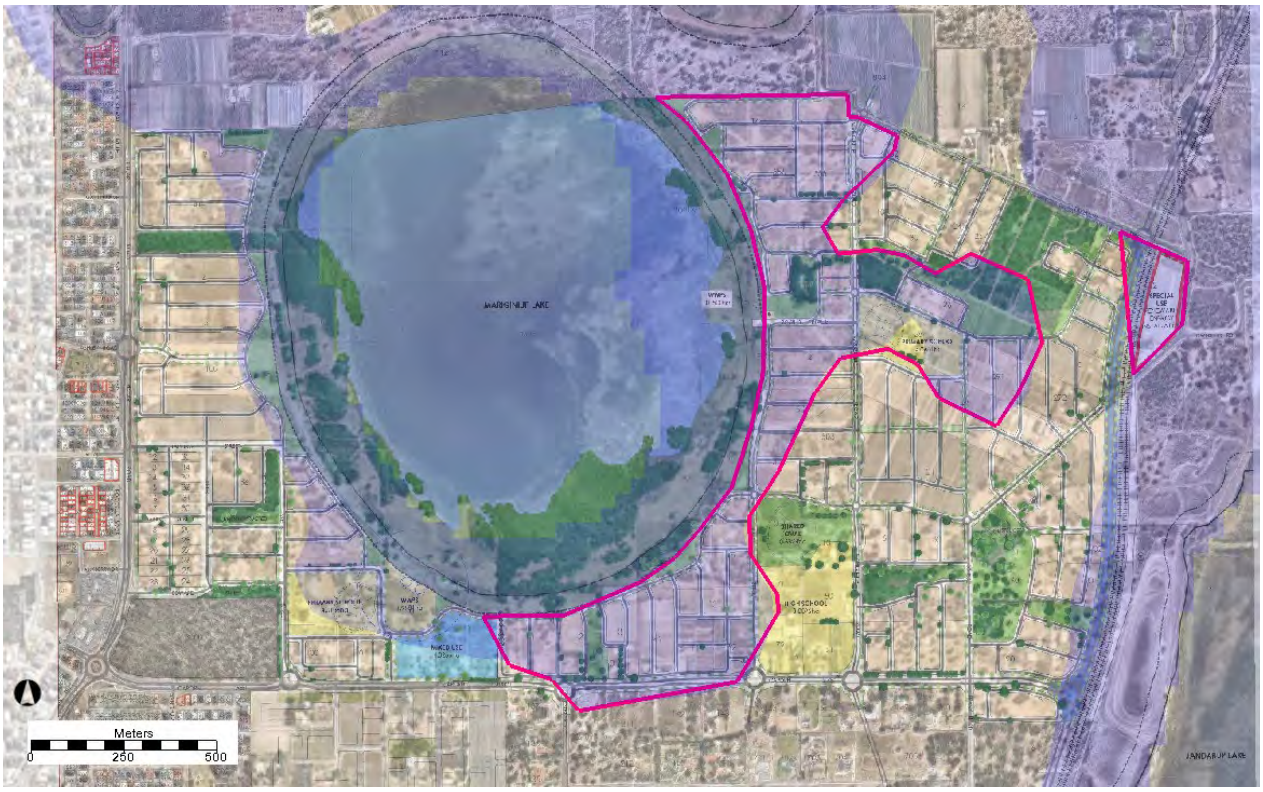

Figure 14: Depth to future groundwater level less than 3 m (shaded blue) and modelled subsoil drainage areas across Precinct 7 (red polygons), noting no subsoil drainage included down gradient of the lakes

4.2 Scenario 2 – with subsoil drainage

The Scenario 2 simulations were carried out by modifying the Scenario 1 model to include subsoil drainage in the areas identified across the DSP area as having a depth to future groundwater surface less than 3 m. Beyond the refined area of the model that included Precinct 7, Lake Mariginiup and Lake Jandabup, subsoil drainage was applied coarsely where required.

4.2.1 Subsoil drainage elevation

The DWMS indicates that subsoil drainage must be installed at invert levels based on the determined controlled groundwater level (CGL) in areas where the predicted future groundwater level is within 2 m of the future design surface. The CGL applied in the model was based on AAMGL information provided to RPS by 360 Environmental within the Precinct 7 area, and the CGL as outlined in the DWMS provided to RPS by Urbaqua.

A conservative subsoil drainage plane (i.e. conservative based on subsoil drainage areas and flow rates) was included in the model as follows:

- For areas where the CGL is within 3 m of the ground surface (post-development surface where available), subsoil drainage was assumed to be at the CGL.
- For areas where groundwater is expected to rise to within 3 m of the ground surface, but the CGL is more than 3 m below ground level, subsoil drainage was assumed to be at a maximum practicable depth of 3 m below ground level (post-development ground surface where available).

4.2.2 Scenario 2a – subsoil drainage assumed to discharge off site

For Scenario 2a, the subsoil drainage flows were assumed to discharge off site into a district-wide groundwater management system (i.e. for the modelling it was assumed no subsoil drainage flows were returned as inflows to the groundwater model). This discharge option would require an appropriately designed district collection and pumping scheme sized to manage the flows from the subsoil collection areas.

The simulated subsoil flow rates for this discharge option, under the Wet 2050 future climate scenario, are shown in Figure 15, and the estimated water levels in Lake Mariginiup over the simulation period are shown in Figure 16. The lake invert level, and some of the lake management levels recommended in the DWMS have been included in Figure 16.

The simulation results for a Wet 2050 future climate scenario with subsoil discharge off-site indicate the following:

- The peak seasonal subsoil drainage rates from the LSP area are estimated to range between ~4 L/s and ~60 L/s, with an average peak seasonal flow rate of ~25 L/s.
- Over the 30 years of simulated future climate (Wet 2050), the average monthly subsoil flow rates from the LSP area are estimated to range from 1.5 L/s in March to 23 L/s in August.
- The average monthly water level in Lake Mariginiup is estimated to range from 41.49 mAHD (March) to 42.12 mAHD (September). The simulated maximum average monthly lake level of 42.12 mAHD was ~0.7 m higher than the average September water level observed between 2014 and 2020, and just above the preferred minimum peak of 42.1 m AHD recommended in the DWMS.
- The simulated seasonal peak water level exceeded the absolute maximum lake level specified in the DWMS during two high rainfall years, but for many years was below the preferred minimum peak (spring) water level.

The simulation results indicate that Lake Mariginiup may require supplementation from an alternate water source so that the peak water level consistently exceeds the preferred minimum peak (spring) recommended in the DWMS. RPS notes however, that the modelling does not account for any stormwater run-off into Lake Mariginiup, which may increase the water levels above those simulated.

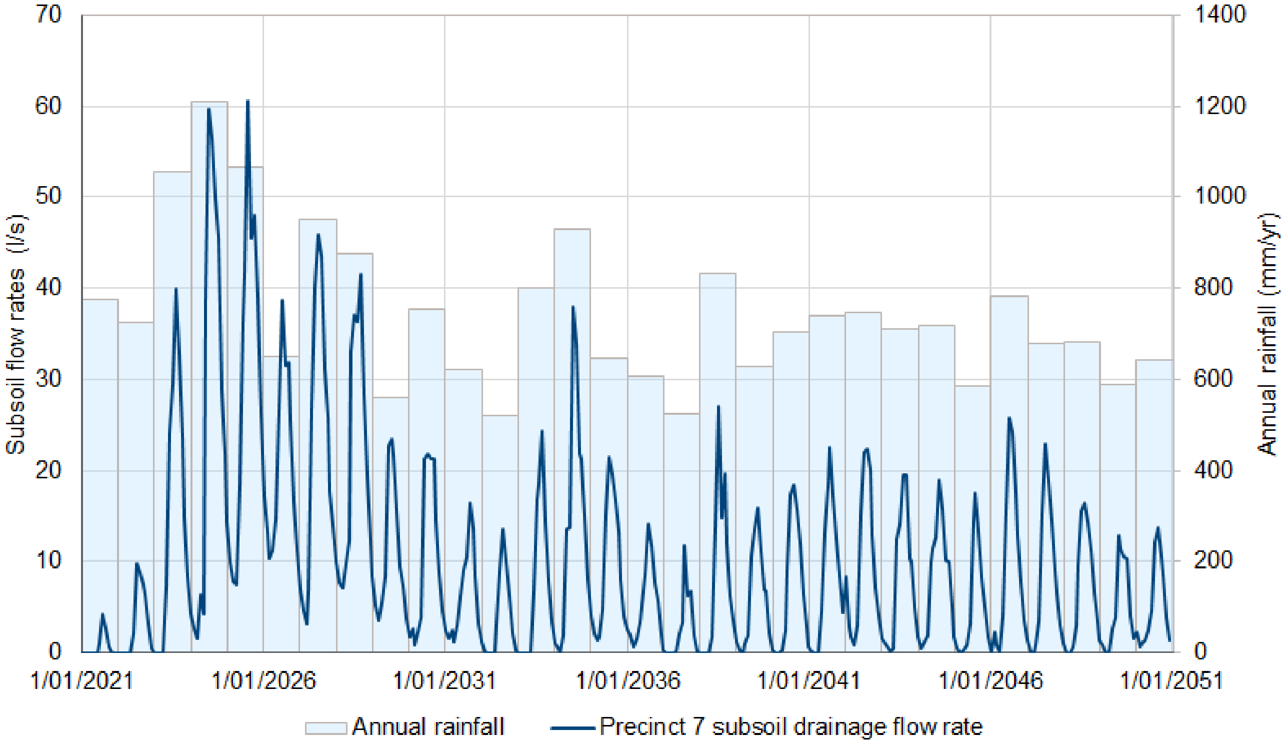

Figure 15: Subsoil drainage flow rate when the subsoil drainage is discharged off site (Scenario 2a)

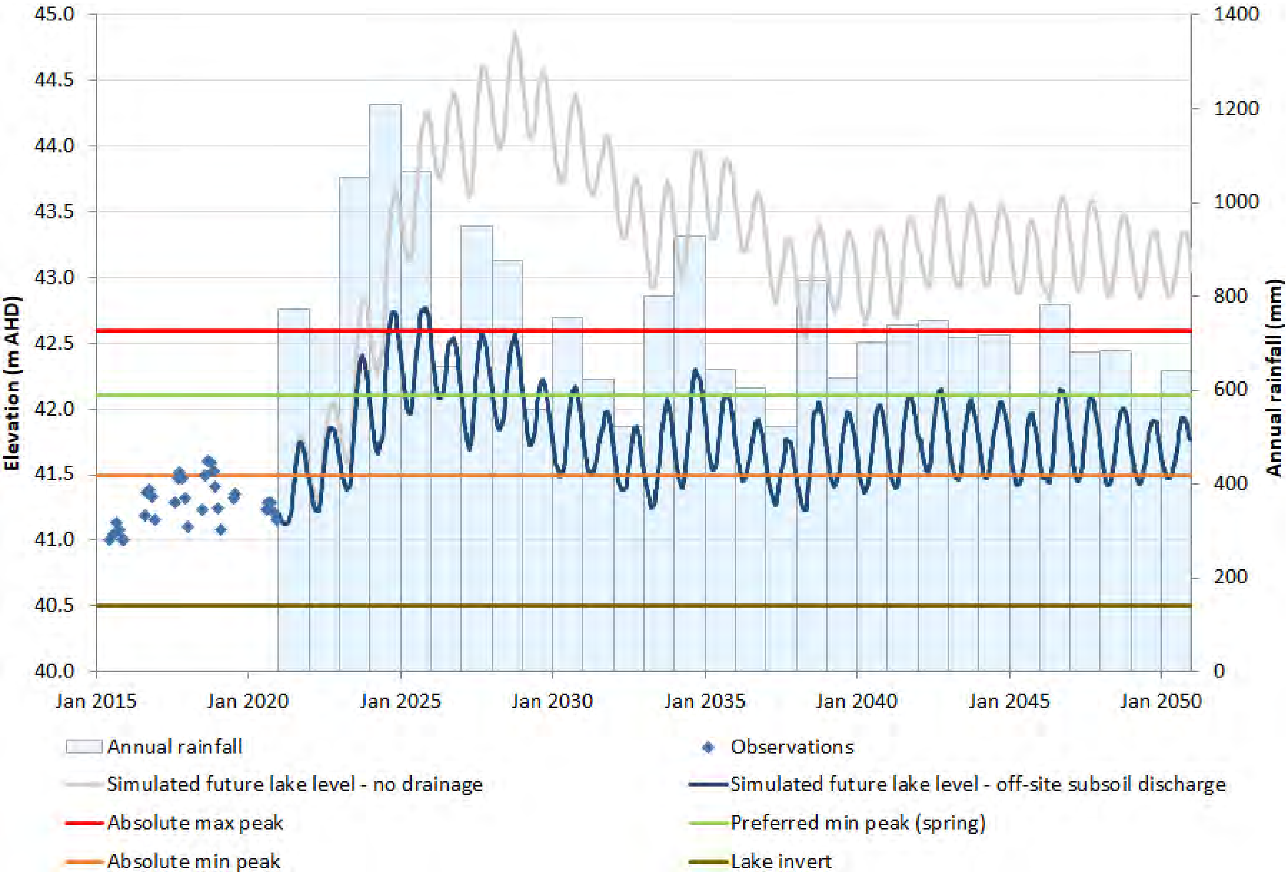

Figure 16: Simulated Lake Mariginiup water levels and DWMS management levels when the Precinct 7 subsoil drainage is discharged off site (Scenario 2a)

4.2.3 Scenario 2b – subsoil drainage discharged into Lake Mariginiup

For Scenario 2b, the discharge of subsoil drainage from Precinct 7 into Lake Mariginiup (after suitable WSUD treatment) was assessed as a potential permanent or interim subsoil drainage disposal option prior to the district wide groundwater management system becoming operational.

To simulate this discharge option, the subsoil drainage flow rates from Precinct 7 obtained from Scenario 2a were included as run-off into Lake Mariginiup. This resulted in higher subsoil flow rates, so the simulation was repeated using the increased flow rate to reduce the iterative error. Once repeated, the maximum difference in simulated flow rates from the subsoil drains was 5.4 L/s with an average difference of ~1 L/s.

For this discharge option the subsoil drainage flow rate time series over the Wet 2050 future climate simulation is shown in Figure 17 and the estimated water levels in Lake Mariginiup over the simulation period are shown in Figure 18.

The simulation results for a Wet 2050 future climate scenario with subsoil discharge into Lake Mariginiup indicate the following:

- Discharging subsoil drainage into Lake Mariginiup increased the estimated peak flow rate to 78 L/s following three high rainfall years (up from ~60 L/s when the subsoil drainage water is discharged off site.
- Discharging subsoil drainage into Lake Mariginiup increases the estimated average monthly subsoil drainage rates to range from ~3 L/s in March to ~30 L/s in August (up from 1.5 L/s in March and 23 L/s in August when subsoil drainage water is discharged off site).
- The discharge of the subsoil drainage into Lake Mariginiup (after suitable WSUD treatment) would raise the average monthly lake levels ~0.3 m to ~0.4 m above the average monthly lake levels outlined in the previous option with subsoil drainage discharged off site (i.e. average monthly lake levels simulated to range from 41.8 m AHD (April) to 42.5 m AHD (September and October).
- The highest average monthly lake elevation of 42.5 m AHD is below the absolute maximum lake elevation of 42.6 mAHD, but above the preferred minimum peak (spring) of 42.1 mAHD recommended in the DWMS.
- A peak lake water elevation of 43.8 m AHD occurred following three years of simulated rainfall exceeding 1000 mm/yr. The peak lake elevations was ~1.1 m higher than the simulated peak when subsoil drainage is discharged off site (Scenario 2a) and was ~1.2 m above the absolute maximum lake level of 42.6 m AHD recommended in the DWMS.
- Under a Wet 2050 climate scenario, the absolute maximum lake level was exceeded during nine of the 30 years simulated. For the majority of years simulated (18 out of 30), discharge of subsoil drainage into Lake Mariginiup resulted in a peak seasonal water level that was above the preferred minimum peak, but did not exceed the absolute maximum peak.

The model results indicate that subsoil drainage water from Precinct 7 could be discharged into Lake Mariginiup (after suitable WSUD treatment), particularly as an interim measure prior to the installation of a district wide groundwater management scheme, as long as there is a means to control the lake elevation to not exceed the absolute maximum elevation during high rainfall periods. Discharging subsoil drainage water into Lake Mariginiup could potentially increase peak lake levels above the preferred minimum peak level (spring) recommended in the DWMS.

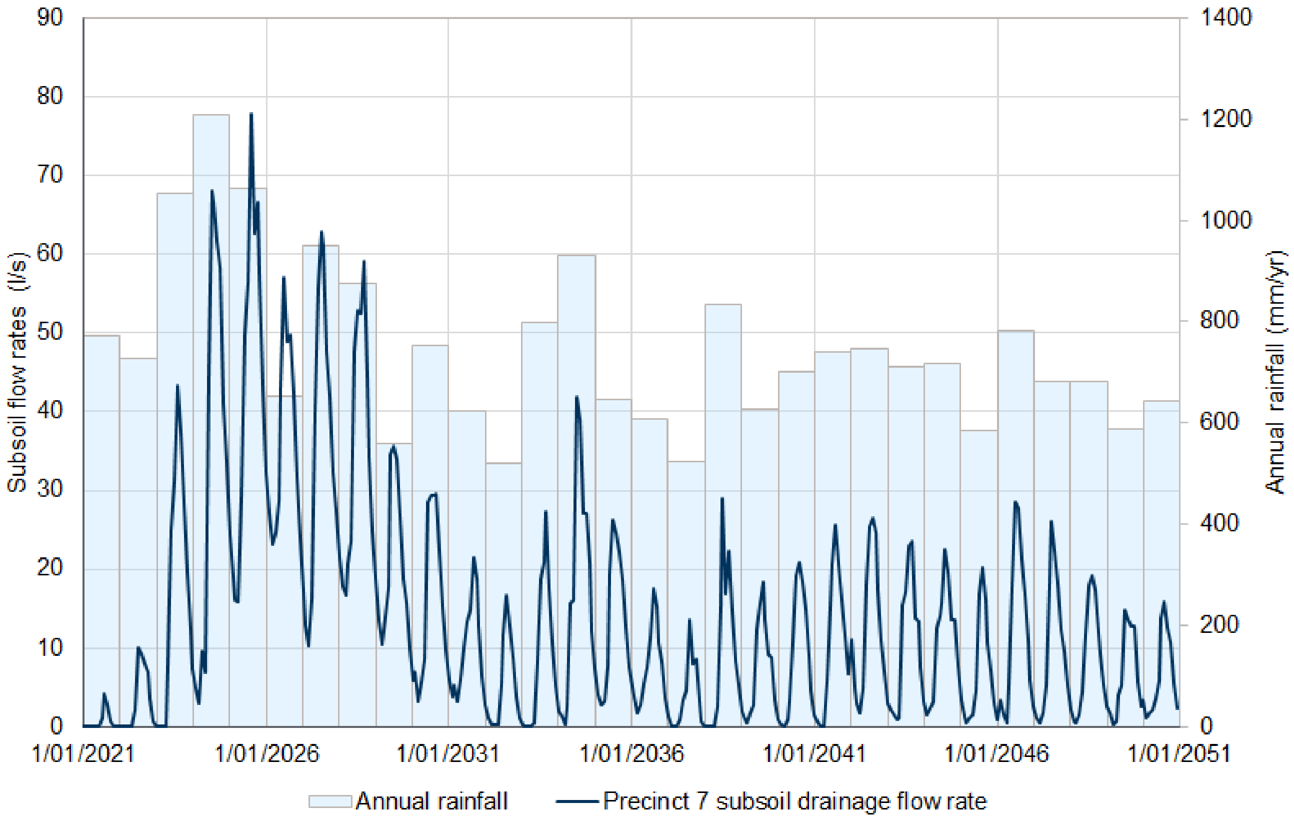

Figure 17: Subsoil drainage flow rate when the subsoil drainage is discharged into Lake Mariginiup (Scenario 2b)

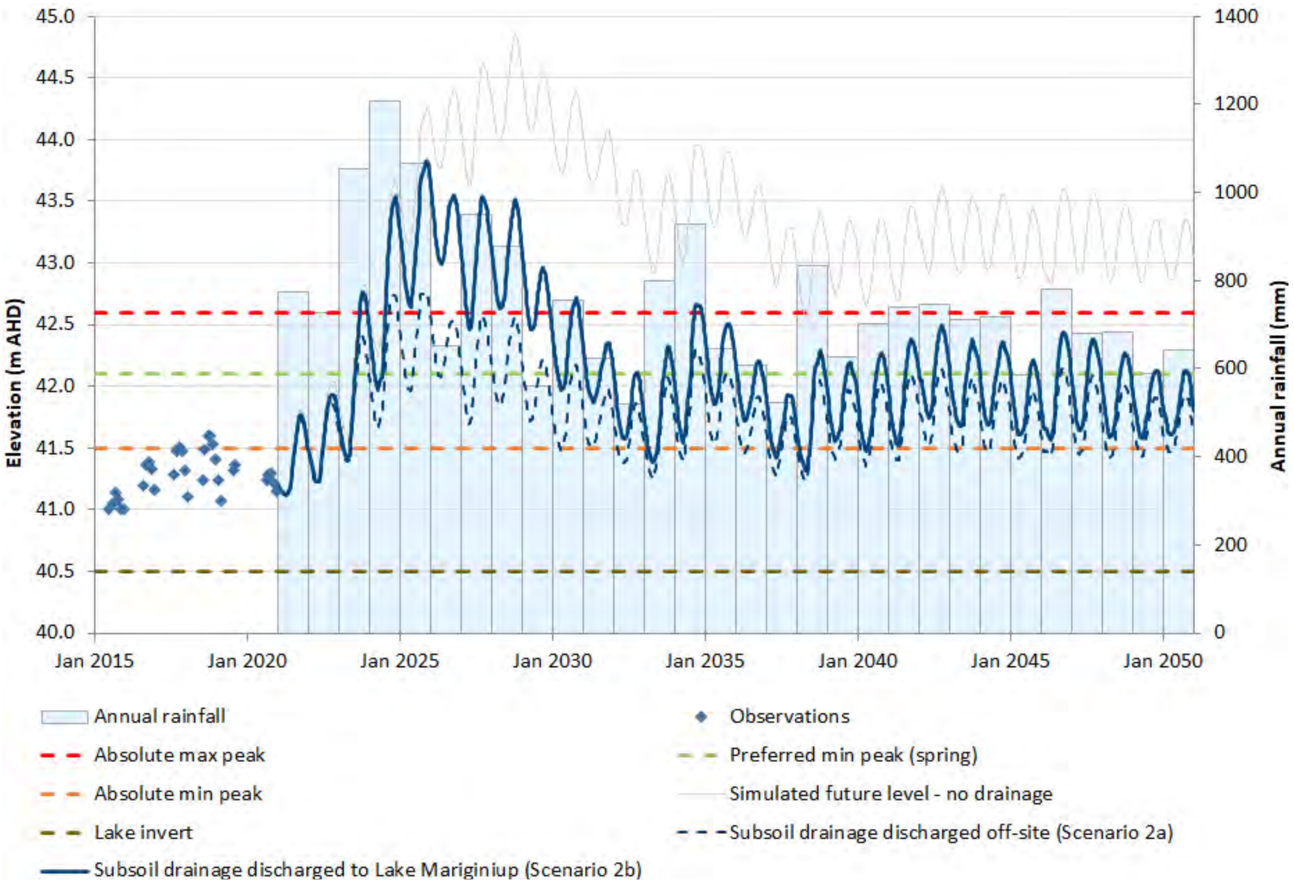

Figure 18: Simulated Lake Mariginiup water levels and DWMS management levels when the Precinct 7 subsoil drainage is discharged into Lake Mariginiup (Scenario 2b)

4.2.4 Lake Jandabup

Lake Jandabup is up gradient of Precinct 7 but adjacent to the southern half of the Precinct 7 eastern boundary. The simulated levels in Lake Jandabup for the two discharge options (Scenarios 2a and 2b) are shown in Figure 19.

The Wet 2050 future climate simulations with subsoil drainage indicate water levels in Lake Jandabup would not be impacted by subsoil discharge into Lake Mariginiup as the model results show no change in the water elevation in Lake Jandabup between the two discharge options. Furthermore, the water levels in Lake Jandabup would not impact the Precinct 7 development area as the simulated lake water level remained below the absolute maximum peak (46.2 m AHD) recommended in the DWMS.

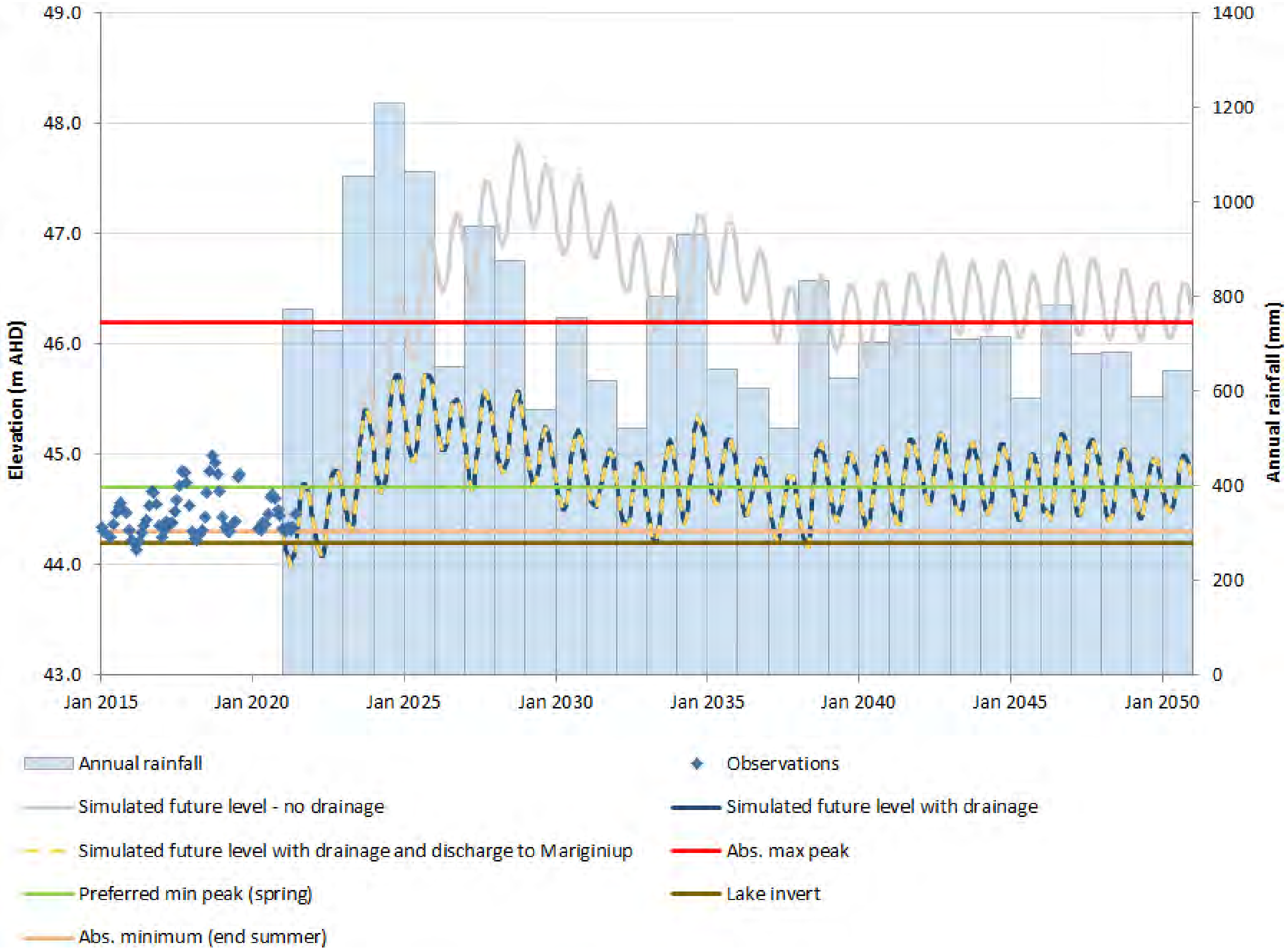

Figure 19: **Simulated Lake Jandabup water levels and DWMS management levels when the Precinct 7 subsoil drainage is discharged off-site (Scenario 2a) and discharged into Lake Mariginiup (Scenario 2b)**

4.3 Model assumptions

Various assumptions were required to model the pre-development groundwater flow system and undertake forecast modelling for Precinct 7, which may have impacted the simulation results. Key modelling assumptions are outlined below:

- Recharge rates are assumed to be a constant percentage of rainfall, based on rates available from previous modelling investigations and reports for the current land use, and any land uses changes over the calibration have not been incorporated into the model.
- Private abstraction rates are assumed to be equal to licence entitlement, not metered flow rates
- Leakage to and from underlying aquifers is based on information provided in Davidson (1995)
- A Wet 2050 future climate scenario has been assumed for the forecast modelling as a conservative estimate

- The CGL surface was based on the CGL provided by Urbaqua, adjusted with the AAMGL data provided by 360 Environmental.
- For the forecast scenarios none of the subsoil drainage abstracted across the EWDSP area outside of Precinct 7 was returned to the model as an inflow. The groundwater modelling has not examined the use of an integrated groundwater management scheme across the EWDSP area.

5 CONCLUSIONS

Groundwater rise is recognised as a key risk to development within the EWDSP area. Groundwater modelling has been undertaken for Precinct 7 within the EWDSP area with the objectives of:

1. Estimating post-development groundwater level changes across the LSP area, including at the key environmental locations of Lake Jandabup and Lake Mariginiup, to estimate areas of the LSP that would require subsoil drainage
2. Estimating subsoil drainage volumes that require management, to inform the design of the groundwater management system.

A pre-development groundwater flow model was calibrated under transient conditions to the measured groundwater levels. This model formed the basis of model forecasting of groundwater level changes associated with urban development, which included urban and industrial groundwater recharge rates and modified abstraction and irrigation rates to reflect the changes associated with development across the entire EWDSP area. Model simulations were carried out without subsoil drainage to ascertain the areas across the EWDSP area that would require subsoil drainage.

The area of Precinct 7 requiring subsoil drainage were identified as those areas where the future maximum groundwater level rises to within 3 m of the ground surface when there is no subsoil drainage.

In the areas that require subsoil drainage, drainage was included in the model across the EWDSP area at the CGL (if the CGL was less than 3 m below ground level) or at the maximum practicable subsoil depth of 3 m.

Based on the Wet 2050 future climate scenarios:

- Peak subsoil drainage flow rates are estimated to be ~60 L/s if the subsoil drainage is discharged off site, and ~ 80 L/s if the subsoil drainage water is discharged into Lake Mariginiup.
- Average maximum subsoil drainage flow rates are estimated to range from 23 L/s if the subsoil drainage is discharged off site, to ~ 30 l/s if the subsoil drainage water is discharged into Lake Mariginiup.
- If subsoil drainage water from Precinct 7 is discharged into Lake Mariginiup, the peak lake elevation may rise up 1.2 m above the absolute maximum lake level.
- If subsoil drainage water from Precinct 7 is discharged into Lake Mariginiup, the highest average monthly lake elevation is expected to be about 42.5 mAHD in September, which is above the preferred minimum peak (spring) of 42.1 mAHD but below the absolute maximum lake elevation of 42.6 mAHD recommended in the DWMS.
- Water levels in Lake Jandabup would not be impacted by subsoil drainage discharge into Lake Mariginiup and the Lake Jandabup water level would not impact Precinct 7 as long as the water level is controlled to be below the absolute maximum water level recommended in the DWMS.

The model results indicate that subsoil drainage water from Precinct 7 could be discharged into Lake Mariginiup, as long as there is a means to control the lake elevation to not exceed the absolute maximum elevation during high rainfall periods.

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Appendix K UNDO Report: Pre-development

Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

SLR Project No.: 675.V64450.00000

6 December 2023

Government of **Western Australia**
Department of **Water and Environmental Regulation**

Project:	Precinct 7	Date:	29-Nov-2023
		Version:	Version 1.2.0.19289

Subregion name: **Subregion 1**

			Input load	
Landuse	**Percent (%)**	**Area (ha)**	**Nitrogen (kg)**	**Phosphorus (kg)**
Residential	0	0.00	0.00	0.00
Industrial, commercial & schools	0	0.00	0.00	0.00
Rural living	25	63.25	4433.83	834.90
Public open space	69	174.57	11530.35	3561.23
Road reserve	6	15.18	0.00	0.00

Total area (ha)	Total percent (%)
253.00	**100**

Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
68.33	**17.53**

Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
6.47	**0.13**

Rural living

Landuse	Percent (%)	Area (ha)
Unrestricted	100	63.25
No livestock	0	0.00
No clearing apart from the housing pad	0	0.00

Total area (ha)	Total percent (%)
63.25	**25**

Nitrogen input (kg)	Phosphorus input (kg)
4433.83	**834.90**

Note: Commercial horticultre is not permitted in the rural living zone, due to spray drift buffers.

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	0	0.00
Non-native gardens	85	148.38
Not fertilised	0	0.00
Nature	15	26.19
Sport	0	0.00
Recreation	0	0.00
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
174.57	69

Nitrogen input (kg)	Phosphorus input (kg)
11530.35	3561.23

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	12.14
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	0	0.00
Road reserve - not fertilised	20	3.04

Total area (ha)	Total percent (%)
15.18	6

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

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**No**
Soil type	**Bassendean**	**Does subregion contain onsite sewage diposal system?**	**No**
Depth to groundwater (m)	**5**		
Groundwater slope (%)	**0.5**		
Soil PRI	**5.0**		

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

Summary: Nutrient stripping devices

Treatment	Name	Size (m^2)	Treated area (ha)	Treating	N removed (kg/ha/yr)	P removed (kg/ha/yr)
Load removed					**0.00**	**0.00**
Net export					**6.47**	**0.13**

Summary: Nutrient load exports

Region	Area (ha)	P export (kg/ha/yr)	N export (kg/ha/yr)
Subregion 1	253.00	0.13	6.47

PRE-TREATMENT LOAD (kg/ha/yr)		LOAD REMOVED (kg/ha/yr)		NET LOAD EXPORT (kg/ha/yr)	
NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS
6.47	**0.13**	**0.00**	**0.00**	**6.47**	**0.13**

Appendix L UNDO Report: Post-development

Local Water Management Strategy

Precinct 7, East Wanneroo District Structure Plan

Hesperia Pty Ltd

SLR Project No.: 675.V64450.00000

6 December 2023

Government of **Western Australia**
Department of Water and Environmental Regulation

Project:	Precinct 7	Date:	04-Sep-2023
		Version:	Version 1.2.0.19289

Subregion name: **Subregion 1**

Landuse	**Input load** **Percent (%)**	**Area (ha)**	**Nitrogen (kg)**	**Phosphorus (kg)**
Residential	54	5.29	196.88	54.00
Industrial, commercial & schools	0	0.00	0.00	0.00
Rural living	0	0.00	0.00	0.00
Public open space	15	1.47	28.71	0.78
Road reserve	31	3.04	17.01	0.55

Total area (ha)	Total percent (%)
9.80	**4**

Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
30.00	**5.80**

Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
2.90	**0.08**

Residential

Size (m²)	Input load Percent (%)	Area (ha)	Nitrogen (kg)	Phosphorus (kg)
<400	73	3.86	90.72	26.58
400-500 m²	20	1.06	69.41	17.73
501-600 m²	5	0.26	26.11	6.98
601-730 m²	2	0.11	10.64	2.71
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
5.28984	**54**

Nitrogen input (kg)	Phosphorus input (kg)
196.88	**54.00**

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	26	0.38
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	59	0.87
Sport	0	0.00
Recreation	15	0.22
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
1.47	**15**

Nitrogen input (kg)	Phosphorus input (kg)
28.71	**0.78**

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	2.43
Road reserve - impervious	0	0.00
Road reserve - native garden	20	0.61
Road reserve - non-native garden	0	0.00
Road reserve - turf	0	0.00
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
3.03676	**31**

Nitrogen input (kg)	Phosphorus input (kg)
17.01	**17.01**

Soil and drainage information

Type of drainage	**Infiltration**
Soil type	**Bassendean**
Depth to groundwater (m)	**3**
Groundwater slope (%)	**0.5**
Soil PRI	**5.0**

Does it contain imported fill? **No**

Does subregion contain onsite sewage diposal system? **No**

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

Subregion name: **Subregion 2**

Landuse	**Percent (%)**	**Area (ha)**	**Input load** **Nitrogen (kg)**	**Phosphorus (kg)**
Residential	46	28.16	1048.20	287.49
Industrial, commercial & schools	9	5.51	457.88	92.64
Rural living	0	0.00	0.00	0.00
Public open space	15	9.18	87.98	1.65
Road reserve	30	18.37	411.43	55.10

Total area (ha)	Total percent (%)
61.23	**25**

Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
37.99	**7.29**

Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
3.60	**0.25**

Residential

Size (m²)	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Phosphorus (kg)
<400	73	20.56	483.01	141.50
400-500 m²	20	5.63	369.54	94.41
501-600 m²	5	1.41	139.00	37.17
601-730 m²	2	0.56	56.66	14.41
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
28.1635	**46**

Nitrogen input (kg)	Phosphorus input (kg)
1048.20	**287.49**

Commercial, Industry and Schools

Landuse	Percent (%)	Area (ha)
Light industrial	0	0.00
Heavy industrial	0	0.00
Commercial / Offices	24	1.32
Schools	76	4.19
Public buildings	0	0.00

Total area (ha)	Total percent (%)
5.51	9

Nitrogen input (kg)	Phosphorus input (kg)
457.88	92.64

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	0	0.00
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	91	8.36
Sport	0	0.00
Recreation	9	0.83
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
9.18	15

Nitrogen input (kg)	Phosphorus input (kg)
87.98	1.65

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	14.69
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	20	3.67
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
18.3675	30

Nitrogen input (kg)	Phosphorus input (kg)
411.43	411.43

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**No**
Soil type	**Bassendean**	**Does subregion contain onsite sewage diposal system?**	**No**
Depth to groundwater (m)	**2**		
Groundwater slope (%)	**0.5**		
Soil PRI	**5.0**		

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

Subregion name: **Subregion 3**

			Input load	
Landuse	**Percent (%)**	**Area (ha)**	**Nitrogen (kg)**	**Phosphorus (kg)**
Residential	41	1.00	37.37	10.25
Industrial, commercial & schools	0	0.00	0.00	0.00
Rural living	0	0.00	0.00	0.00
Public open space	19	0.47	5.03	0.10
Road reserve	40	0.98	21.94	2.94

Total area (ha)	Total percent (%)
2.45	**1**
Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
31.51	**5.58**
Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
3.17	**0.04**

Residential

			Input load	
Size (m²)	Percent (%)	Area (ha)	Nitrogen (kg)	Phosphorus (kg)
<400	73	0.73	17.22	5.04
400-500 m²	20	0.20	13.17	3.37
501-600 m²	5	0.05	4.96	1.33
601-730 m²	2	0.02	2.02	0.51
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
1.00409	**41**

Nitrogen input (kg)	Phosphorus input (kg)
37.37	**10.25**

Public Open Space (POS)

Landuse	**Percent (%)**	**Area (ha)**
Native gardens	0	0.00
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	89	0.41
Sport	0	0.00
Recreation	11	0.05
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
0.47	**19**

Nitrogen input (kg)	Phosphorus input (kg)
5.03	**0.10**

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	0.78
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	20	0.20
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
0.9796	**40**
Nitrogen input (kg)	**Phosphorus input (kg)**
21.94	**21.94**

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**No**
Soil type	**Bassendean**	**Does subregion contain onsite sewage diposal system?**	**No**
Depth to groundwater (m)	**9**		
Groundwater slope (%)	**0.5**		
Soil PRI	**5.0**		

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

Subregion name: **Subregion 4**

			Input load	
Landuse	**Percent (%)**	**Area (ha)**	**Nitrogen (kg)**	**Phosphorus (kg)**
Residential	54	5.29	196.88	54.00
Industrial, commercial & schools	0	0.00	0.00	0.00
Rural living	0	0.00	0.00	0.00
Public open space	10	0.98	11.81	0.25
Road reserve	36	3.53	78.99	10.58

Total area (ha)	Total percent (%)
9.80	**4**
Nitrogen input (kg/ha/yr)	**Phosphorus input (kg/ha/yr)**
34.60	**6.77**
Nitrogen export (kg/ha/yr)	**Phosphorus (kg/ha/yr)**
3.35	**0.07**

Residential

		Input load		
Size (m²)	Percent (%)	Area (ha)	Nitrogen (kg)	Phosphorus (kg)
<400	73	3.86	90.72	26.58
400-500 m²	20	1.06	69.41	17.73
501-600 m²	5	0.26	26.11	6.98
601-730 m²	2	0.11	10.64	2.71
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
5.28984	**54**

Nitrogen input (kg)	Phosphorus input (kg)
196.88	**54.00**

Public Open Space (POS)

Landuse	**Percent (%)**	**Area (ha)**
Native gardens	0	0.00
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	87	0.85
Sport	0	0.00
Recreation	13	0.13
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
0.98	**10**

Nitrogen input (kg)	Phosphorus input (kg)
11.81	**0.25**

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	2.82
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	20	0.71
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
3.52656	**36**
Nitrogen input (kg)	Phosphorus input (kg)
78.99	**78.99**

Soil and drainage information

Type of drainage	**Infiltration**
Soil type	**Bassendean**
Depth to groundwater (m)	**3.5**
Groundwater slope (%)	**0.5**
Soil PRI	**5.0**

Does it contain imported fill? **No**

Does subregion contain onsite sewage diposal system? **No**

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

Subregion name: **Subregion 5**

			Input load	
Landuse	**Percent (%)**	**Area (ha)**	**Nitrogen (kg)**	**Phosphorus (kg)**
Residential	36	12.34	459.39	125.99
Industrial, commercial & schools	23	7.89	796.46	158.50
Rural living	0	0.00	0.00	0.00
Public open space	18	6.17	189.53	13.33
Road reserve	23	7.89	176.64	23.66

Total area (ha)	Total percent (%)
34.29	**14**
Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
52.54	**9.53**
Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
4.98	**0.58**

Residential

		Input load		
Size (m²)	Percent (%)	Area (ha)	Nitrogen (kg)	Phosphorus (kg)
<400	73	9.01	211.68	62.01
400-500 m²	20	2.47	161.95	41.38
501-600 m²	5	0.62	60.92	16.29
601-730 m²	2	0.25	24.83	6.31
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
12.34296	**36**

Nitrogen input (kg)	Phosphorus input (kg)
459.39	**125.99**

Commercial, Industry and Schools

Landuse	**Percent (%)**	**Area (ha)**
Light industrial	0	0.00
Heavy industrial	0	0.00
Commercial / Offices	0	0.00
Schools	100	7.89
Public buildings	0	0.00

Total area (ha)	Total percent (%)
7.89	**23**

Nitrogen input (kg)	Phosphorus input (kg)
796.46	**158.50**

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	0	0.00
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	62	3.83
Sport	35	2.16
Recreation	3	0.19
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
6.17	18
Nitrogen input (kg)	**Phosphorus input (kg)**
189.53	13.33

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	6.31
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	20	1.58
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
7.88578	23
Nitrogen input (kg)	**Phosphorus input (kg)**
176.64	176.64

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**No**
Soil type	**Bassendean**	**Does subregion contain onsite sewage diposal system?**	**No**
Depth to groundwater (m)	**1.5**		
Groundwater slope (%)	**0.5**		
Soil PRI	**5.0**		

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

Subregion name: **Subregion 6**

Landuse	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Phosphorus (kg)
Residential	55	4.04	150.39	41.25
Industrial, commercial & schools	0	0.00	0.00	0.00
Rural living	0	0.00	0.00	0.00
Public open space	23	1.69	15.14	0.27
Road reserve	22	1.62	36.21	4.85

Total area (ha)	Total percent (%)
7.35	3

Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
32.69	6.46

Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
3.20	0.04

Residential

Size (m²)	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Phosphorus (kg)
<400	73	2.95	69.30	20.30
400-500 m²	20	0.81	53.02	13.55
501-600 m²	5	0.20	19.94	5.33
601-730 m²	2	0.08	8.13	2.07
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
4.04085	55

Nitrogen input (kg)	Phosphorus input (kg)
150.39	41.25

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	0	0.00
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	92	1.55
Sport	0	0.00
Recreation	8	0.14
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
1.69	23

Nitrogen input (kg)	Phosphorus input (kg)
15.14	0.27

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	1.29
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	20	0.32
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
1.61634	22

Nitrogen input (kg)	Phosphorus input (kg)
36.21	36.21

Soil and drainage information

Type of drainage	**Infiltration**
Soil type	**Bassendean**
Depth to groundwater (m)	**12**
Groundwater slope (%)	**0.5**
Soil PRI	**5.0**

Does it contain imported fill?	**No**
Does subregion contain onsite sewage diposal system?	**No**

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

Subregion name: **Subregion 7**

Landuse	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Phosphorus (kg)
Residential	36	10.58	393.76	108.00
Industrial, commercial & schools	5	1.47	38.79	9.40
Rural living	0	0.00	0.00	0.00
Public open space	19	5.58	45.12	0.85
Road reserve	40	11.76	263.32	35.27

Total area (ha)	Total percent (%)
29.39	**12**

Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
30.44	**5.37**

Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
2.88	**0.33**

Residential

Size (m²)	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Phosphorus (kg)
<400	73	7.72	181.44	53.16
400-500 m²	20	2.12	138.82	35.47
501-600 m²	5	0.53	52.21	13.96
601-730 m²	2	0.21	21.28	5.41
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
10.57968	**36**

Nitrogen input (kg)	Phosphorus input (kg)
393.76	**108.00**

Commercial, Industry and Schools

Landuse	Percent (%)	Area (ha)
Light industrial	0	0.00
Heavy industrial	0	0.00
Commercial / Offices	100	1.47
Schools	0	0.00
Public buildings	0	0.00

Total area (ha)	Total percent (%)
1.47	5
Nitrogen input (kg)	**Phosphorus input (kg)**
38.79	9.40

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	17	0.95
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	83	4.63
Sport	0	0.00
Recreation	0	0.00
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
5.58	19
Nitrogen input (kg)	**Phosphorus input (kg)**
45.12	0.85

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	9.40
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	20	2.35
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
11.7552	40
Nitrogen input (kg)	**Phosphorus input (kg)**
263.32	263.32

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**No**
Soil type	**Bassendean**	**Does subregion contain onsite sewage diposal system?**	**No**
Depth to groundwater (m)	**1.5**		
Groundwater slope (%)	**0.5**		
Soil PRI	**5.0**		

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

Subregion name: **Subregion 8**

			Input load	
Landuse	**Percent (%)**	**Area (ha)**	**Nitrogen (kg)**	**Phosphorus (kg)**
Residential	51	24.98	929.71	254.99
Industrial, commercial & schools	5	2.45	247.35	49.22
Rural living	0	0.00	0.00	0.00
Public open space	21	10.29	98.54	1.85
Road reserve	23	11.27	252.34	33.80

Total area (ha)	Total percent (%)
48.98	**20**
Nitrogen input (kg/ha/yr)	**Phosphorus input (kg/ha/yr)**
36.43	**7.09**
Nitrogen export (kg/ha/yr)	**Phosphorus (kg/ha/yr)**
3.45	**0.05**

Residential

		Input load		
Size (m²)	Percent (%)	Area (ha)	Nitrogen (kg)	Phosphorus (kg)
<400	73	18.24	428.41	125.51
400-500 m²	20	5.00	327.77	83.74
501-600 m²	5	1.25	123.28	32.97
601-730 m²	2	0.50	50.26	12.78
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
24.9798	**51**

Nitrogen input (kg)	Phosphorus input (kg)
929.71	**254.99**

Commercial, Industry and Schools

Landuse	**Percent (%)**	**Area (ha)**
Light industrial	0	0.00
Heavy industrial	0	0.00
Commercial / Offices	0	0.00
Schools	100	2.45
Public buildings	0	0.00

Total area (ha)	Total percent (%)
2.45	**5**

Nitrogen input (kg)	Phosphorus input (kg)
247.35	**49.22**

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	0	0.00
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	91	9.36
Sport	0	0.00
Recreation	9	0.93
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
10.29	**21**

Nitrogen input (kg)	Phosphorus input (kg)
98.54	**1.85**

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	9.01
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	20	2.25
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
11.2654	**23**

Nitrogen input (kg)	Phosphorus input (kg)
252.34	**252.34**

Soil and drainage information

Type of drainage	**Infiltration**
Soil type	**Bassendean**
Depth to groundwater (m)	**12.5**
Groundwater slope (%)	**0.5**
Soil PRI	**5.0**

Does it contain imported fill?	**No**
Does subregion contain onsite sewage diposal system?	**No**

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

Subregion name: Subregion 9

			Input load	
Landuse	**Percent (%)**	**Area (ha)**	**Nitrogen (kg)**	**Phosphorus (kg)**
Residential	50	2.45	91.15	25.00
Industrial, commercial & schools	16	0.78	20.69	5.02
Rural living	0	0.00	0.00	0.00
Public open space	7	0.34	2.28	0.03
Road reserve	27	1.32	29.62	3.97

Total area (ha)	Total percent (%)
4.90	**2**
Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
34.58	**7.09**
Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
3.42	**0.27**

Residential

			Input load	
Size (m²)	Percent (%)	Area (ha)	Nitrogen (kg)	Phosphorus (kg)
<400	73	1.79	42.00	12.30
400-500 m²	20	0.49	32.13	8.21
501-600 m²	5	0.12	12.09	3.23
601-730 m²	2	0.05	4.93	1.25
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
2.449	**50**
Nitrogen input (kg)	Phosphorus input (kg)
91.15	**25.00**

Commercial, Industry and Schools

Landuse	Percent (%)	Area (ha)
Light industrial	0	0.00
Heavy industrial	0	0.00
Commercial / Offices	100	0.78
Schools	0	0.00
Public buildings	0	0.00

Total area (ha)	Total percent (%)
0.78	16

Nitrogen input (kg)	Phosphorus input (kg)
20.69	5.02

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	11	0.04
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	89	0.31
Sport	0	0.00
Recreation	0	0.00
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
0.34	7

Nitrogen input (kg)	Phosphorus input (kg)
2.28	0.03

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	1.06
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	20	0.26
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
1.32246	27

Nitrogen input (kg)	Phosphorus input (kg)
29.62	29.62

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**No**
Soil type	**Bassendean**	**Does subregion contain onsite sewage diposal system?**	**No**
Depth to groundwater (m)	**2**		
Groundwater slope (%)	**0.5**		
Soil PRI	**5.0**		

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

Subregion name: **Subregion 10**

			Input load	
Landuse	**Percent (%)**	**Area (ha)**	**Nitrogen (kg)**	**Phosphorus (kg)**
Residential	26	0.64	23.70	6.50
Industrial, commercial & schools	16	0.39	10.34	2.51
Rural living	0	0.00	0.00	0.00
Public open space	4	0.10	1.14	0.03
Road reserve	54	1.32	29.62	3.97

Total area (ha)	Total percent (%)
2.45	**1**

Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
31.69	**5.46**

Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
3.19	**0.13**

Residential

			Input load	
Size (m²)	Percent (%)	Area (ha)	Nitrogen (kg)	Phosphorus (kg)
<400	73	0.46	10.92	3.20
400-500 m²	20	0.13	8.35	2.13
501-600 m²	5	0.03	3.14	0.84
601-730 m²	2	0.01	1.28	0.33
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
0.63674	**26**
Nitrogen input (kg)	Phosphorus input (kg)
23.70	**6.50**

Commercial, Industry and Schools

Landuse	**Percent (%)**	**Area (ha)**
Light industrial	0	0.00
Heavy industrial	0	0.00
Commercial / Offices	100	0.39
Schools	0	0.00
Public buildings	0	0.00

Total area (ha)	Total percent (%)
0.39	**16**
Nitrogen input (kg)	Phosphorus input (kg)
10.34	**2.51**

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	32	0.03
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	68	0.07
Sport	0	0.00
Recreation	0	0.00
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
0.10	**4**

Nitrogen input (kg)	Phosphorus input (kg)
1.14	**0.03**

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	1.06
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	20	0.26
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
1.32246	**54**

Nitrogen input (kg)	Phosphorus input (kg)
29.62	**29.62**

Soil and drainage information

Type of drainage	**Infiltration**
Soil type	**Bassendean**
Depth to groundwater (m)	**2.5**
Groundwater slope (%)	**0.5**
Soil PRI	**5.0**

Does it contain imported fill? **No**

Does subregion contain onsite sewage diposal system? **No**

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

Subregion name: **Subregion 11**

			Input load	
Landuse	**Percent (%)**	**Area (ha)**	**Nitrogen (kg)**	**Phosphorus (kg)**
Residential	40	1.96	72.92	20.00
Industrial, commercial & schools	0	0.00	0.00	0.00
Rural living	0	0.00	0.00	0.00
Public open space	16	0.78	8.48	0.17
Road reserve	44	2.16	48.27	6.47

Total area (ha)	Total percent (%)
4.90	**2**
Nitrogen input (kg/ha/yr)	**Phosphorus input (kg/ha/yr)**
31.70	**5.59**
Nitrogen export (kg/ha/yr)	**Phosphorus (kg/ha/yr)**
3.14	**0.05**

Residential

		Input load		
Size (m²)	Percent (%)	Area (ha)	Nitrogen (kg)	Phosphorus (kg)
<400	73	1.43	33.60	9.84
400-500 m²	20	0.39	25.71	6.57
501-600 m²	5	0.10	9.67	2.59
601-730 m²	2	0.04	3.94	1.00
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
1.9592	**40**
Nitrogen input (kg)	**Phosphorus input (kg)**
72.92	**20.00**

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	0	0.00
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	89	0.70
Sport	0	0.00
Recreation	11	0.09
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
0.78	**16**

Nitrogen input (kg)	Phosphorus input (kg)
8.48	**0.17**

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	1.72
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	20	0.43
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
2.15512	**44**

Nitrogen input (kg)	Phosphorus input (kg)
48.27	**48.27**

Soil and drainage information

Type of drainage	**Infiltration**
Soil type	**Bassendean**
Depth to groundwater (m)	**4**
Groundwater slope (%)	**0.5**
Soil PRI	**5.0**

Does it contain imported fill? **No**

Does subregion contain onsite sewage diposal system? **No**

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

Subregion name: **Subregion 12**

			Input load	
Landuse	**Percent (%)**	**Area (ha)**	**Nitrogen (kg)**	**Phosphorus (kg)**
Residential	67	13.13	488.55	133.99
Industrial, commercial & schools	0	0.00	0.00	0.00
Rural living	0	0.00	0.00	0.00
Public open space	2	0.39	3.26	0.06
Road reserve	31	6.07	136.05	18.22

Total area (ha)	Total percent (%)
19.59	**8**
Nitrogen input (kg/ha/yr)	Phosphorus input (kg/ha/yr)
37.28	**7.92**
Nitrogen export (kg/ha/yr)	Phosphorus (kg/ha/yr)
3.53	**0.05**

Residential

			Input load	
Size (m²)	Percent (%)	Area (ha)	Nitrogen (kg)	Phosphorus (kg)
<400	73	9.58	225.12	65.95
400-500 m²	20	2.63	172.24	44.00
501-600 m²	5	0.66	64.79	17.32
601-730 m²	2	0.26	26.41	6.71
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
13.12664	**67**
Nitrogen input (kg)	Phosphorus input (kg)
488.55	**133.99**

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	18	0.07
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	82	0.32
Sport	0	0.00
Recreation	0	0.00
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
0.39	2

Nitrogen input (kg)	Phosphorus input (kg)
3.26	0.06

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	4.86
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	20	1.21
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
6.07352	31

Nitrogen input (kg)	Phosphorus input (kg)
136.05	136.05

Soil and drainage information

Type of drainage	**Infiltration**	**Does it contain imported fill?**	**No**
Soil type	**Bassendean**	**Does subregion contain onsite sewage diposal system?**	**No**
Depth to groundwater (m)	**10**		
Groundwater slope (%)	**0.5**		
Soil PRI	**5.0**		

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

Subregion name: **Subregion 13**

Landuse	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Phosphorus (kg)
Residential	39	3.82	142.19	39.00
Industrial, commercial & schools	19	1.86	187.99	37.41
Rural living	0	0.00	0.00	0.00
Public open space	18	1.76	9.59	0.10
Road reserve	24	2.35	52.66	7.05

Total area (ha)	Total percent (%)
9.80	**4**
Nitrogen input (kg/ha/yr)	**Phosphorus input (kg/ha/yr)**
45.29	**8.68**
Nitrogen export (kg/ha/yr)	**Phosphorus (kg/ha/yr)**
4.38	**0.31**

Residential

Size (m²)	Percent (%)	Area (ha)	Input load Nitrogen (kg)	Phosphorus (kg)
<400	73	2.79	65.52	19.19
400-500 m²	20	0.76	50.13	12.81
501-600 m²	5	0.19	18.86	5.04
601-730 m²	2	0.08	7.69	1.95
>730 m²	0	0.00	0.00	0.00
Multiple dwellings	0	0.00	0.00	0.00

Total area (ha)	Total percent (%)
3.82044	**39**
Nitrogen input (kg)	**Phosphorus input (kg)**
142.19	**39.00**

Commercial, Industry and Schools

Landuse	Percent (%)	Area (ha)
Light industrial	0	0.00
Heavy industrial	0	0.00
Commercial / Offices	0	0.00
Schools	100	1.86
Public buildings	0	0.00

Total area (ha)	Total percent (%)
1.86	**19**

Nitrogen input (kg)	Phosphorus input (kg)
187.99	**37.41**

Public Open Space (POS)

Landuse	Percent (%)	Area (ha)
Native gardens	6	0.11
Non-native gardens	0	0.00
Not fertilised	0	0.00
Nature	94	1.66
Sport	0	0.00
Recreation	0	0.00
Golf course	0	0.00
Bowling green	0	0.00
Impervious	0	0.00
Water body	0	0.00

Total area (ha)	Total percent (%)
1.76	**18**

Nitrogen input (kg)	Phosphorus input (kg)
9.59	**0.10**

Road reserve

Landuse	Percent (%)	Area (ha)
Roads	80	1.88
Road reserve - impervious	0	0.00
Road reserve - native garden	0	0.00
Road reserve - non-native garden	0	0.00
Road reserve - turf	20	0.47
Road reserve - not fertilised	0	0.00

Total area (ha)	Total percent (%)
2.35104	**24**

Nitrogen input (kg)	Phosphorus input (kg)
52.66	**52.66**

Soil and drainage information

Type of drainage	**Infiltration**	Does it contain imported fill?	**No**
Soil type	**Bassendean**	Does subregion contain onsite sewage diposal system?	**No**
Depth to groundwater (m)	**2**		
Groundwater slope (%)	**0.5**		
Soil PRI	**5.0**		

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

Summary: Nutrient stripping devices

Treatment	Name	Size (m²)	Treated area (ha)	Treating	N removed (kg/ha/yr)	P removed (kg/ha/yr)
Biofilter	Biofilter 1	256.00	9.80	Sandy soils – Runoff only (infiltration on lots)	0.43	0.01
Biofilter	Biofilter 2	2829.00	61.22	Sandy soils – Runoff only (infiltration on lots)	0.59	0.05
Biofilter	Biofilter 3	315.00	2.45	Sandy soils – Runoff only (infiltration on lots)	0.58	0.01
Biofilter	Biofilter 4	770.00	9.80	Sandy soils – Runoff and subsoil drains	1.52	0.03
Biofilter	Biofilter 5	1960.00	34.29	Sandy soils – Runoff and subsoil drains	2.23	0.22
Biofilter	Biofilter 6	567.00	7.35	Sandy soils – Runoff only (infiltration on lots)	0.56	0.01
Biofilter	Biofilter 7	3386.00	29.39	Sandy soils – Runoff only (infiltration on lots)	0.52	0.07
Biofilter	Biofilter 8	3582.00	48.98	Sandy soils – Runoff only (infiltration on lots)	0.60	0.01
Biofilter	Biofilter 9	464.00	4.90	Sandy soils – Runoff and subsoil drains	1.56	0.10
Biofilter	Biofilter 10	272.00	2.45	Sandy soils – Runoff and subsoil drains	1.46	0.05
Biofilter	Biofilter 11	192.00	4.90	Sandy soils – Runoff only (infiltration on lots)	0.50	0.01
Biofilter	Biofilter 12	1521.00	19.59	Sandy soils – Runoff and subsoil drains	1.60	0.02
Biofilter	Biofilter 13	600.00	9.80	Sandy soils – Runoff and subsoil drains	1.97	0.12
Detention / infiltration basin	Detention / infiltration basin 1	4991.00	48.98	Sandy soils – Runoff only (infiltration on lots)	0.06	0.00

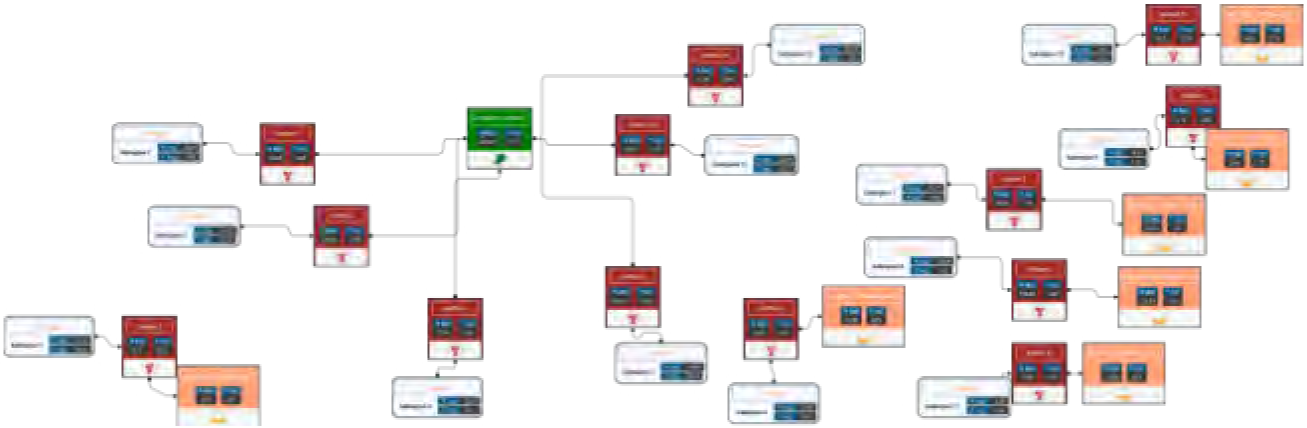
Detention / infiltration basin	Detention / infiltration basin 2	665.00	2.45	Sandy soils – Runoff only (infiltration on lots)	0.08	0.00
Detention / infiltration basin	Detention / infiltration basin 3	1092.00	7.35	Sandy soils – Runoff only (infiltration on lots)	0.07	0.00
Detention / infiltration basin	Detention / infiltration basin 4	5002.00	29.39	Sandy soils – Runoff only (infiltration on lots)	0.06	0.00
Detention / infiltration basin	Detention / infiltration basin 5	933.00	4.90	Sandy soils – Runoff and subsoil drains	0.10	0.00
Detention / infiltration basin	Detention / infiltration basin 6	584.00	2.45	Sandy soils – Runoff and subsoil drains	0.10	0.00
Detention / infiltration basin	Detention / infiltration basin 7	428.00	4.90	Sandy soils – Runoff only (infiltration on lots)	0.06	0.00
Constructed wetland	Constructed wetland 1	20000.00	144.51	Sandy soils – runoff, subsoils and groundwater	6.83	0.69
Load removed					**1.77**	**0.15**
Net export					**1.86**	**0.07**

Summary: Nutrient load exports

Region	Area (ha)	P export (kg/ha/yr)	N export (kg/ha/yr)
Subregion 1	9.80	0.08	2.90
Subregion 2	61.23	0.25	3.60
Subregion 3	2.45	0.04	3.17
Subregion 4	9.80	0.07	3.35
Subregion 5	34.29	0.58	4.98
Subregion 6	7.35	0.04	3.20
Subregion 7	29.39	0.33	2.88
Subregion 8	48.98	0.05	3.45
Subregion 9	4.90	0.27	3.42
Subregion 10	2.45	0.13	3.19
Subregion 11	4.90	0.05	3.14
Subregion 12	19.59	0.05	3.53
Subregion 13	9.80	0.31	4.38

PRE-TREATMENT LOAD (kg/ha/yr)		LOAD REMOVED (kg/ha/yr)		NET LOAD EXPORT (kg/ha/yr)	
NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS	NITROGEN	PHOSPHORUS
3.63	**0.23**	**1.77**	**0.15**	**1.86**	**0.07**

Treatment diagram



Making Sustainability Happen

Memo

Date: 12th December 2023
To: John Hunt
From: Dan Williams
Pages: 7 pages
Regarding: East Wanneroo Precinct 7 - Stormwater Modelling

The following provides an overview of the stormwater modelling undertaken by Pentium Water to inform the Precinct 7 Local Water Management Strategy. This memo is intended to document the methodology and outputs of the stormwater modelling, and to inform the structure planning and preliminary civil and landscape design process in terms of stormwater management basin locations and sizes.

Summary of tasks completed:

1. Review design earthworks contours against latest district-scale Controlled Groundwater Levels and consider (at a high level) potential subsoil drainage requirements and design levels.
2. Review design contours and stormwater catchments as provided by Tabec Civil Engineering Consultants. Undertake drainage catchment calculations to provide breakdown of land uses for stormwater modelling based on Structure Plan Map (HES MAR 03-05f-02).
3. Undertake sizing calculations for bioretention basins, based on assessment of direct connected impervious area, for all catchments adjacent to Lake Mariginiup or Lake Jandabup.
4. XPSWMM hydrological and hydraulic modelling to determine 1% AEP basin volume and area requirements, based on hydrologic routing and adopted loss parameters for catchments that do not outfall to Lake Mariginiup or Lake Jandabup.

Subsoil requirements

Figure 1 below provides an assessment of the preliminary design levels against the district-scale Controlled Groundwater Levels (determined in the DWMS (Urbaqua, 2021)) which indicates that there is generally approximately 3 m or more separation to the controlled groundwater level, with the minimum separation being 2.5 m along a section of the perimeter road along the south-east part of the lake. Given the separation between the design surface and the proposed controlled groundwater level, it is not anticipated that subsoil drainage is a significant design constraint for Precinct 7. However, subsoils may be installed beneath parts of the project area as a contingency against rising groundwater levels.

The minimum level at which those subsoil drains can be set has been determined as the Controlled Groundwater Level (GGL) in the District Water Management Strategy (Urbaqua, 2021), which was established as the 1986-1995 average annual maximum groundwater level. However, elevations of some areas of subsoil drainage are likely to not be practically installed at CGL given the significant depth to that level. In this instance, if it is considered necessary to install subsoil drains to control groundwater level rise, they will be installed at a more practical level (eg. 1.5m below road pavement level).

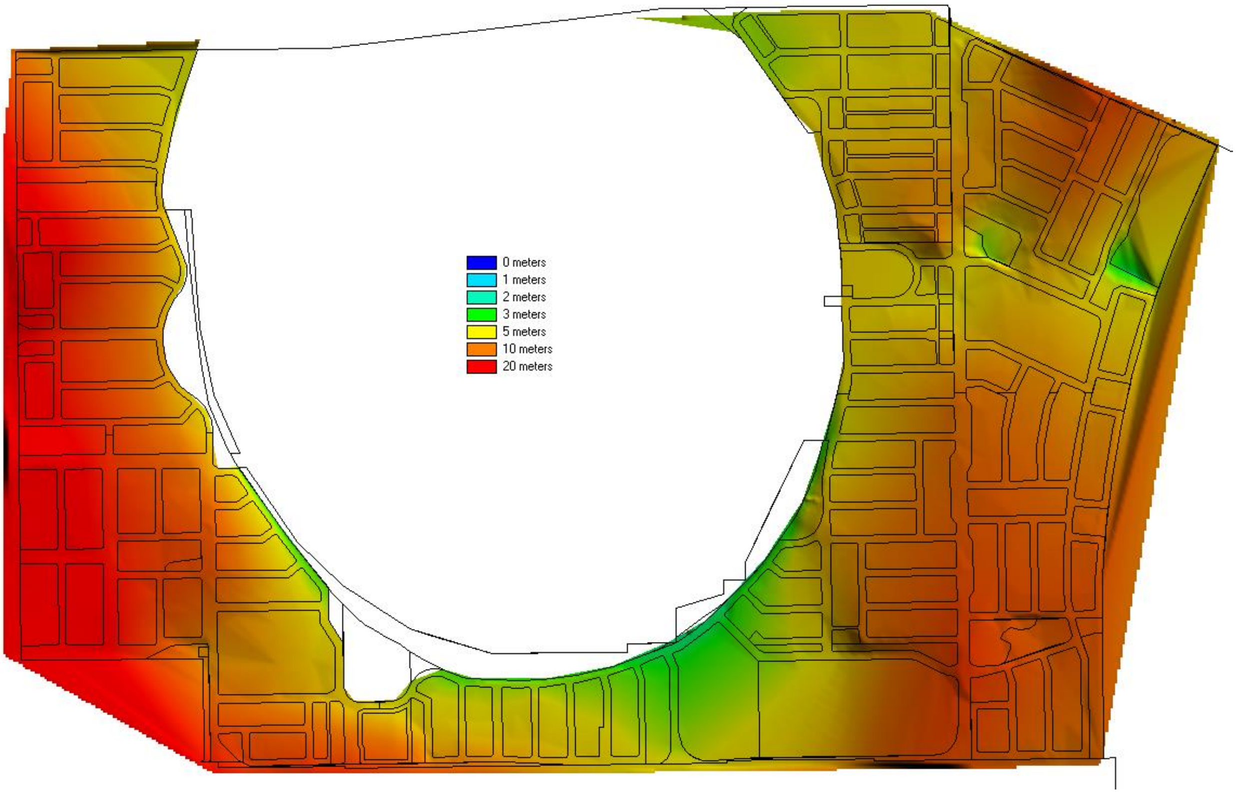


Figure 1: Approximate depth from design surface to Controlled Groundwater Level

Groundwater modelling undertaken by RPS (2021) estimated post-development groundwater levels across Precinct 7 in the scenario that the entire EWDSP area was developed and there was no district-scale groundwater level management to control the groundwater level rise that would otherwise result from the change in land use and associated increased recharge and decreased abstraction. The RPS assessment then identified areas where the separation from this post-development groundwater level to the preliminary design earthworks levels across Precinct 7 was less than 3 metres. These areas were nominated as potential subsoil drainage areas to control post-development groundwater level in Precinct 7, by discharging intercepted groundwater to Lake Mariginiup. The areas identified by RPS (2021) comprised a relatively small portion of Precinct 7 abutting the eastern and southern sides of the lake.

It is understood that a district-scale groundwater / lake water level management system will be implemented to facilitate development of the broader EWDSP area. Therefore, the preliminary assessment by RPS described above is not considered to reflect the likely post-development groundwater levels or the extent of subsoil drainage that will actually be required in Precinct 7.

The minimum design earthworks level along the eastern and southern sides of Lake Mariginiup is approximately 45.5 mAHD (and only in very minor areas, with design levels typically being much higher than this). A 2020 review into the water level thresholds for the management of Gnangara Mound wetlands in accordance with Ministerial Statement No. 819 (Kavazos et al., 2020) proposes a maximum water level threshold for Lake Mariginiup of 42.6 mAHD. This is, therefore, the maximum level at which the district-scale groundwater level control system would maintain water levels in Lake Mariginiup (other than, potentially, for short periods following large or successive rainfall events).

Whilst more significant groundwater rise / mounding beneath the Precinct 7 development area is possible, it is considered unlikely that subsoil drainage will be required in Precinct 7, with the possible exception of some localised areas fringing Lake Mariginiup. Based on the preliminary design levels described above (ie. minimum 45.5 mAHD), any such subsoil drainage will be able to outlet well above the maximum / controlled water level in Lake Mariginiup for treatment prior to discharge to the lake.

It is understood that subsoil drainage will be required to be treated outside of wetland buffers and then overland flow into the lake, with no or minimal alteration of natural surface levels through wetland buffer areas. This design outcome is achievable based on the preliminary design levels, and it is noted that there also exists opportunity to locally adjust (ie. lift) the design earthworks levels at the detailed design stage if required in any locations to facilitate subsoil drainage treatment and outlet level requirements.

It is anticipated that specific locations requiring subsoil drainage will be defined at the subdivision stage and documented in future Urban Water Management Plans, once the district-scale groundwater management system and associated groundwater modelling is further progressed.

Stormwater catchments

Figure 2 below provides the post-development stormwater catchments. The stormwater management strategy is described in the LWMS and broadly comprises:

- For catchments that drain to locations adjacent to Lake Mariginiup or Lake Jandabup: retention, treatment and infiltration of runoff generated from constructed impervious surfaces during the first 15mm of rainfall, with larger events allowed to overtop the bioretention basins and flow (as overland flow through vegetated areas) towards the lakes for flood storage.
- For catchments that drain to low points not associated with either of the lakes: treatment of the first 15mm event and flood storage (via retention and infiltration) of larger events up to 1% AEP within landscaped drainage basins in POS areas.

It is noted that the boundary between Catchment D and Catchment F shown in Figure 2 differs slightly from that shown in Tabec's engineering plans (drawing SK-003D). The reason for the discrepancy is a slight change in the development layout upon which the modelling was based and that reflected in the final LSP and engineering plans. The impact of the layout and catchment boundary change is that Catchment D and Catchment F will be slightly larger and smaller, respectively, than what has been assumed and documented herein. Therefore, the required basin sizes for Catchment D and Catchment F will be slightly larger and smaller, respectively, than documented herein. There will, however, be zero net change to the overall drainage basin volume or spatial requirement, or to the volume and rate of discharge to Lake Mariginiup. Therefore, this minor inaccuracy in the modelled catchment areas will have no material impact on the objectives or general design outcomes documented in the LWMS. The necessary changes to the Basin D and F sizes will be reflected in subsequent revisions to the stormwater modelling and drainage design which are to be documented in future Urban Water Management Plans, and are considered consistent with the degree of catchment boundary refinement that typically occurs at detailed design stage.

It is also noted that there is some external catchment area to the south of Precinct 7 which will contribute stormwater flows into Precinct 7. No specific assessment or modelling of the catchment area to the south of the Precinct 7 LSP has been undertaken as it is assumed that the drainage design for the (external) Precinct 6 area will involve treating the first 15mm within its own LSP area and larger events simply being conveyed through Precinct 7 to discharge to Lake Mariginiup. Figure 2 shows the two locations of external catchment inflows along the southern boundary of Precinct 7, as per the DWMS (Urbaqua, 2021). Also noted on the figure is the peak 1% AEP flow estimates provided in the DWMS. The DWMS flags these flow paths as potentially being overland flow through a large conveyance swale. The Precinct 7 structure plan has considered and responded to these flow paths with provision for open channel conveyance along Caporn Street (within the High School site) and through POS 5 towards Lake Mariginiup.

Pentium Water considers that the DWMS flow estimates may be very conservative, given the sandy site conditions, and opportunity for infiltration and detention of flows higher in the catchment (thus reducing the magnitude of flows and size of drainage infrastructure through Precincts 6 and 7). However, no further assessment has been made on this given the flows will be generated outside of Precinct 7 and the planning, earthworks and drainage details for that external catchment area (Precinct 6) are unknown. Therefore, Pentium Water considers that in the absence of more refined drainage design for Precinct 6, the LWMS for Precinct 7 should accommodate the external flow rates identified in the DWMS. There is the potential for any land take associated with drainage corridors for these external flows to be recouped at a later date should the future planning and water management for Precinct 6 result in significantly smaller inflows to Precinct 7.

Catchments P and U grade eastwards towards Lake Jandabup and stormwater from these catchments will be managed in the relatively low-lying area on the eastern boundary of Precinct 7 adjoining WAPC-owned land which is zoned ‘Parks and Recreation’ in the MRS and is associated with the Lake Jandabup foreshore. These catchments will retain, treat, and infiltrate the 15 mm event within the POS proposed along the eastern boundary of Precinct 7 prior to discharging as overland flow towards Lake Jandabup. This is consistent with the principles of the DWMS which shows this eastern portion of Precinct 7 as ultimately discharging to Lake Jandabup.

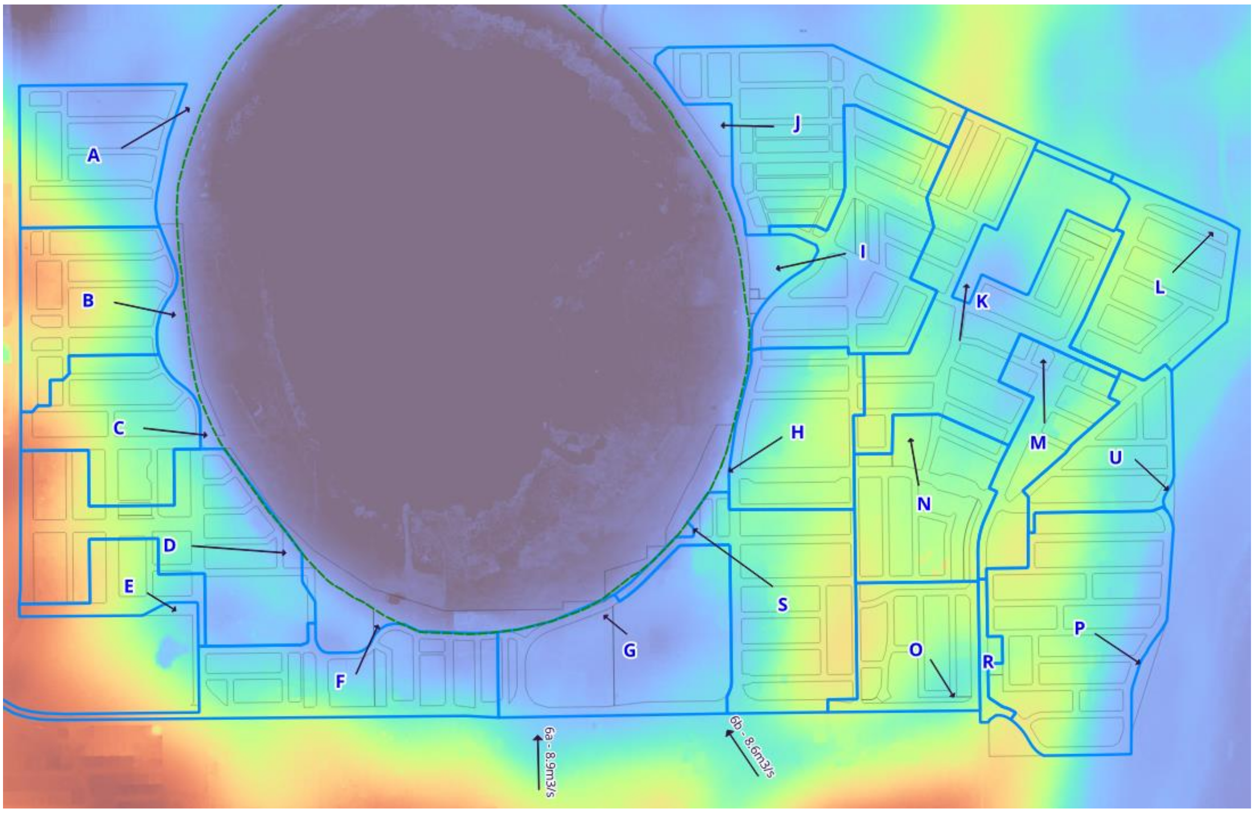


Figure 2: *Stormwater catchments (colour shading shows existing topography)*

A detailed breakdown of land uses within each stormwater catchment (according to Structure Plan Map HES MAR 03-05f-02) is provided in Table 1 below.

Table 1: Catchment area breakdown (ha)

Catchment	Total	Road reserve	R30 Lots	R40 Lots	Special use	POS	School
A	11.722	5.308	0.000	3.786	0.000	2.628	0.000
B	11.565	7.283	0.000	4.282	0.000	0.000	0.000
C	10.442	6.967	0.000	3.475	0.000	0.000	0.000
D	18.683	7.914	0.000	5.097	0.000	1.701	3.971
E	4.360	1.976	0.000	2.299	0.000	0.085	0.000
F	13.749	5.950	0.000	6.495	1.260	0.044	0.000
G	16.336	0.418	0.000	2.709	0.000	4.141	9.068
H	10.871	3.408	0.000	3.455	0.000	0.000	4.008
I	15.547	9.146	0.095	5.940	0.000	0.366	0.000
J	16.360	1.413	8.815	6.132	0.000	0.000	0.000
K	22.141	13.826	0.000	8.273	0.000	0.042	0.000
L	12.762	6.296	0.000	5.947	0.000	0.519	0.000
M	9.734	3.143	0.000	5.141	0.000	1.450	0.000
N	11.946	6.446	0.000	4.166	0.000	1.334	0.000
O	9.739	3.998	0.000	4.144	0.000	1.597	0.000
P	20.032	13.530	0.000	6.390	0.000	0.112	0.000
R	1.840	0.000	0.000	1.617	0.000	0.223	0.000
S	15.606	9.875	0.000	5.719	0.000	0.009	0.003
U	7.664	4.407	0.000	3.257	0.000	0.000	0.000
TOTAL	241.099	111.304	8.910	88.324	1.260	14.251	17.050

Modelling approach / assumptions

Stormwater drainage modelling has been undertaken in XPSWMM as a 1D hydrological and hydraulic model, with the following parameters and assumptions:

- Catchment breakdown per Table 1 above
- Hydrologic modelling methodology is based on Australian Rainfall and Runoff 2019 including the use of design rainfall intensity-frequency-duration data derived using the ARR 2019 methodology and the simulation of the full range of design rainfall event durations and temporal pattern ensembles in order to identify the critical duration. Results reported herein are based on the median temporal pattern result.
- Catchment types each modelled with specific initial and proportional losses described below in Table 2, based on the following assumptions:
    - All residential (ie. including smaller, R40 zoned lots) will be required to utilise soakwells to contain all stormwater on-site, however a small runoff assumption has been included to account for potential runoff from driveway areas, overflow from soakwells etc. Therefore, these catchment areas have been modelled with a 0.90 proportional loss (ie. a 0.10 volumetric runoff coefficient). No initial losses applied to this catchment type given the high proportional loss and the logic that the 0.10 effective runoff coefficient is applicable in part to impervious driveway areas etc which will have minimal initial loss.
    - Special use areas assumed to comprise high density / highly impervious use (eg. town centre). This area assumed to retain the first 15mm on site and therefore has been excluded from bioretention basin sizing, however for the purpose of modelling major event discharge rates to Lake Mariginiup a low proportional loss (ie. large runoff coefficient) has been adopted.
    - Road reserves modelled with a 1.5mm initial loss which is appropriate for the impervious portion of the catchment (ie. carriageways and foot paths) and conservative for the pervious portions (ie. verges). A proportional loss of 0.20 applied which represents the expected infiltration losses through verge areas (and potentially through the piped system if measures such as bottomless pits are used).
- Hydraulic modelling of basin sizes adopted the following infiltration rates:
    - 3 m/d for bioretention basins, including the lower (bioretention) portion of flood storage areas. This rate is based on ideal hydraulic conductivity for treatment media as well as potential long-term clogging.

- 5 m/d for flood storage areas E, K, L, M, N, O & R where estimated groundwater separation is at least 6 m.
- Slightly reduced rate of 4 m/d for flood storage area K where estimated groundwater separation is only ~3m and may impede infiltration during major events given large basin size.

Table 2: Model loss parameters

Catchment type	Initial loss (mm)	Proportional loss
Residential	0	0.90
Road reserves	1.5	0.20
Special use	15	0.20

Bioretention basin sizes

Table 3 below provides sizing details for bioretention basins. Basins E, K, L, M, N, O & R have been omitted as these are sized through the XPSWMM modelling to contain the 1:100yr event (details provided further below). The bioretention basin sizing assumes 0.5m deep basins, with 1:6 batters and a design infiltration rate of 3 m/d.

Table 3: Bioretention basin sizing

Catchment	Base area	Top area	Depth	Volume
A	490 m^2	792 m^2	0.5 m	318 m^3
B	564 m^2	885 m^2	0.5 m	359 m^3
C	444 m^2	733 m^2	0.5 m	291 m^3
D	686 m^2	1036 m^2	0.5 m	428 m^3
F	898 m^2	1294 m^2	0.5 m	545 m^3
G	333 m^2	588 m^2	0.5 m	227 m^3
H	441 m^2	729 m^2	0.5 m	290 m^3
I	814 m^2	1193 m^2	0.5 m	499 m^3
J	842 m^2	1227 m^2	0.5 m	514 m^3
P	882 m^2	1275 m^2	0.5 m	536 m^3
S	780 m^2	1151 m^2	0.5 m	480 m^3
U	583 m^2	909 m^2	0.5 m	370 m^3

Flood storage basin sizes

The modelled sizing details for basins which are not adjacent to the lake and thus provide a flood storage function (ie. Basins E, K, L, M, N, O & R) are provided in Table 4. These basins have been modelled with 1:6 batter slopes and a maximum storage depth of 1.2 m for the 1% AEP event.

Table 4: Basin sizing details for 1% AEP retention basins

Catch-ment	Base area (m2)	15mm event			20% AEP			1% AEP		
		Depth (m)	Top area (m2)	Volume (m3)	Depth (m)	Top area (m2)	Volume (m3)	Depth (m)	Top area (m2)	Volume (m3)
E	440	0.55	760	324	0.72	880	467	1.18	1250	945
K	2620	0.40	3140	1143	0.59	3400	1757	1.19	4300	4083
L	1520	0.47	1990	831	0.66	2200	1232	1.19	2850	2560
M	1190	0.49	1630	690	0.68	1820	1019	1.20	2390	2106
N	1020	0.49	1440	598	0.68	1610	892	1.19	2150	1853
O	960	0.50	1370	576	0.69	1540	850	1.19	2060	1750
R	210	0.59	470	195	0.76	560	285	1.19	840	583

1% AEP discharge rates

The XPSWMM model was also used to estimate the peak discharge rates and total discharge volumes to Lake Mariginiup and Lake Jandabup during major (1% AEP) events. Table 5 below reports these parameters. The peak discharge rate is reported for the critical duration (typically 1 hour event) whilst the total discharge volume is reported for a longer duration / higher rainfall depth events (24 hours and 168 hours hours). Discharge volumes are reported to inform any potential district-scale assessment of surface water flow volumes to lakes and corresponding potential flood rise in the lakes.

Based on only the discharge volumes reported below in Table 5, the corresponding flood rise in Lake Mariginiup (based on stage-storage calculations from LiDAR) is estimated as ~0.14 m. However, it is noted that the Precinct 7 catchments detailed herein do not represent the entire catchment area discharging to Lake Mariginiup. Furthermore, it is acknowledged that this very high-level assessment does not take into account any other potential inflows or outflows such as subsoil drainage discharge to the lake or pumped outflow from the lake as part of the district water level management system. Nonetheless, this basic assessment demonstrates that the potential for significant flood rise in Lake Mariginiup is low given the very large size and storage capacity of the water body.

Table 5: Discharges to Lake Mariginiup

Catchment	1% AEP peak discharge	1% AEP discharge volume [1] (24-hour event)	1% AEP discharge volume [1] (168-hour event)
A	0.69 m^3/s	4.51 ML	6.35 ML
B	0.40 m^3/s	5.24 ML	7.27 ML
C	0.68 m^3/s	4.36 ML	6.02 ML
D	0.90 m^3/s	6.15 ML	8.63 ML
F	1.26 m^3/s	8.72 ML	12.42 ML
G	0.45 m^3/s	2.89 ML	4.27 ML
H	0.63 m^3/s	3.97 ML	5.64 ML
I	0.80 m^3/s	7.18 ML	9.89 ML
J	0.86 m^3/s	7.98 ML	10.59 ML
S	1.02 m^3/s	7.00 ML	9.75 ML
Total	-	57.98 ML	80.80 ML
Flood rise [2]	-	0.04 m	0.06 m

1. Discharge volume taken as full runoff volume reporting to bioretention basin (ie. excluding infiltration losses in basins) on the assumption that water infiltrated at basins migrates to lake as sub-surface flow or via subsoil drains.
2. Refer to commentary above regarding the limitations of this high-level assessment of flood rise in Lake Mariginiup associated with discharge from the adjacent bioretention basins.

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