360 environmental

Various Lots Larsen Road & Briggs Road, Byford

Local Water Management Strategy

Prepared for

I.Q. Property and Projects Pty Ltd

June 2020

people • planet • professional

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Disclaimer

Executive Summary

360 Environmental Pty Ltd (360 Environmental) was commissioned by I.Q. Project Management Pty Ltd (the Client) to prepare a Local Water Management Strategy (LWMS) to support the Local Structure Plan application for Lots 57, 58 and 70 Briggs Road and Lots 53, 81, 83, 100 and 105 Larsen Road, Byford.

Table 1 provides an overview of the site and a summary of the water management strategies that will enable the future development to achieve total water cycle management.

Table 1: Key Elements of the LWMS

Site Overview	Description
Location Section 1.1	The Local Structure Plan application is for Lots 57, 58 and 70 Briggs Road and Lots 53, 81, 83, 100 and 105 Larsen Road, Byford. The site is within the Shire of Serpentine Jarrahdale The site is 16.7 ha
Proposed Development Section 1.3	The Structure Plan proposed for the site is shown in Figure 2 and includes: • 164 residential lots with an average lot size of 369 m^2 (R20 to R60 density) • 11 low density residential lots with an average lot size of 4.363 m^2 (R5 density). These lots already exit in the southern portion of the development and will be retained • 5,157 m^2 of high density grouped dwellings • 1.29 ha of Public Open Space (POS) and Drainage Areas.
Existing Landuse Section 2.1	The site is currently used for rural residential and agricultural purposes and contains residence and sheds. A narrow area of POS abuts the northern and eastern boundary.
Topography Section 2.2	The site varies between 33 and 39 meters Above Height Datum (mAHD) and gently slopes from the south east to the north west (Figure 3). The topography (Section 4.2) indicates that the site drains northwest towards Oaklands Drain located outside the site's northern boundary
Soil Type Section 2.4	The soil landscape subsystem (Department of Primary Industries and Regional Development (DPIRD) 2019) classifies the surface soils onsite as 'Shallow pale sand to sandy loam over very gravelly clay, moderately well drained'.
Wetland Mapping Section 2.6	The site is mapped as a multiple use wetland (UFI 15797)
Groundwater levels Section 2.7.2	• A search of the Perth Groundwater Map (DWER, 2019c) was conducted and it is noted that the maximum groundwater level contours were found not to extend to the site • Four boreholes were installed on site to a depth of 5.5m to 7.5 m under the supervision of 360 Environmental staff in July 2019 for the purpose of determining the pre-development groundwater levels

Site Overview	Description
	• Peak 2019 groundwater levels occurred in September, with the minimum separation from the groundwater to the existing ground level being 0.66 m in the east of the site and greater than 5m in the west and south of the site.
Surface water Section 2.8	• There are no surface water features located in the site • Oaklands Drain is located outside the sites northern boundary • A narrow strip in the north of the site is located in the floodway of the Oaklands Drain • The applicable 1% AEP flood levels are 39.75 m AHD to 33.71 m AHD.
Water Servicing Section 3	• The development will be connected to existing Water Corporation infrastructure for water supply and wastewater disposal • Public Open Space (POS) will be landscaped with waterwise species and irrigated with groundwater.
Water Conservation Strategy Section 4.0	• The use of waterwise landscaping and efficient irrigation design. Landscape Plans will be developed to align with neighbouring landscape works which have been completed along Oaklands Drain. The site contains mature trees which will be retained as far as possible to reduce the need to establish new vegetation in the POS which requires higher initial rates of irrigation • Groundwater will be used for irrigation of POS • The use of water efficient fixtures and fittings.
Stormwater Management (Section 5)	• Stormwater runoff will be managed via soakwells and/or lot connections for smaller lots to retain the first 15 mm of rainfall close to source • The first 15mm of rainfall will be infiltrated in the POS and streetscapes • Road drainage networks will be sized to convey up to the 20% AEP event • Stormwater runoff up to the 1% AEP event will be detained in a drainage basin located within the POS. Discharge from the basin will be controlled to ensure flows are similar to pre-development conditions entering Oaklands Drain.
Flood Management (Section 6)	• Development will be excluded from the floodway. The floodplain of Oaklands Drain extends into the POS area. Finish lot levels will be 0.5m above the 1% AEP flood level and 0.3m above the 1% AEP static water level of the drainage basin.
Groundwater Management (Section 7)	• The groundwater monitoring program will continue to collect the 2020 peak groundwater levels • The MGL will be determined once the groundwater monitoring program has been completed and the bores have been surveyed • The development will achieve a minimum separation between proposed finished lot levels and the maximum groundwater level (MGL) of at least 1.2 m • Fill will be required to achieve a suitable site classification which will provide adequate clearance to maximum groundwater levels • Groundwater quality will be maintained by the proposed stormwater management system.
Monitoring and Maintenance (Section 8)	• The impacts of the development on the receiving environment will be monitored by post development monitoring of groundwater quality • Regular maintenance is proposed to ensure the functionality of the proposed stormwater management system.

Site Overview	Description
Implementation (Section 9)	• Subdivision design should conform to the strategy proposed in this LWMS and be the subject of an Urban Water Management Plan designed to provide a detailed description of how this will be achieved.

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1 Introduction

360 Environmental Pty Ltd (360 Environmental) was commissioned by I.Q. Project Management Pty Ltd (the Client) to prepare a Local Water Management Strategy (LWMS) to support the Local Structure Plan application for Lots 57, 58 and 70 Briggs Road and Lots 53, 81, 83, 100 and 105 Larsen Road, Byford (Figure 1).

1.1 Location

The site is within the Shire of Serpentine Jarrahdale (the Shire) local government area and is approximately 16.7 ha. Briggs Road is to the west and Larsen Road is to the south. Oaklands Drain is located outside the site's northern boundary within the regional public open space.

1.2 Planning Context

The site is zoned 'Urban' and 'Urban Deferred' under the Metropolitan Region Scheme (MRS), and 'Urban Development' and 'Rural Living A' under the Serpentine-Jarrahdale Town Planning Scheme No.2 (TPS 2). This LWMS has been prepared to support a Local Structure Plan (LSP) application.

1.2.1 District Planning

The site lies within the area covered by the Byford District Structure Plan, which was approved in 2005 by the Shire and the Western Australian Planning Commission (WAPC). A Drainage and Water Management Plan (DWMP) was prepared by the Department of Water (now Department of Water and Environmental Regulation (DWER)) in 2008 and presented the proposed arterial drainage scheme for the Byford townsite in accordance with the responsibilities for drainage planning assigned to the DWER by the state government.

1.2.2 Byford District Water Management Strategy

A District Water Management Strategy (DWMS) (Urbaqua 2018) was prepared as part of the Byford District Structure Plan (Hames Sharley 2018). These documents were out for public comment when the LWMS was started. The DWMS has bene referred to but not strictly followed as we do not believe the regional scale flood mapping and volumes of storage to be provided for each sub catchment is correct, the volumes are extremely high for the size of some of the smaller sub catchments in particular.

1.3 Proposed Developments

The Structure Plan proposed for the site is shown in Figure 2 and includes:

- 164 residential lots with an average lot size of 369 m^2 (R20 to R60 density)
- 11 low density residential lots with an average lot size of 4.363 m^2 (R5 density). These lots already exit in the southern portion of the development and will be retained
- 5,157 m^2 of high density grouped dwellings

- 1.29 ha of Public Open Space (POS) and Drainage Areas.

1.4 Guidance and Previous Studies

The aim of a LWMS is to provide 'proof of concept' for water management at a proposed development, taking account of all forms of water management.

The LWMS has been prepared in accordance with Better Urban Water Management (WAPC, 2008), Guidelines for District Water Management Strategies (DoW, 2013), and Interim: Developing a Local Water Management Strategy (DoW, 2008). Additional guidance for the preparation of the LWMS is provided in:

In addition to the documents previously mentioned, there are several State Government plans and policy documents relating to urban water management which have been used as a basis to prepare this LWMS including:

- Decision Process for Stormwater Management in Western Australia (DWER, 2017)
- Guidelines for district water management strategies (DoW, 2013)
- Guidelines for local water management strategies (DoW, 2008)
- Stormwater Management Manual of Western Australia (DoW, 2007)
- Better Urban Water Management (WAPC, 2008)
- State Water Plan 2007 (Government of Western Australia, 2007)
- *State Planning Policy 2.9 Water Resources* (WAPC, 2006).

1.5 Design Objectives

The design objectives for this site are presented in Table 2.

Table 2: Design Objectives

Element	Principle	Objective
Surface Water Management	Manage catchments to maintain or improve water resources.	Manage and treat stormwater as close to source as possible.
		Maintain pre-development surface water discharges from the site.
	Seek opportunities to gather stormwater for reuse.	Where possible, apply stormwater collection and treatment system for stormwater reuse.
Groundwater Management	Manage stormwater infiltration where possible to maintain or improve groundwater quality.	Maintain or improve groundwater quality.
	Maintain groundwater levels similar to pre-development	Provide adequate separation distance to groundwater for built infrastructure.

Element	Principle	Objective
Flood Risk Management	Manage risks to human life and property.	Protect people and the built environment from flooding and inundation onsite.
		No adverse impact in terms of flood risk to communities upstream and downstream of the development.
Water conservation strategy (potable and wastewater)	Management catchments to maintain or improve water resources.	Achieve WA State Water Plan targets of household potable water consumption.
	Ensure the efficient use of water resources.	Minimise the external use of potable water.

2 Existing Environment

The pre-development environmental conditions provide opportunities and constraints for water management on the site. A summary of the environmental characteristics of the site is provided below.

2.1 Land Use

The site consists of approximately 16.7 hectares (ha) of land. Most of the site has been cleared, though Lot 58 is vegetated. The site is currently used for rural residential and agricultural purposes and contains residence and sheds. A narrow area of POS abuts the northern and eastern boundary.

2.1.1 Land Use Change

Aerial imagery of the site is available from Landgate dated from 1953 (Plate 1). The aerial images show that the land was cleared prior to 1953 and was undeveloped. Only one lot was developed in the western area of the site between 1953 and 1983. The buildings were constructed after 1983 and planting increased vegetation, particularly along property boundaries and fencelines. No additional infrastructure has been built since 1995, and vegetation density in the north and southwestern area increased.

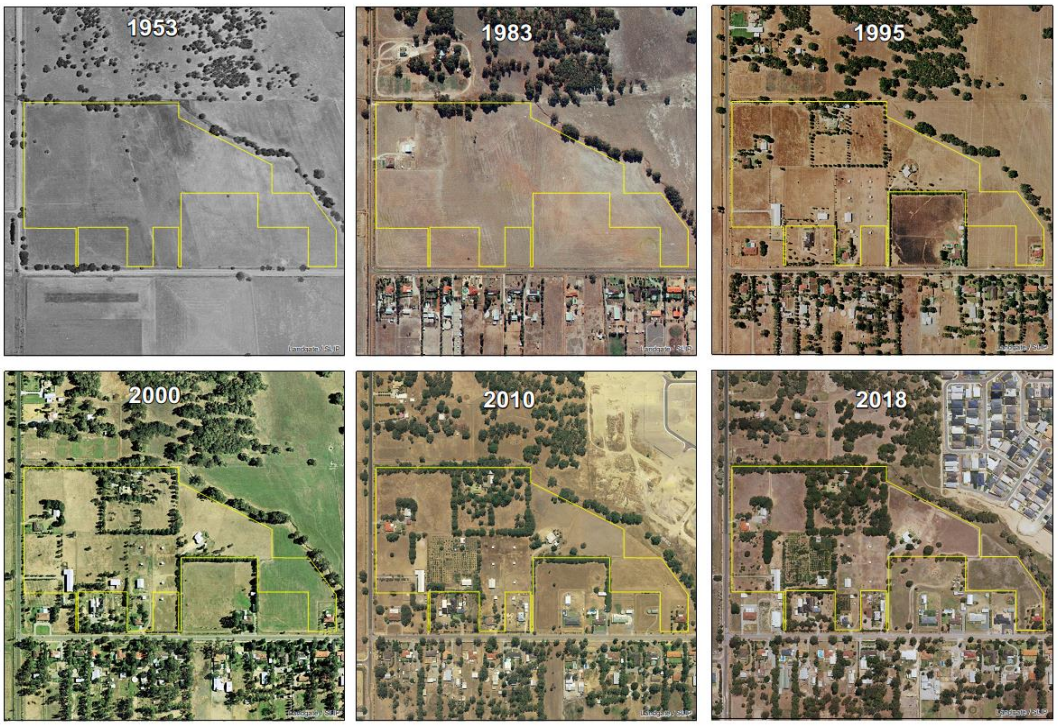

Plate 1: Historical Imagery

2.2 Topography

The site varies between 33 and 39 meters Above Height Datum (mAHD) and gently slopes from the south east to the north west (Figure 3). The topography (Section 4.2) indicates that the site drains northwest towards Oaklands Drain located outside the site's northern boundary.

A site survey is provided in Appendix A)

2.3 Climate

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 recorded rainfall data to present is Jarrahdale Station (site number: 009023), located 13 km from the site. The monitoring station recorded daily rainfall data from 1882 to present. The average annual rainfall is approximately 1172.7 mm for the period 1882 – 2018.

2.4 Soil Type

2.4.1 Regional Data

The soil landscape subsystem (Department of Primary Industries and Regional Development (DPIRD) 2019) classifies the surface soils onsite as 'Shallow pale sand to sandy loam over very gravelly clay, moderately well drained'. The site's surface geology is presented in Figure 4.

2.4.2 Geotechnical Investigation

A geotechnical investigation was undertaken (Douglas. Partners, 2019). Subsurface conditions are described as follows:

- Topsoil (SITLY SAND) – brown, fine to medium grained, silty sand topsoil with trace roots, encountered from surface to depths of between 0.1 m and 0.2 m
- FILL (GRAVELLY CLAY) – stiff gravelly clay with sand fill underlying the topsoil fill at Pit 8 to a depth of 0.4 m
- CLAYEY SAND, SANDY CLAY – generally hard, orange-brown clayey sand and sandy clay underlying the topsoil at test locations Pit 1 to Pit 7 and Pit 9 to depths of between 0.4 m and test pit termination depths up to 1.65 m
- SANDY GRAVEL – generally dense, sandy gravel underlying clayey sand at Pits 1 and Pit 4 and fill and topsoil at Pit 8 and Pit 10 respectively, to test pit termination depths of between 1.0 and 1.3 m. An exception to this was encountered at Pit 8, where clayey sand was encountered below the sandy gravel between depths of 1.0 m and termination depth of 1.5 m.

Permeability testing was undertaken using the constant head method, at two locations at depths of 0.14 m and 0.35 m. The permeability results were 9.5 m/day for Test Location 1 and 3.6 m/day for Test Location 11. The geotechnical report suggested that the results of these permeability

were influenced by the sandy topsoil, and the representative permeability values of the clayey soils at the site are lower than the results indicate.

A preliminary permeability value in the order of 1 x 10-6 m/s (<0.1 m/day) or less is suggested for the clayey soils underlying at the site 2019 (Douglas. Partners, 2019).

2.5 Acid Sulfate Soils

Regional Acid Sulfate Soil (ASS) mapping indicates that there is moderate to low risk of ASS onsite (DWER, 2019a) (Figure 5).

2.6 Wetland Mapping

Geomorphic wetlands mapping indicates that the site is mapped as a Multiple Use wetland (Palusplain UFI 15797) (Figure 6).

2.7 Groundwater

2.7.1 Aquifers

Water Register database (DWER, 2019b) indicates that the site is located within Serpentine Groundwater Management Area and belongs to Byford 3 subarea. Three aquifer resources are identified at the site location: Superficial Swan, Leederville and Cattamara Coal aquifers. The site is not located within a Public Drinking Water Source Area (PDWSA) (DWER, 2019c).

An aquifer allocation report requested from DWER in July 2019 indicated that Leederville and Cattamara Coal aquifers are nearly fully allocated (Table 3). The superficial Swan aquifer is shown to have spare resource not allocated or committed.

Table 3: Aquifer Allocations

Aquifer	Allocation Limit (kL)	Allocated Volume (kL)	Committed Volume (kL)	Remaining Volume (kL)	Allocated and Committed (%)
Superficial Swan	13,291,660	1,417,407	407,500	11,466,753	13.73%
Leederville	2,270,000	2,293,360	0	-23,360	101.03%
Cattamara Coal	1,130,000	1,030,639	90,000	9,361	99.17%

2.7.2 Groundwater Levels

A search of the Perth Groundwater Map (DWER, 2019c) was conducted and it is noted that the maximum groundwater level contours were found not to extend to the site.

Four boreholes were installed on site to a depth of 5.5m to 7.5 m under the supervision of 360 Environmental staff in July 2019 for the purpose of determining the pre-development groundwater levels. The bore locations are shown on (Figure 7). Pre-development groundwater monitoring commenced in July 2018 and groundwater was initially proposed to be monitored for 18 months. As a majority of the site is recording a clearance to groundwater of greater than

5 m, the groundwater monitoring program has been scaled back. In addition, the Geotechnical Investigation (Douglas Partners, 2019) recommends 1.2 to 1.7m of sand fill is required, this will achieve even greater clearance to groundwater. The groundwater monitoring program will continue to collect the 2020 peak groundwater levels to confirm the site MGL, however this is no longer as important to the water management strategy as initially thought due to the site preparation requirements. The groundwater levels have been recorded in 'meters below ground level' (m bgl) only by the time of completion of this report (October 2019) are provided in Table 4.

Table 4: Site Groundwater Levels

Date	Groundwater Level (m bgl)			
	GW01	GW02	GW03	GW04
July 2019	Dry	Dry	0.99	0.79
August 2019	6.53	NA	0.90	1.26
September 2019	5.51	6.21	0.66	0.79
October 2019	6.00	NA	1.39	1.69
November 2019	Dry	6.53	1.86	1.93

N/A – no site access was possible

It can be seen that the site peak groundwater level occurred in September, with the minimum separation from the groundwater to the existing ground level being 0.66 m. Groundwater levels recorded in GW01 and GW02 have a clearance to natural surface of more than 5 m.

Groundwater levels in meters above Australian Height Datum (m AHD) can be determined once the survey of the monitoring wells is completed.

2.7.3 Groundwater Quality

The Perth Groundwater Map has been reviewed to assess groundwater quality. Groundwater underlying the site is expected to have salinity levels ranging between 500 – 1,000 mg/L, which is classified as 'Marginally' suitable for watering household gardens. The groundwater is considered to be 'Unsuitable' for garden bores.

Groundwater quality has been assessed quarterly, both in-situ and using laboratory analysis. The groundwater quality results recorded by the completion of this report (October 2019), are shown in Table 5.

Table 5: Site Groundwater Quality

	ANZEC C Values	GW01		GW02		GW03		GW04	
In-situ Parameters		July 2019	October 2019	July 2019	October 2019	July 2019	October 2019	July 2019	October 2019
Temperature (˚C)	-	Dry	20.5	Dry	NA	17.0	19.5	17.3	19.4
pH	6.5-8.0	Dry	**5.30**	Dry	NA	**5.52**	**5.14**	**5.59**	**4.86**

	ANZEC C Values	GW01		GW02		GW03		GW04	
Electrical Conductivity (mS/cm)	0.12-0.30	Dry	0.25	Dry	NA	**0.90**	**0.92**	**0.65**	**0.74**
DO (%)	80-120	Dry	**49.3**	Dry	NA	**55.5**	**28.5**	**12.2**	**2.78**
Redox (mV)	-	Dry	176.6	Dry	NA	218.3	178.9	111.6	201.9
Nutrients (mg/L)									
Ammonia	0.08	Dry	<0.02	Dry	NA	0.03	<0.02	0.07	0.05
NOx	0.15	Dry	1.2	Dry	NA	0.06	0.07	0.05	<0.01
TKN	-	Dry	<0.2	Dry	NA	<0.2	<0.2	<0.2	<0.2
TN	1.2	Dry	1.3	Dry	NA	<0.2	<0.2	<0.2	<0.2
TP	0.065	Dry	0.06	Dry	NA	0.04	0.04	0.05	0.05
OrthoP	0.04	Dry	<0.01	Dry	NA	<0.01	<0.01	<0.01	<0.01

2.8 Surface Water

2.8.1 Oaklands Drain

Oaklands drain runs adjacent, and outside the site's northern boundary (Figure 8). The drain flows westwards under Briggs Road

The 1% AEP flood mapping of the Oaklands Drain is included in the Byford DWMP (DWER, 2008). The DWMS (DWER 2008) indicates the 1% AEP flood level at the site is 39.75 m AHD (at node 87) to 33.71 m AHD (at node 101). A longitudinal section of Oaklands Drain is provided in Appendix C.

Minor areas in the north of the site are located in the floodway of the Oaklands Drain, as shown on Figure 8.

The DWMP identified that the area west of Byford townsite, (which the site is nearby), experiences regular water logging. This is considered to be due to a combination of persistent winter rainfall and poor drainage which results in the elevation of the shallow groundwater.

2.8.2 Regional and District Drainage Study

The DWMP (DWER, 2008) presents the proposed arterial drainage scheme for the Byford townsite, which aims to protect wetlands and waterways from the impacts of urban runoff and protect infrastructure and assets from flooding and inundation. The DWMP promotes onsite retention of rainfall events up to one-year annual recurrence interval (ARI) and proposes to manage catchment runoff for up to and including a 100-year event within the development area to pre-development peak flow rates.

The 2019 DWMS (Urbaqua 2019) follows principles similar to the 2008 DWMP. The DWMS considers a larger study area than the DWMP and presents a detailed review of the arterial drainage scheme for the Byford townsite.

2.8.3 Existing Catchment and Runoff

Figure 9 shows the pre-development modelling catchment. The runoff from the lots along Larsen Road will remain unchanged as these lots are proposed to remain. Consequently, these lots have been excluded from the pre-development model

XPSTORM has been used to model the pre-development runoff generated from the catchment area. Laurenson method is applied in the model as the hydrological method and model the peak flow rate. This method has been widely used in Western Australia for hydrological assessment and drainage design.

The modelled catchment area is approximately 11.8 ha, consistent with the proposed development area in the LSP. The model input parameters in Table 6 are similar to the DWMP and DWMS for pervious areas.

Table 6: Pre-development Runoff Model Parameters

Model Input	Catchment Area (ha)	Slope (%)	Initial Loss (mm)	Continuing Loss (mm/hr)
Values	11.8	1.4	10	2.9

An initial-continuing loss method was applied in the model. This method has been recommended by the 2019 Australian Rainfall and Runoff guidelines (ARR, 2019). The loss values in Table 6 were used in the model and are similar to the DWMS.

The model simulated multiple storm events based on the Bureau of Meteorology's 2016 Design Rainfall Data System (BoM, 2019) and the temporal patterns from the 2016 Australian Rainfall and Runoff (ARR, 2016). Runoff model was run with 0.5 hr, 1hr,3 hr, 6 hr, 12hr, 24 hr, 48 hr and 72 hr durations at 20% AEP and 1% AEP.

The model results for peak flow rates in 20% and 1% AEP events are summarized in Table 7.

Table 7: Pre-development Peak Flows

	20% AEP	1% AEP
Critical Duration (hr)	3	1
Peak Flow (m3/s)	0.44	1.25

The peak flow results will be used as the design criteria of the storage requirement onsite.

3 Water Servicing

3.1 Potable Water Supply

Potable water supply will be provided via extension of the existing Water Corporation distribution water mains along Larsen Road and Briggs Road.

3.2 Wastewater Management

Wastewater will be managed using the sewer pipe along Larsen Road.

3.3 POS Irrigation

POS irrigation water is proposed to be sourced from groundwater.

There is an existing groundwater licence held by the owners of Lot 81 Larsen Road for the Leederville aquifer with an annual volume of 11,500 kl (Table 8).

Table 8: Groundwater License Details

Licence Number	Licence Allocation	Groundwater Area	Groundwater Subarea	Issue Date	Expiry Date
159693	11,500kL	Serpentine	Byford 3	16/06/2010	15/06/2020

The total area of the proposed POS is approximately 1.29 ha. Based on an irrigation rate of 7,500 kL/ha/year, the annual amount of water required for POS irrigation is 9,675 kL. As Lot 81 Larsen Road is currently included in the proposed development area, the intent will be to transfer its water licence to provide irrigation water for the site.

In the unlikely event that the existing groundwater licence is not transferred to the eventual developer of the LSP, a new groundwater license will be applied for to irrigate the POS and MUC in the short term (if required by the Shire). An aquifer allocation report obtained from DWER in July 2019, as detailed in Table 3 indicates groundwater allocation is available in the Superficial, Leederville and Cattamarra Coal Measure aquifers at the site.

4 Water Conservation Strategy

The proposed development will incorporate the following water conservation strategies:

- The use of waterwise landscaping and efficient irrigation design. In consultation with the Shire, Landscape Plans will be developed to align with neighboring landscape works which have been completed along Oaklands Drain. The site contains mature trees which will be retained as far as possible to reduce the need to establish new vegetation in the POS which requires higher initial rates of irrigation. The active and unrestricted POS is shown in Appendix D
- Groundwater will be used as the water source for irrigation to limit potable water consumption. An existing groundwater licence will be transferred for this use, or a new groundwater license will be applied for if required
- The use of water efficient fixtures and fittings within the site: water efficient shower heads and tap fittings are already mandated as part of the Building Code of Australia (ABCB, 2011).

5 Stormwater Management Strategy

5.1 Proposed Stormwater Management

The objectives for stormwater management are to ensure that urban development does not increase the peak flows discharging to the receiving environment, and that runoff water quality is maintained or improved. The following details the proposed stormwater management designed to achieve these objectives

5.1.1 The First 15 mm Runoff

The runoff from constructed impervious surfaces generated by the first 15 mm of rainfall is proposed to be retained at-source for residential lots and road reserves as far as practical. This is consistent with Shire policy and what has been proposed in the 2008 DWMP and 2019 DWMS.

It is the first 15 mm of rainfall that mobilises the majority of pollutants from the catchment. Consequently, the retention of runoff from the first 15mm provides the opportunity for at-source treatment via bioretention structures (or similar) so that the runoff quality to the downstream receiving environmental is maintained.

As there is no road layout in the proposed LSP, it is difficult to determine how much runoff from the first 15 mm of rainfall could be retained in the road reserves. For a conservative estimation, it has been assumed that the first 15 mm runoff from the road reserve could be treated within a bioretention area within the POS, in the case that the road layout does not allow in-situ retention and treatment. In such case, runoff from road reserves should be captured by pipe system and discharge to the bioretention area in POS, which will provide retain and treat the runoff. Flows above the first 15 mm event will overflow from the bioretention area into a detention basin (Section 5.1.2).

Options to collect and infiltrate as much of the first 15mm as possible in the streetscapes will be investigated further at the detailed design phase and presented in the UWMP. The Geotechnical Investigation (Douglas. Partners, 2019) states that imported sand fill is needed to achieve the required site classification which will allow for infiltration to occur within lots and biofiltration areas.

Table 12 details the volume of the bioretention area that will be required to retain the road reserve runoff in the first 15 mm. If in the future subdivision stage the in-situ retention within road reserve is possible, then the bioretention area in the POS can be smaller.

5.1.2 Minor and Major Events (up to 1% AEP)

The minor event management features of the road drainage pipes and the detention basin in POS, are as follows:

- Lots and road reserves will retain the first 15 mm at source as far as practical

- Runoff generated in events larger than 15 mm will be conveyed by the road pipe drainage system. The drainage structures will be sized to convey up to the 20% AEP event to the drainage basin in POS, ensuring roads are serviceable
- Runoff generated in larger than 20% AEP and up to the 1% AEP events will be allowed to drain to the basin within the POS via overland flow
- The bioretention area within POS will overflow into the drainage basin
- The drainage basin and its outlet in the POS have been designed to enable sufficient detention so that the flow to Oaklands Drain is no greater than pre-development flows for events up to 1% AEP
- The main drainage basin is to be located outside the floodway of the Oaklands Drain.

The key objective for managing minor and major events is to maintain the peak flow discharging the Oaklands Drain. Table 9 details the peak flows for 20% AEP and 1% AEP events. The allowable peak flow has been assessed based on the 2008 DWMP, the 2019 DWMS and the pre-development model in this LWMS as the site is included in the nominated sub-catchment described in the DWMP and DWMS.

Pro rata rates are also calculated and shown in Table 9.

Table 9: Minor and Major Event Drainage Criteria

Document	Subcatchment	Area	Peak Discharge Flow (m^3/s)		Pro Rata Peak Flow (l/s/ha)	
		(ha)	20% AEP	1 % AEP	20% AEP	1% AEP
2008 DWMP	3C	68.1	0.4	3.5	5.9	51.4
2019 DWMS	BM_02	32.6	2.437	6.189	74.7	189.9
LWMS	Modelled Site	11.8	0.44	1.25	37	106

It noted that the 2008 DWMP and 2019 DWMS modelled a much larger area than the area covered by this LWMS. Therefore, the peak flow criteria from these two documents are based on the critical duration for the entire model area. It is proposed that the determination of the storage requirement for the 20% and 1% AEP for this site should be based on the pre-development peak flows detailed in this LWMS.

Modelling of the post development scenario was undertaken to assess the storage requirement onsite, based on the proposed land use and hydrologic parameters detailed in Tables 10 and 11 respectively.

Table 10: Land Uses

Type	Group Housing	Lots < 300 m^2	Lots 300 -600 m^2	Lots 600-1000 m^2	Road Reserves	POS	Total
Area (ha)	0.52	0.95	4.75	0.33	3.94	1.29	11.8
Impervious (%)	95%	90%	80%	70%	90%	10%	75%

Table 11: Post Development Model Parameters

Parameters	Group and Lots < 300 m^2 Impervious	Lots > 300 m^2 Impervious	Roads Impervious	Pervious
Area (ha)	1.32	4.03	3.68	2.72
Impervious (%)	100	100	100	0
Slope (%)	1.4	1.4	1.4	1.4
Manning's n	0.015	0.015	0.015	0.025
Initial Loss (mm)	15	15	15	10
Continuing Loss (mm/hr)	0	0.07	0	2.9

The discharge pipe will drain water from the basin to Oaklands Drain. A 450 mm diameter pipe located at the basin invert was modelled as the discharge pipe. This is because the soil onsite is clayey and accumulated water is not able to infiltrate within the required timeframe.

Table 12 summarises the proposed stormwater management system.

Table 12: Proposed Stormwater Management System

	Frequent Event Management
	First 15 mm
Storage Feature	Residential Lots: Soakwells (or similar) Road Reserve: Bioretention Area within POS (or similar)
Storage Volume (m^3)	Residential Lots: 807 m^3 Road Reserves: 532.5 m^3
	Minor Event Management
	20% AEP
Storage feature	Detention basin in POS, 450 mm diam outflow pipe at basin invert Full capacity of basin: 3,120 m^3
Critical duration (hr)	3
Depth of storage (m)	1.2
Bottom Area (m^2)	1,800
Side Slope (v:h)	1:6
Depth of water (m)	0.62
Top water surface area (m^2)	2,626
Stored volume (m^3)	1,372
Peak discharge (m^3/s)	0.4
Allowable maximum flow (m^3/s)	0.44
Basin emptying time (hr)	17
	Major Event Management
	1% AEP

Frequent Event Management	
Storage feature	Detention basin in POS, 450 mm diam outflow pipe at basin invert Full capacity of basin: 3,120 m^3
Critical duration (hr)	3
Depth of storage (m)	1.2
Bottom Area (m^2)	1,800
Side Slope (v:h)	1:6
Depth of water (m)	1.155
Top water surface area (m^2)	3,340
Stored volume (m^3)	2,968
Peak discharge (m^3/s)	0.713
Allowable maximum flow (m^3/s)	1.25
Basin emptying time (hr)	12

The peak discharge rates in the 20% and 1% AEP events do not exceed the allowable maximum flows, which are based on the pre-development model. An orifice is proposed for the 450 mm discharge so that the outflow from events smaller than the 20%AEP can be restricted. The detailed design of the flow restriction structure shall be completed in the UWMP stage.

The provided storage volumes by the basin are compared with the storage volumes modelled in the DWMP and DWMS in Table 13.

Table 13: Stormwater Storage

Document	Subcatchment	Area	Storage Volume (m3)		Pro Rata Storage Volume (m3/ha)	
		(ha)	20% AEP	1 % AEP	20% AEP	1% AEP
2008 DWMP	3C	68.1	9,000	20,100	132	295
2019 DWMS	BM_02	32.6	3,700	9,789	113.5	300.3
LWMS	Modelled Site	11.8	1,372	3,120	116.3	264

The proposed drainage basin provided similar pro rata storage volume to the DWMP and DWMS.

5.1.3 Basin Drain Time

Stormwater Management Manual WA (DoW, 2007) and Australia Runoff Quality (Engineers Australia, 2006) provide recommendations for emptying times of stormwater management systems for different AEPs:

- 20% AEP: 1.5 days
- 1% AEP: 3.5 days.

The emptying times for the proposed basin are within the recommended time for 20% and 1% AEP as shown in Table 12. There are no known mosquito concerns at the site, the drainage basin

is expected to drain within the recommended times and will not create additional breeding habit for mosquitos. Additionally, when the Oaklands Drain is carrying water, the water is expected to be flowing, which again will not provide mosquito breeding areas.

5.1.4 Water Quality Management

Frequent rainfall events (usually referred as the first 15 mm) mobilise the majority of pollutants from a catchment and DWER currently recommends that. where possible the frequent event runoff shall be treated and infiltrated at source. The proposed water quality management measures on this site are as follows:

- Lots will retain the runoff from the first 15 mm as much as practical before discharging to road drainage pipe systems
- Roads will retain the runoff from the first 15 mm in various structures wherever possible, including but not limited to: bottomless pits, roadside swales, median strip bioretention, and street tree pits.

Details of the water quality treatment measures will be determined and designed in future subdivision stages and provided in the related UWMP(s).

6 Flood Management

The floodplain management strategy typically recommended by DWER (2000) is as follows:

- Development (i.e. filling, building, etc) that is located within the flood fringe is considered acceptable with respect to major river flooding. However, a minimum habitable flood level of 0.50 metre above the adjacent 100-year flood level is recommended to ensure adequate flood protection
- Development (i.e. filling, building, etc) that is located within the floodway and is considered obstructive to major river flows is not acceptable as it will increase flood level upstream.

The 'flood fringe' is defined as the area of the floodplain, outside of the floodway, which is affected by flooding but where development could be permitted provided appropriate measures are taken. These areas are generally covered by still or very slow-moving waters during a 100 year ARI (equivalent to 1% AEP) flood.

Following this advice, development has been excluded from the floodway and finish floor levels will be raised to provide 0.5m clearance to the 1% AEP flood level of 39.75 m AHD to 33.71 m AHD.

As discussed further in Section 7.1.1 below, sand fill will be required to achieve lots with a site classification of Class A (or Class S). This filling will provide adequate clearance to the flood levels of the Oaklands Drain and maximum groundwater levels.

7 Groundwater Management Strategy

7.1.1 Groundwater Levels

Variability in the clay content found in the soils on site was observed during the drilling and installation of the groundwater monitoring bores which appears to be influencing the groundwater levels recorded on site in 2019. The depth to groundwater significantly varies through the site with peak 2019 groundwater levels in the west and south west being approximately 5.5 m bgl (GW01) to 6.2 m bgl (GW02), while groundwater levels recorded in the east of the site were significantly closer to the natural surface with GW03 recording a peak groundwater level 0.66 m bgl and 0.79 m bgl at GW04.

The Geotechnical Investigation (Douglas Partners, 2019) provided in Appendix E states that the site is underlain by reactive clay material with varying sand and gravel content. The preliminary analysis by the geotechnical report indicated that amending the site classification to Class S would require enough non-reactive fill to produce a separation of at least 0.8 m from the finished surface level to reactive material. To achieve a site classification of Class A, which is typically provided for urban development, approximately 1.7 to 1.8 m of compacted sand filling would be required.

Urban development usually requires the finished lot levels to have a minimum clearance of 1.2 m to the MGL. The calculation of MGL separation is presented for the follwoing scenarios:

- Scenario A: The site will achieve Class A with the import of 1.7 m of sand fill.

  In this scenario, the minimum separation from the finished lot levels to the MGL will be equal to 2.36 m (existing minimum groundwater separation 0.66 m, with 1.7 m fill).

- Scenario B: The site will achieve Class S with the import of 0.8 m of sand fill.

  In this scenario, the minimum separation from the finished lot level to the MGL will be equal to 1.46 m (existing minimum groundwater separation 0.66 m, with 0.8 m fill)

In both scenarios, the minimum separation from the finished levels to the MGL will be greater than 1.2 m, which would provide sufficient clearance to groundwater levels across the entire site. At this stage of the planning process, it would appear that subsoil drainage is not required to manage groundwater levels post development.

The predevelopment groundwater monitoring program will continue to collect the peak 2020 groundwater levels. This data, along with a comparison of other publicly available groundwater monitoring data will be completed, to confirm the peak groundwater levels in the future UWMP.

The need to import fill to provide suitable site conditions for urban development is likely to dictate the earthworks strategy rather than providing adequate clearance to groundwater.

7.1.2 Groundwater Quality

The proposed lot sizes and stormwater management practices will assist with maintaining groundwater quality. Other key strategies for managing groundwater quality at the site include:

- Use of reticulated sewerage
- Maximising native vegetation within POS
- Fertiliser and pesticide use on site to be minimised through the use of waterwise and or native landscaping, minimal community open space and private gardens due to the style of development.

8 Monitoring and Maintenance Plan

8.1 Post Development Monitoring

Post development monitoring is proposed to be implemented to ensure the functionality of the stormwater management structures throughout the site. The final post development monitoring schedule will be confirmed in the future UWMP, the below provides an example of possible monitoring requirements.

8.1.1 Drainage Basin

It is proposed that the drainage basin will be visually monitored on a quarterly basis to ensure there is no standing water and the discharge structures are not blocked.

8.1.2 Groundwater Quality

Depending on the final earthworks strategy and clearance to groundwater, groundwater monitoring may be required to ensure that the development will not have adverse impact on the groundwater quality post development.

To allow an assessment of the water quality parameters, it is proposed that post development groundwater quality will be compared to baseline values that are established in pre-development monitoring (Section 2.7). Once the pre-development monitoring is finished, the baseline values shall be determined and included in the future UWMP.

At this stage, trigger values for water quality is calculated by increasing the pre-development maximum recorded values by 20% (Table 14). If the calculated values are lower than the ANZECC guideline values then the ANZECC guideline values are to be used. The trigger values provided in Table 14 can be refined in the future UWMP when more water quality data is available.

Table 14: Trigger Values for Post Development Monitoring

	ANZEC C Values	Pre-Development Maximum Values	Trigger Values
In-situ Parameters			
pH	6.5-8.0	4.86 (Lower Limit) 5.59 (Upper Limit)	3.88 (Lower Limit) 6.71 (Upper Limit)
Electrical Conductivity (mS/cm)	0.12-0.30	0.92	1.10
DO (%)	80-120	2.78 (Lower Limit) 55.5 (Upper Limit)	2.22 (Lower Limit) 120 (Upper Limit)
Nutrients (mg/L)			
Ammonia	0.08	0.07	0.084
NOx	0.15	1.2	1.44
TKN	-	<0.2	0.24
TN	1.2	1.3	1.56
TP	0.065	0.06	0.072
OrthoP	0.04	<0.01	0.04

If the results from samples taken during monitoring record a trigger value, resampling should be undertaken to confirm the result. Once the result is confirmed an action is required to address an issue, several contingency measures may be employed. These may include:

- Identify and remove the source if possible
- Remove sediment-bound nutrients by removing basin sediments
- Review implementation of landscaped areas and basins management practices; and
- Manual removal of plant material from landscaped areas and basins to facilitate further nutrient uptake by growing vegetation.

The post development monitoring usually lasts for two to three years, commencing upon the completion of the development. This will be detailed in the future UWMP and is subject to Shire's approval.

8.1.3 Groundwater Level

Groundwater level monitoring is completed to assess the impact of the development on the groundwater levels.

Depending on the earthworks strategy, groundwater levels may need to be sampled on a quarterly basis and compared to the pre-development monitoring data and rainfall records for the respective years to assess if the development has impacted on the groundwater environment. Post development groundwater monitoring locations should be provided in the UWMP.

The post development monitoring usually lasts for two to three years, commencing upon the completion of the development. This will be detailed in the future UWMP and is subject to Shire's approval.

8.2 Maintenance

Regular maintenance of the stormwater structures will be required to ensure their functionality. The detailed maintenance actions, timeframe and responsibilities shall be determined in the subdivision stages and included in future UWMP(s).

9 Future Subdivision and Urban Water Management Plans

The requirement to undertake more detailed water management plans is generally imposed as a condition of subdivision. The development of any future UWMP(s) should follow the guidance provided in *UWMPs: Guidelines for Preparing Plans and for Complying with Subdivision Conditions* (DoW, 2008b).

While strategies have been provided within this LWMS to address planning for water management within the site, future subdivision designs and the associated UWMP(s) will provide and clarify the details not provided within this LWMS. The main areas to be addressed within future UWMP(s) are detailed below.

9.1 Detailed Design of the Proposed Stormwater Infrastructures

The LWMS provided a general strategy for stormwater management and indicative location and requirements. Future UWMP(s) will need to provide the detailed engineering and construction details, and exact locations of these structures. These include but not limit to: soakwells, lot connections, road entries and pits, drainage pipes and basin, and bioretention areas.

9.2 Implementation of Water Conservation Strategies

Several potential measures to conserve water have been presented in this LWMS. Landscape design measures that will be incorporated into the water conservation strategy should be further detailed within the UWMP. The way the developer intends to promote water conservation measures to future lot owners should also be discussed within the UWMP.

9.3 Finalisation of Irrigation Supply

The water source for irrigation shall be finalised in the UWMP stage. This may include transferring the existing groundwater licences to the site developer. Section 3.3 has showed that the existing allocations onsite is sufficient for the POS irrigation requirement.

9.4 Groundwater Management System

Groundwater management strategy has been presented in two scenarios in this LWMS. The detailed management plan, including the imported fill and the post-development MGL calculation, shall be presented in the future UWMP.

9.5 Monitoring and Maintenance Requirements

The post development monitoring program, including monitoring locations, parameters, trigger values, frequency, timeframe and related contingency actions will to be detailed in future UWMP(s).

The stormwater management structures will require ongoing maintenance. It is expected that future UWMP(s) will provide actions, timing, locations and responsibilities.

9.6 Erosion and Sediment Control

Erosion and sediment control plays an important role in the subdivision and water quality protection. The UWMP will provide detailed measures in the construction and post-development stages.

9.7 Potable Water and Sewerage Services

The UWMP should include confirmation that Water Corporation agree to supply potable water and sewerage connections to the development and how these services will be connected to the existing mains.

10 Limitations

This report is produced strictly in accordance with the scope of services set out in the contract or otherwise agreed in accordance with the contract. 360 Environmental makes no representations or warranties in relation to the nature and quality of soil and water other than the visual observation and analytical data in this report.

In the preparation of this report, 360 Environmental has relied upon documents, information, data and analyses ("client's information") provided by the client and other individuals and entities. In most cases where client's information has been relied upon, such reliance has been indicated in this report. Unless expressly set out in this report, 360 Environmental has not verified that the client's information is accurate, exhaustive or current and the validity and accuracy of any aspect of the report including, or based upon, any part of the client's information is contingent upon the accuracy, exhaustiveness and currency of the client's information. 360 Environmental shall not be liable to the client or any other person in connection with any invalid or inaccurate aspect of this report where that invalidity or inaccuracy arose because the client's information was not accurate, exhaustive and current or arose because of any information or condition that was concealed, withheld, misrepresented, or otherwise not fully disclosed or available to 360 Environmental.

Aspects of this report, including the opinions, conclusions and recommendations it contains, are based on the results of the investigation, sampling and testing set out in the contract and otherwise in accordance with normal practices and standards. The investigation, sampling and testing are designed to produce results that represent a reasonable interpretation of the general conditions of the site that is the subject of this report. However, due to the characteristics of the site, including natural variations in site conditions, the results of the investigation, sampling and testing may not accurately represent the actual state of the whole site at all points.

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.

11 References

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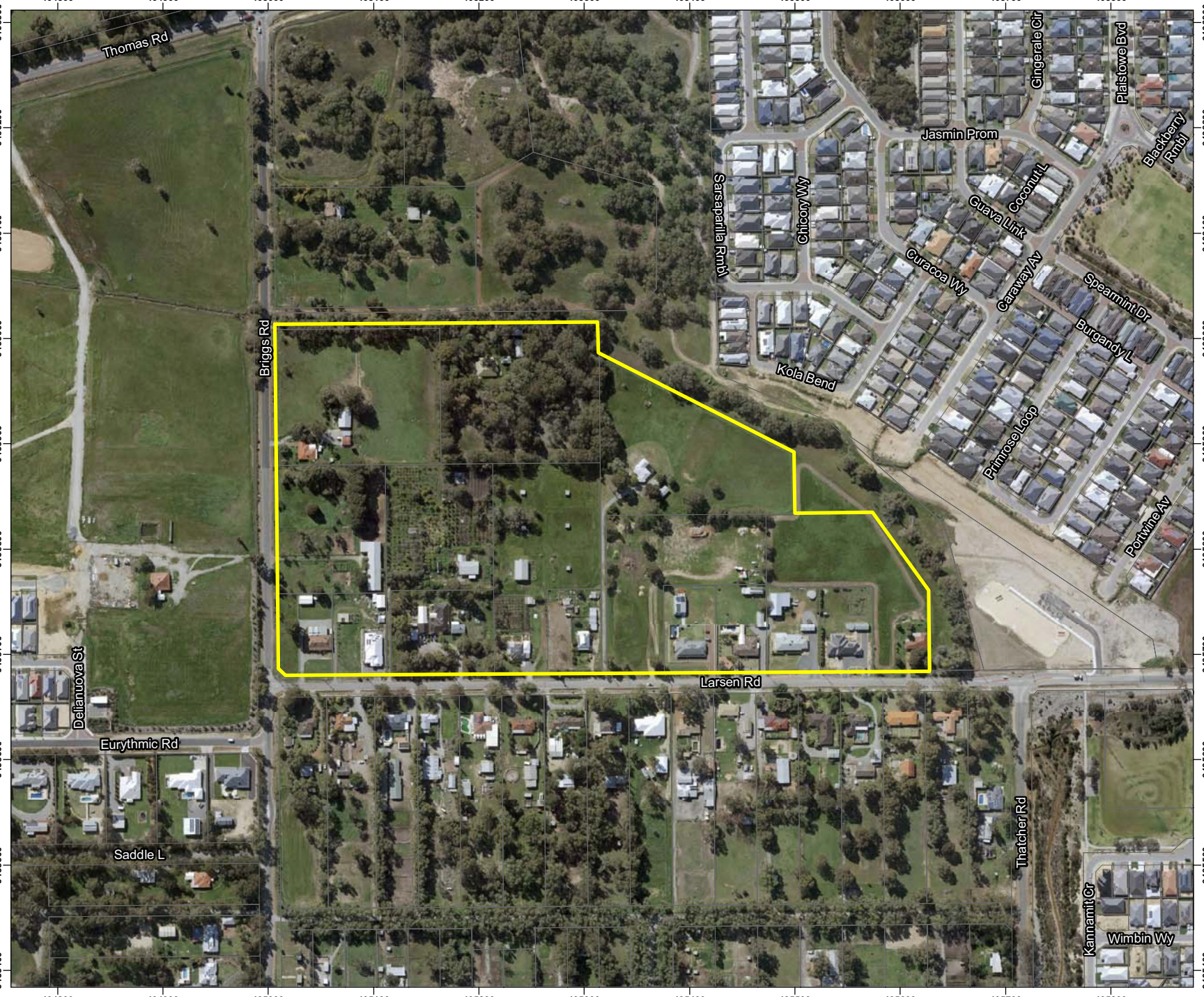
Figures



Legend

- Site Boundary
- Lot Boundaries
- Local Road

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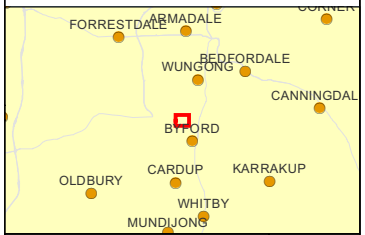

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I.Q. Property and Projects
Briggs Rd & Larsen Rd, Byford

Local Water Management Strategy

Figure 1 Site Location

K:\Projects\10. WAM\2960 Larsen Road LWMS\2960 F1 Site Location.mxd

Legend

Site Boundary

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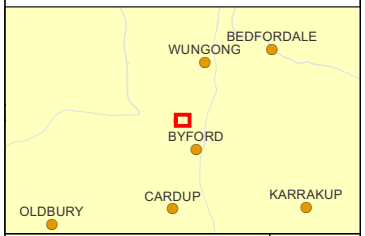

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LWMS and Groundwater Monitoring

Figure 2 Local Structure Plan

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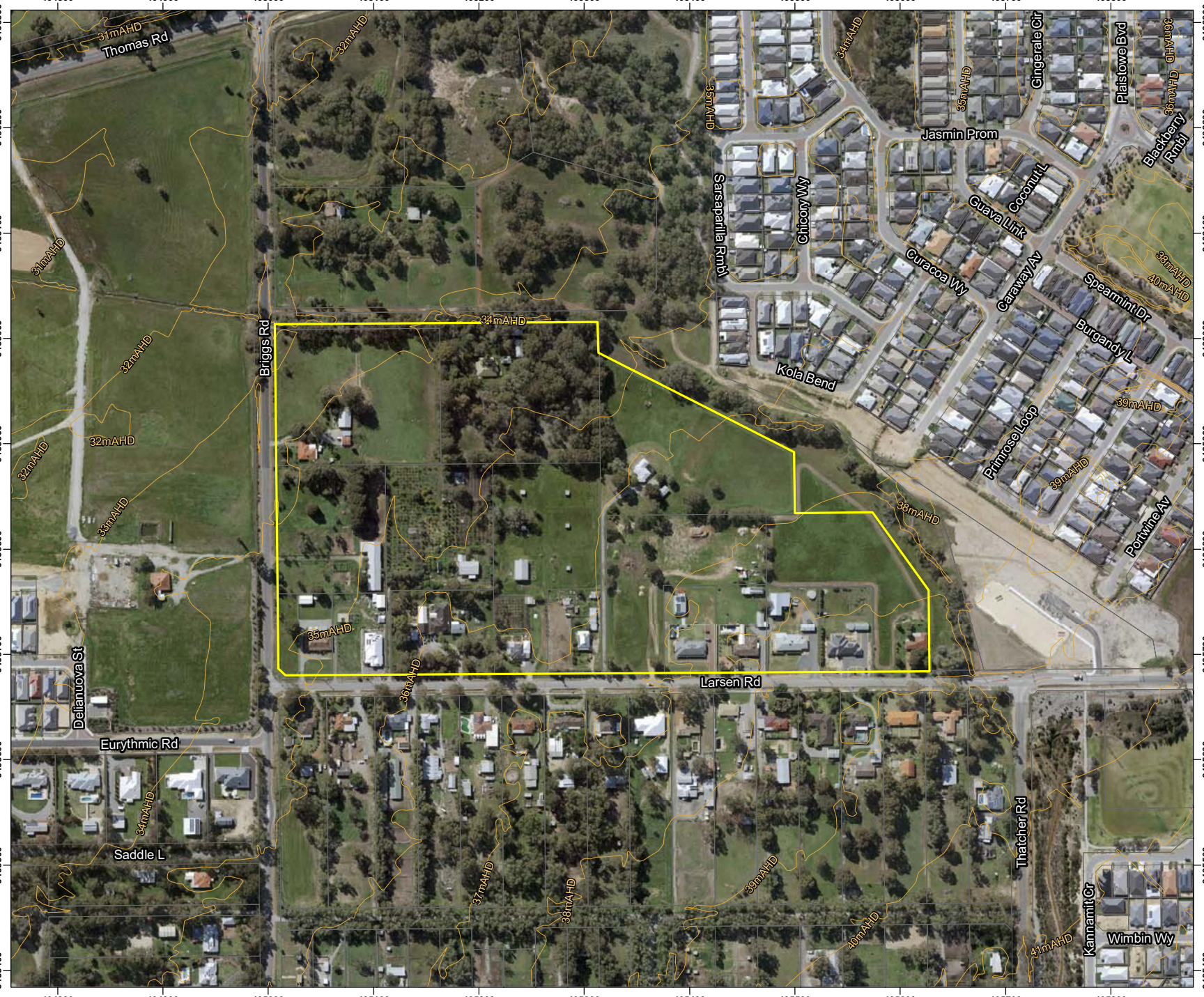

Legend

- Site Boundary
- Contours 1m
- Lot Boundaries

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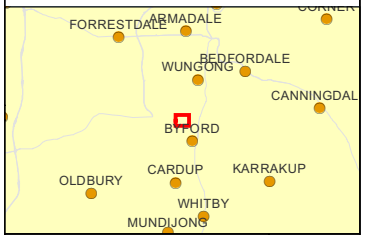

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Local Water Management Strategy

Figure 3 Topography

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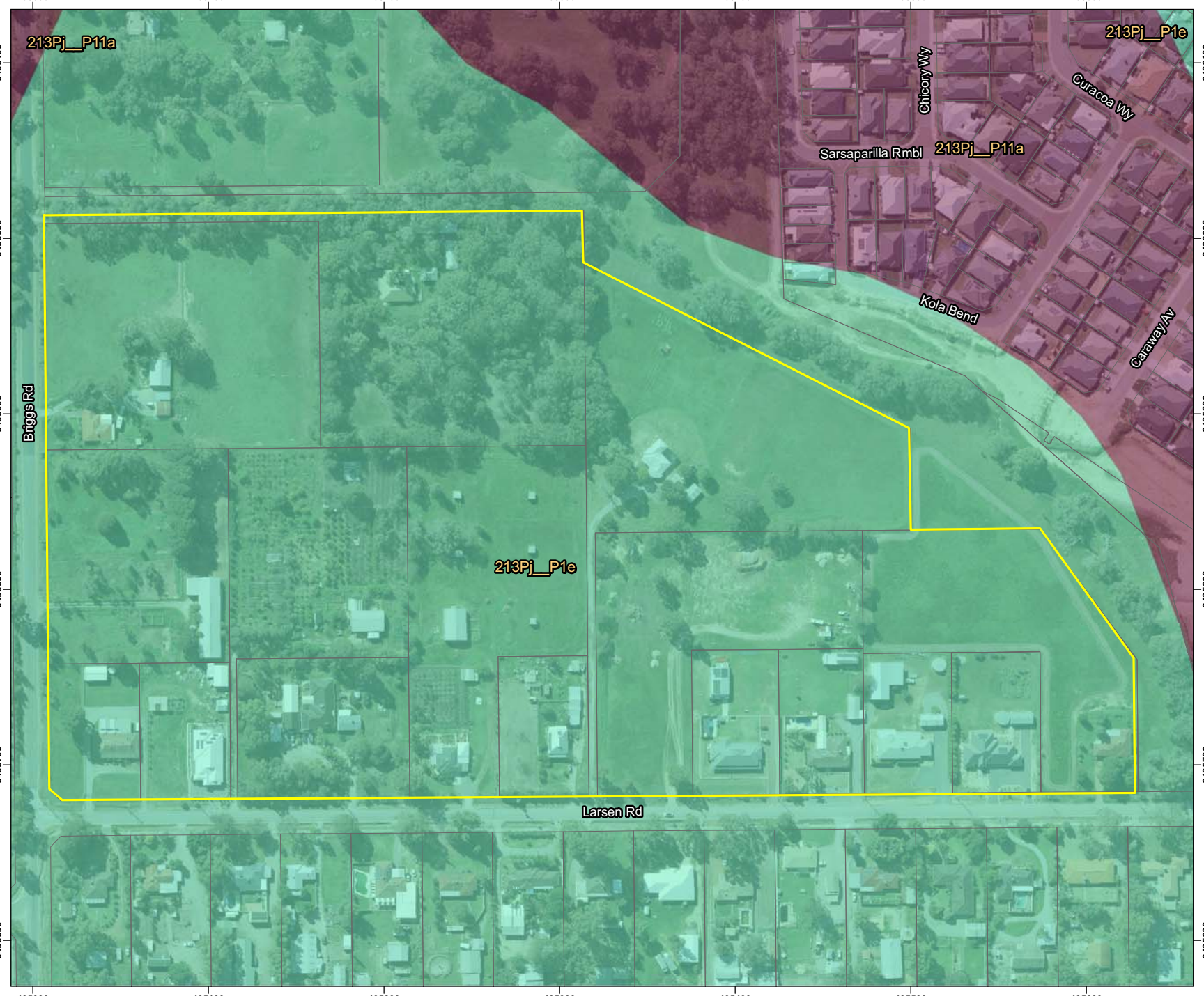

Legend

Site Boundary

Lot Boundaries

Soils Subsystem Central

213Pj__P11a

Shallow sand to sandy loam over lateritic material; imperfect to moderately well drained.

213Pj__P1e

Flat to very gently undulating plain with deep acidic mottled yellow duplex soils. Shallow pale sand to sandy loam over very gravelly clay; moderately well drained.

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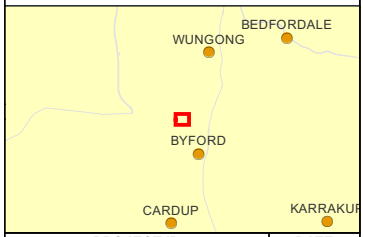

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Local Water Management Strategy

Figure 4 Soil

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Legend

- Site Boundary
- Lot Boundaries

Acid Sulfate Soils

- Moderate to low risk

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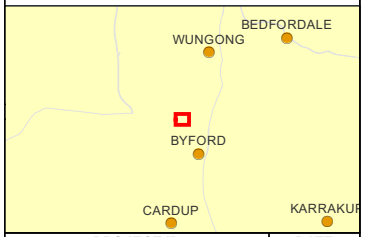

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Local Water Management Strategy

Figure 5 Acid Sulfate Soils

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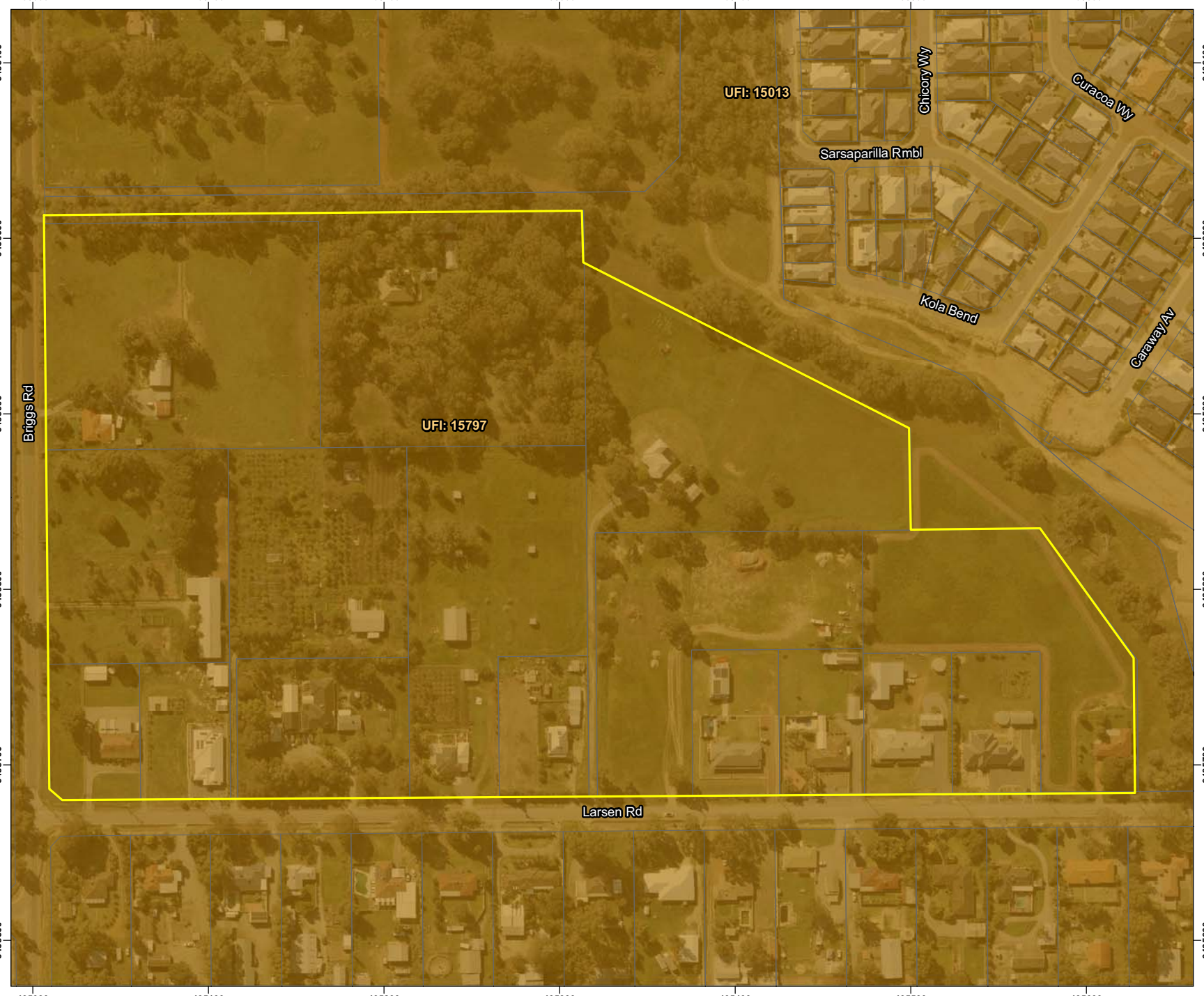

Legend

- Site Boundary
- Lot Boundaries

Geomorphic Wetlands

- Multiple Use

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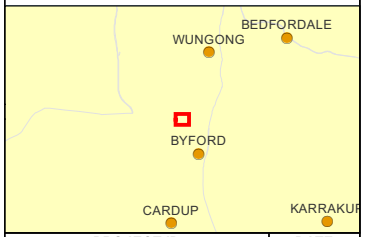

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Local Water Management Strategy

Figure 6 Wetlands

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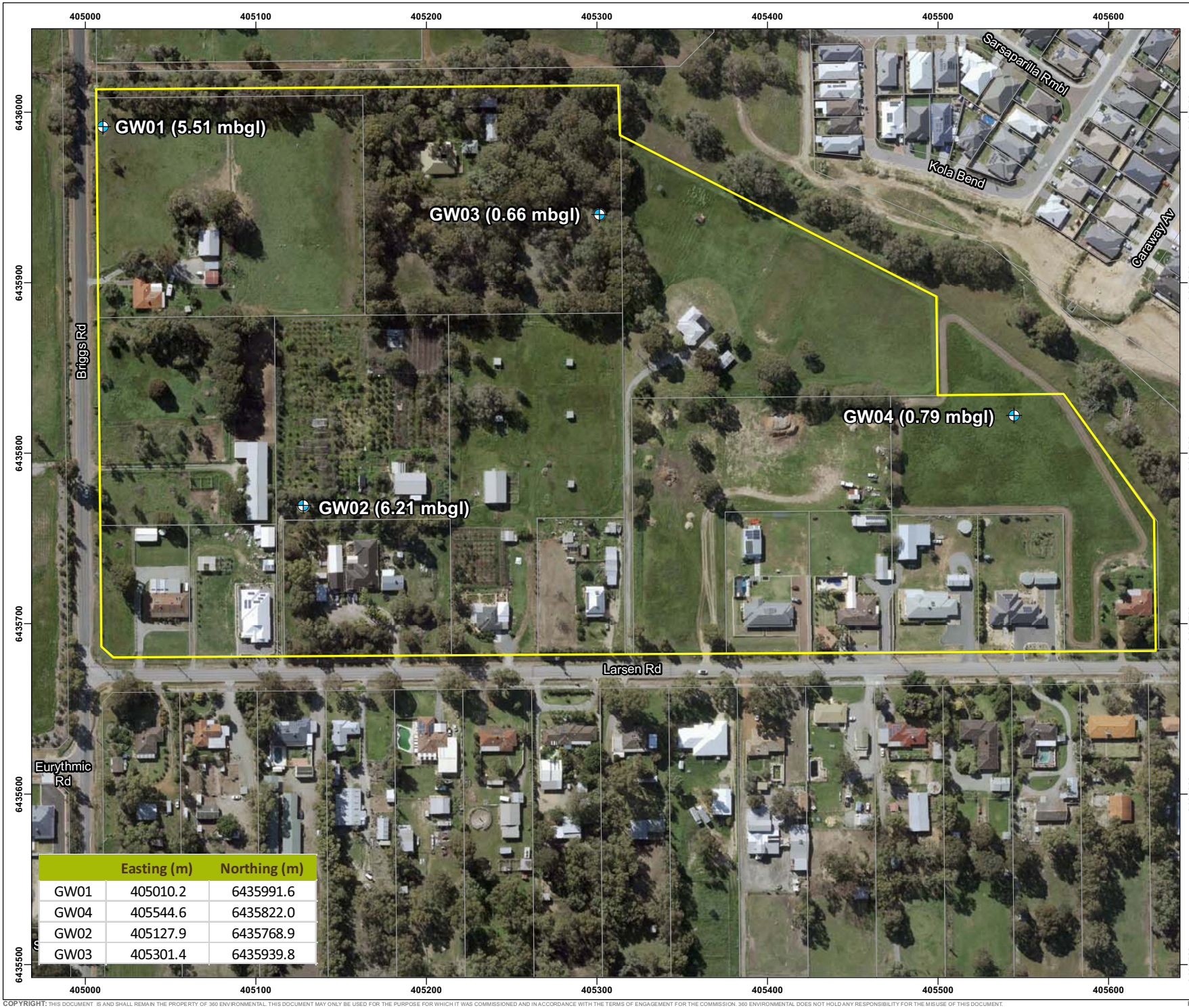

	Easting (m)	Northing (m)
GW01	405010.2	6435991.6
GW04	405544.6	6435822.0
GW02	405127.9	6435768.9
GW03	405301.4	6435939.8

Legend

- Site Boundary
- Lot Boundaries
- Groundwater Monitoring Well Locations (2019 max level)

- 'mbgl' REPRESENTS METERS BELOW GROUND LEVEL
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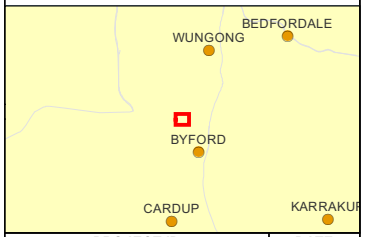

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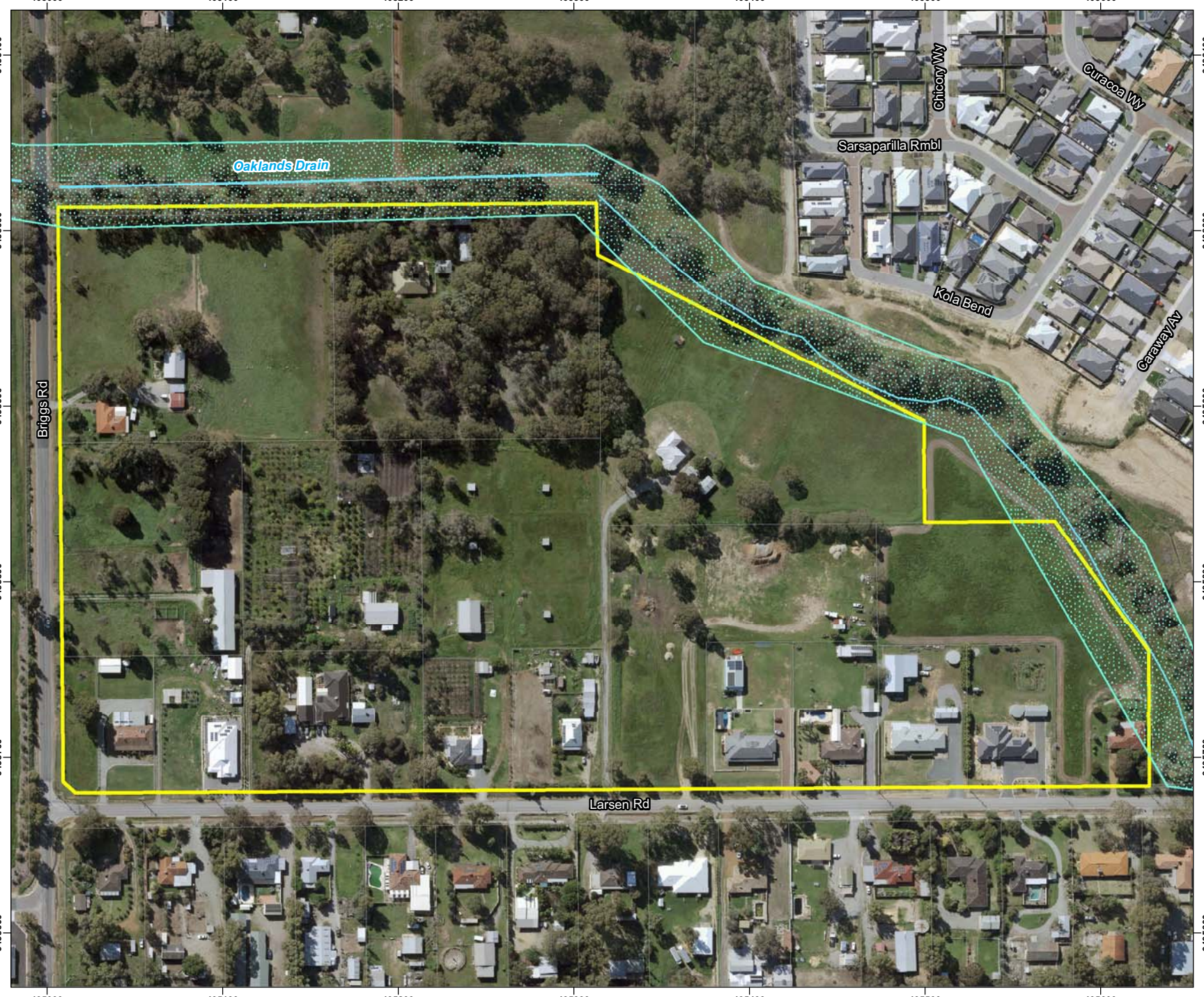
Local Water Management Strategy
Figure 7 2019 Peak Groundwater Level

K:\Projects\10. WAM\2960 Larsen Road LWMS\2960 F7 Groundwater Level.mxd



Legend

- Site Boundary
- Lot Boundaries
- 1% AEP Floodway
- Watercourse - minor
- Drain - major

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2019
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2019
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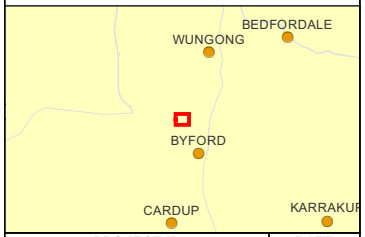
0 25 50 75 100 N
Meters
1:3,000 @ A4

LOCALITY MAP



PROJECT ID	DATE
2960	05/11/2019

HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50

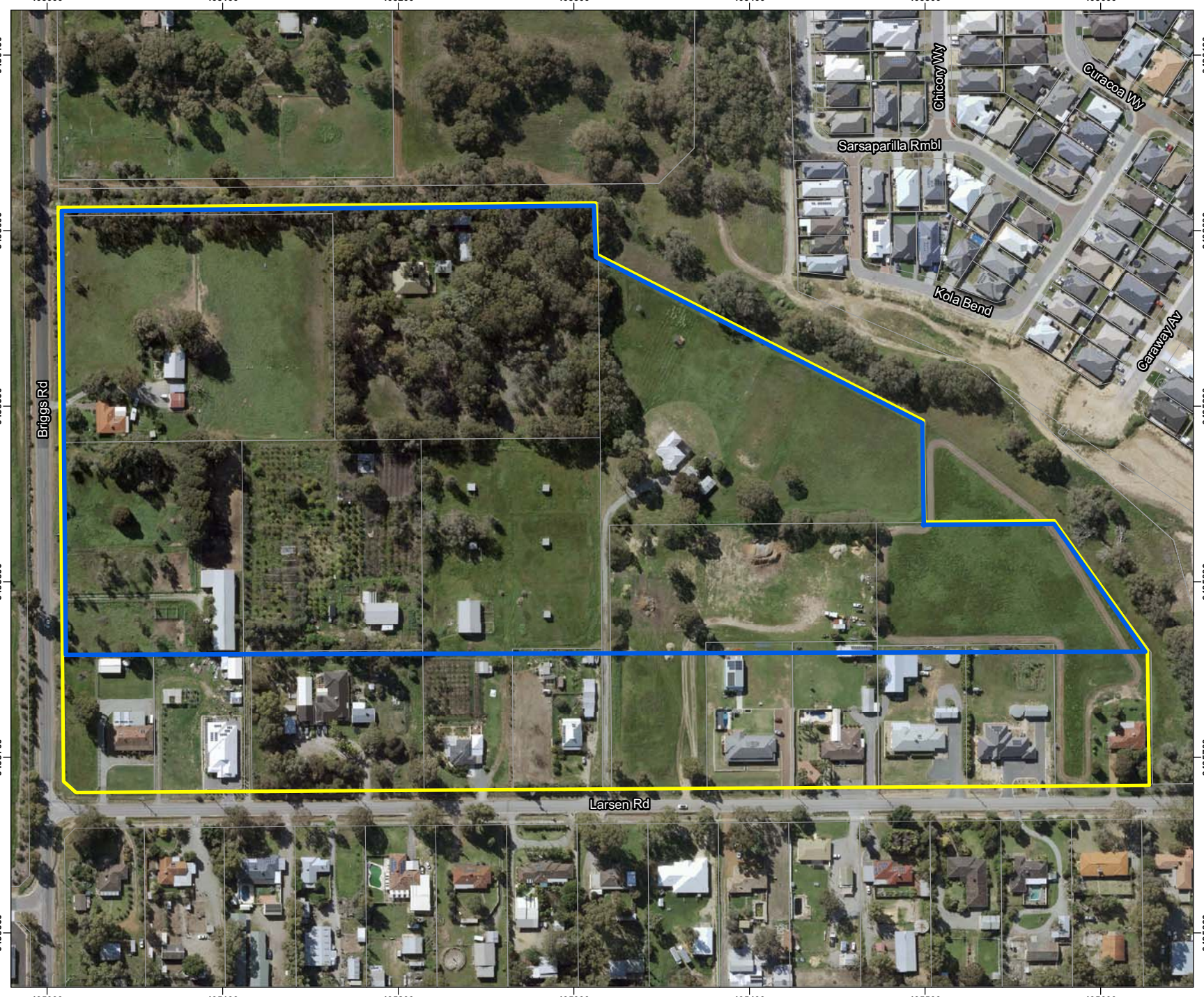
CREATED	CHECKED	APPROVED	REVISION
LF	LPZ	KL	0

I.Q. Property and Projects
Briggs Rd & Larsen Rd, Byford

LWMS and Groundwater Monitoring

Figure 8 Surface Water Features and Floodway

K:\Projects\10. WAM\2960 Larsen Road LWMS\2960 F8 Surface Water Features and Floodway.mxd



Legend

- Site Boundary
- Lot Boundaries
- Pre-development Modelling Catchment

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2019
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2019 (© Western Australian Land Information Authority 2018)

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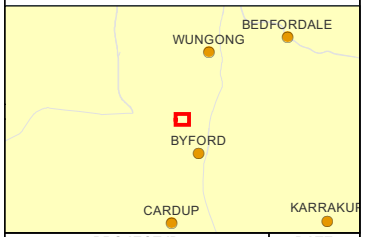
0 25 50 75 100 N
Meters
1:3,000 @ A4

LOCALITY MAP



PROJECT ID	DATE
2960	05/11/2019

HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50

CREATED	CHECKED	APPROVED	REVISION
LF	LPZ	KL	0

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Local Water Management Strategy

Figure 9 Pre-development Modelling Catchment

K:\Projects\10. WAM\2960 Larsen Road LWMS\2960 F9 pre-development Modelling Catchment.mxd

Legend

- Site Boundary
- Detention Basin

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2019
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2019
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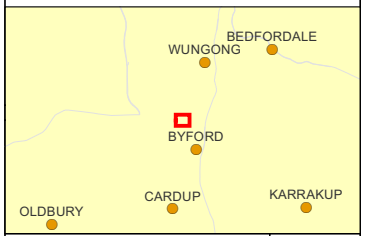
0 25 50 75 100 Meters
1:3,500 @ A4
N

LOCALITY MAP



PROJECT ID	DATE
2960	17/06/2020

HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50

CREATED	CHECKED	APPROVED	REVISION
LF	KL	KL	03

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LWMS and Groundwater Monitoring

Figure 10 Detention Basin

K:\Projects\10. WAM\2960 Larsen Road LWMS\2960 F10 Detention Basin R03.mxd

Legend

- Site Boundary
- Detention Basin (Surface dimension 80m x 30m)
- 20% AEP Inundation Area (Surface dimension 79m x 29m)
- Indicative Flow Path

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2019
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2019
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0 25 50 75 100 Meters
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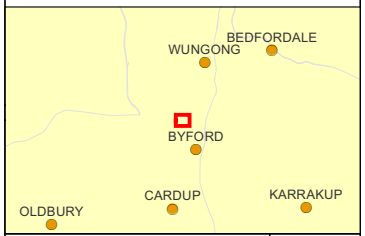
LOCALITY MAP



PROJECT ID	DATE
2960	17/06/2020

HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50

CREATED	CHECKED	APPROVED	REVISION
LF	KL	KL	03

I.Q. Property and Projects
Briggs Rd & Larsen Rd, Byford

LWMS and Groundwater Monitoring

Figure 11a
Minor Event Plan

K:\Projects\10. WAM\2960 Larsen Road LWMS\2960 F11a Minor Event Plan R03.mxd

Legend

- Site Boundary
- Detention Basin (Surface dimension 80m x 30m)
- 1% AEP Inundation Area (Surface dimension 80m x 30m)
- Indicative Flow Path

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2019
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2019
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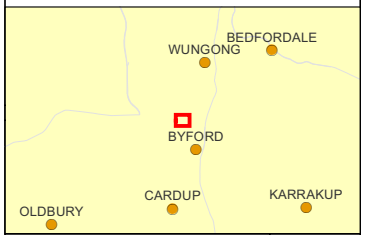
0 25 50 75 100 Meters
1:3,500 @ A4

LOCALITY MAP



PROJECT ID	DATE
2960	17/06/2020

HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50

CREATED	CHECKED	APPROVED	REVISION
LF	KL	KL	03

I.Q. Property and Projects
Briggs Rd & Larsen Rd, Byford

LWMS and Groundwater Monitoring

Figure 11b
Major Event Plan

K:\Projects\10. WAM\2960 Larsen Road LWMS\2960 F11b Major Event Plan R03.mxd

Appendices

Appendix A
Site Survey

This plan has been prepared for I.Q. Project Management Pty Ltd from a combination of field survey and existing records for the purpose of showing the physical features of the land to assist in designing future development. It should not be used for any other purpose.

The title boundaries shown hereon were not verified or marked at the time of survey but are derived from the SCDB 08 2018. They are estimated to be accurate only to +/- 0.05m, This plan should not be used for building to boundary, or to prescribed set-backs, without further boundary survey.

Underground services shown on this drawing have been plotted from service authority records obtained from 'Dial Before You Dig' or a similar source. Unless indicated otherwise only surface features have been located by survey .

Before starting any demolition, excavation or construction on the site, the relevant person should make an independent and updated enquiry of 'Dial Before You Dig' and any relevant service providers to ascertain the existence of further services (if any) and the accurate location of those not surveyed at the time of preparing this plan (or data).

No responsibility can be accepted by Harley Dykstra for any damage caused to any underground service or any loss or injury so suffered if enquiry and verification have not been completed in accordance with this note.

AHD connection made to SSM WUN 20 total station survey methods.

Contractors to verify all survey control marks to be correct (by field checks) prior to utilisation for construction purposes.

This note is an integral part of this plan or the data as transmitted. Failure to reproduce this note on providing this plan or accompanying data or any part thereof to any third party will render this plan or data invalid.

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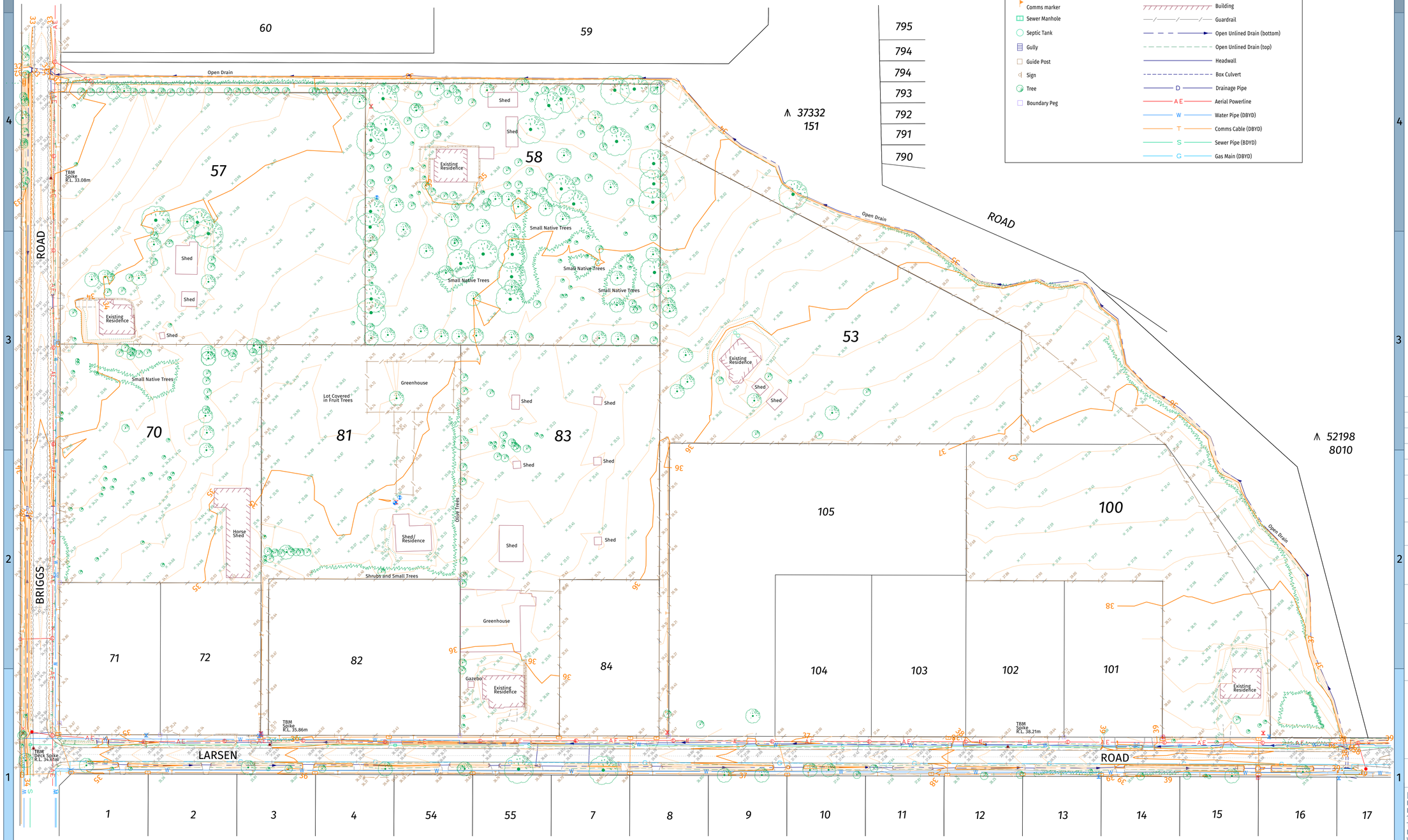
INTERESTS AND NOTIFICATIONS

LAND BURDENED	PURPOSE	COMMENT
70	NOTIFICATION	SEE DOC. M358673
81	NOTIFICATION	SEE DOC. I822377
83	NOTIFICATION	SEE DOC. I100495
83	NOTIFICATION	SEE DOC. I100496
100	NOTIFICATION	SEE DOC. I320299

LEGEND

- Power Pole/Light
- Electrical Service Pole
- Stay Pole
- Stay Wire
- Power Dome
- Electrical Meter
- Earth Pit
- Water Meter
- Stop Valve
- Hydrant (ground)
- Retic Control Point
- Water Pump
- Comms Pit
- Comms marker
- Sewer Manhole
- Septic Tank
- Gully
- Guide Post
- Sign
- Tree
- Boundary Peg
- SCDB Boundary
- Shoulder
- Edge of Bitumen
- Road Centreline
- Bottom of Kerb
- Top of Kerb
- Driveway
- Concrete Footpath
- Bottom of Bank
- Top of Bank
- Brick Wall
- Fence
- Vegetation Line
- Building
- Guardrail
- Open Unlined Drain (bottom)
- Open Unlined Drain (top)
- Headwall
- Box Culvert
- D — Drainage Pipe
- A E — Aerial Powerline
- W — Water Pipe (DBYD)
- T — Comms Cable (DBYD)
- S — Sewer Pipe (BDYD)
- G — Gas Main (DBYD)



rev	details	approved	date
A	Original drawing	AV	11/09/18

survey: TT 04/09/18	cad file: 21645-01A.lcd
drawn: TT 06/09/18	checked: AV 11/09/18
horiz datum: PCG94	level datum: AHD
scale at A1: 1 : 1000	all distances are in metres: 0 10 20 30 40 50

plan type: Feature and Contour Survey

client: I.Q. PROJECT MANAGEMENT PTY LTD

description: LOTS 53, 57 & 58 ON PLAN 13067
LOT 70 ON DP 71757
LOT 81 ON DP 39989
LOT 83 ON DP 27383
& LOT 100 ON DP 29735
BRIGGS ROAD & LARSEN ROAD, BYFORD

drawing no: 21645-01A

Harley Dykstra
PLANNING & SURVEY SOLUTIONS

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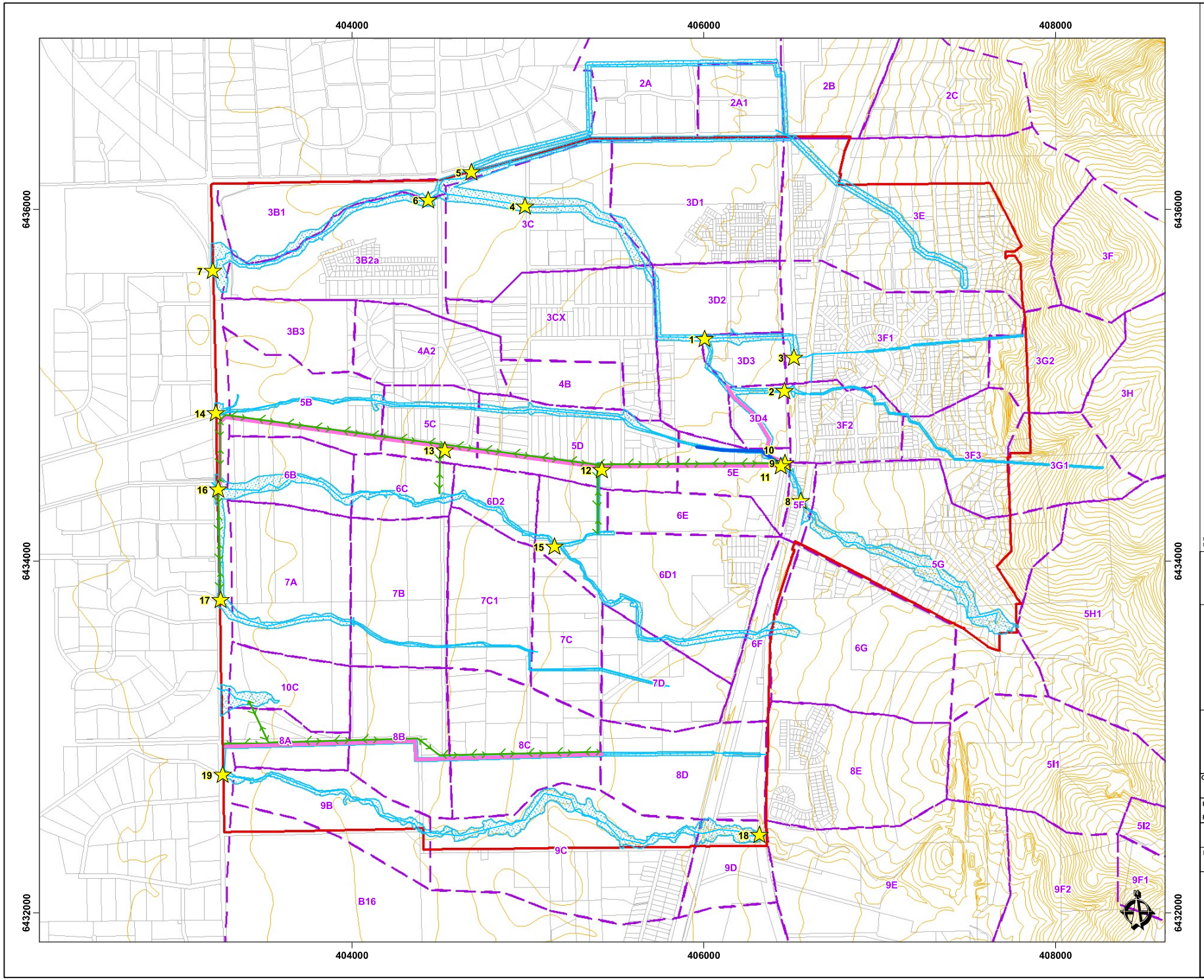
ALBANY | BUNBURY | BUSSELTON | FORRESTDALE | PERTH

Appendix B
2008 DWMP 100 Year ARI Floodway



LEGEND

- Byford Drainage and Water Management Plan Area (GHD, 20070625)
- Modelled Subcatchment (GHD, 20070823)
- Cadastre (DLI, 20061201)
- 100 Year ARI Floodways (GHD, 20080215)
- 5m Contours (GHD, 20080718)
- Critical Flow and Level Locations (GHD, 20080718)

Drains (GHD, 20080131)

- Main Waterway (Restored)
- Modelled Overland Flowpath
- Modelled Swale Drain
- Modelled Piped Drain

MAP UNITS PROJECTED IN MGA ZONE 50
NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS.

SCALE

200 0 200 400 600 m

1:20,000 at A3

LOCALITY MAP

South West WA

CREATED BY	CHECKED	APPROVED
NT	ML	

HORIZONTAL DATUM: GDA94 **PROJECTION:** MGA ZONE 50

HEIGHT DATUM: **METADATA RECORDED:**

DATE	FILE LOCATION
18.07.08	G:\61\19569\GIS\mxds\619569-G10.mxd

REVISION	DRAWING NO
0	6119569-G10

Department of Water Government of Western Australia

GHD

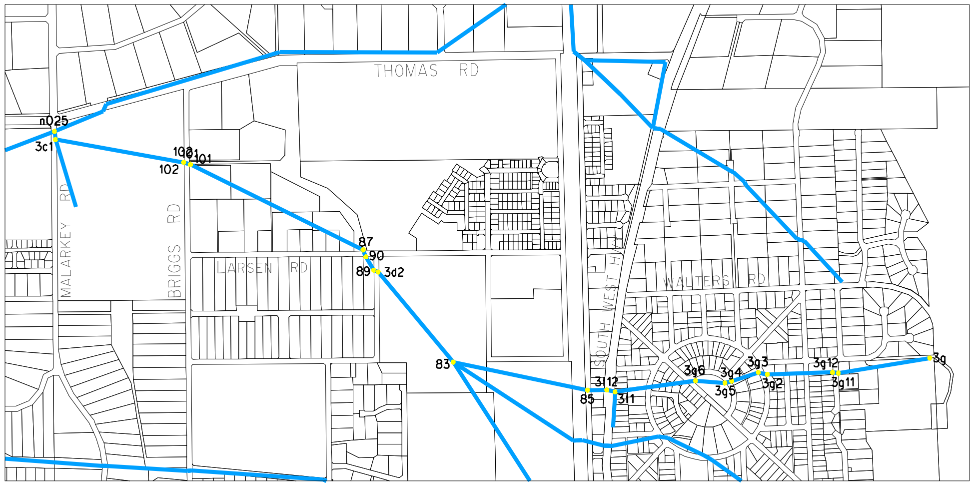
BYFORD TOWNSITE -
DRAINAGE & WATER MANAGEMENT PLAN

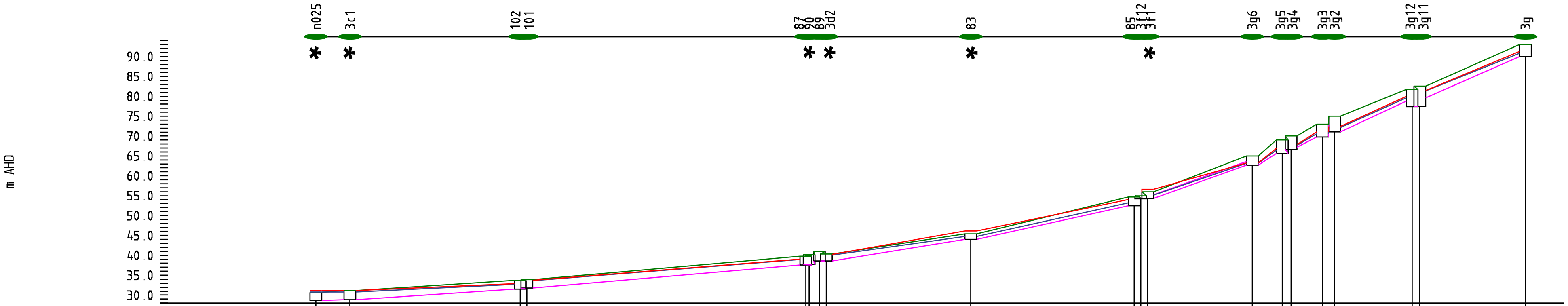
Figure A-8
Stormwater Strategy

Appendix C
2008 DWMP Oaklands Drain Longitudinal Section

THE INFORMATION CONTAINED HEREIN IS SUBJECT TO ONGOING REVIEW AND AMENDMENTS AND SHOULD BE READ IN CONJUNCTION WITH THE ASSOCIATED REPORT.

N





Chainage (m)	Ground level (m AHD)	5 year ARI HGL level (m AHD)	100 year ARI HGL level (m AHD)	Invert level (m AHD)	
0	30.67	30.75	31.12	-	28.67
100	31.16	30.79	31.17	28.84	28.84
600	33.70	32.74	32.85	31.56	31.56
620	33.90	33.59	33.71	31.76	31.76
1440	39.80	38.93	39.06	37.61	37.61
1450	40.11	39.63	39.75	37.71	37.71
1480	41.00	39.89	40.04	38.60	38.60
1500	40.30	40.09	40.23	38.60	38.60
1925	45.43	44.72	46.12	44.00	44.00
2405	54.70	53.25	54.01	52.50	54.20
2425	55.00	54.84	54.93	54.70	54.20
2445	56.00	55.14	56.61	54.30	54.30
2752	65.00	63.14	63.25	62.69	62.69
2840	69.00	66.49	66.90	65.67	65.67
2866	70.00	67.67	67.80	66.68	67.18
2959	73.00	70.63	71.05	69.78	69.80
2993	75.00	72.19	72.39	72.00	71.08
3221	81.74	79.57	79.99	78.74	77.40
3244	82.57	81.36	81.45	77.50	79.57
3555	93.00	90.83	91.26	90.00	-

Segment (chainage, m)	Size (mm)	Max 5 year ARI flow (m3/s)	Max 100 year ARI flow (m3/s)
0–100		12.59	28.83
100–600		13.62	26.05
600–620	1880 x1220	6.39	7.03
620–1440		14.43	25.58
1440–1450	1220	4.34	4.37
1450–1480		13.45	24.10
1480–1500	1220 x1200	2.37	2.37
1500–1925		13.45	24.10
1925–2405		4.87	10.31
2405–2425		3.47	10.18
2425–2445	2x1520 x640	1.73	5.09
2445–2752	900	0.17	0.19
2752–2840		3.47	10.21
2840–2866	900	0.32	0.46
2866–2959		3.47	10.22
2959–2993	900	0.07	0.14
2993–3221		3.47	10.24
3221–3244	300	0.26	0.26
3244–3555		3.47	10.28

* INDICATES FLOODING DURING 100 YR ARI STORM EVENT

AUTHOR: P Haywood DESIGN FILE: Fig10-02 OaklandsDrainCentral pre.dgn

Department of Water
Government of Western Australia

OAKLANDS DRAIN CENTRAL

LONGITUDINAL SECTION
EXISTING SYSTEM
Figure A10.2

PROJECT N°: 6119569 DATE: 04/08/2008 COORDINATE SYSTEM: MGA94 - Zone 50

...\FigA10-02_OaklandsDrainCentral_pre.dgn 5/08/2008 9:20:55 AM

Appendix D
Landscape Plan

N:\TOWN PLANNING\8000-8999\8902\DRAFTING\CAD - ADAM GLASKIN - 2019.11.12\
8902_FIG16A_20191112_Byford (POS Plan) - DRAWN: A. GLASKIN - DATE CREATED: 2019.11.12 - PROJECTION: MGA50 GDA94 - CADASTE: LANDGATE

PUBLIC OPEN SPACE PLAN

VARIOUS LOTS, BRIGGS AND LARSEN ROAD PRECINCT, BYFORD

FIGURE 9

NORTH

0 50 m

SCALE @ A3: 1:2000

8902-FIG-16-A

ROWE GROUP DESIGN

Appendix E
Geotechnical Investigation

Douglas Partners
Geotechnics / Environment / Groundwater

Integrated Practical Solutions

Report on
Geotechnical Investigation

Proposed Local Structure Plan
Briggs & Larsen Roads, Byford

Prepared for
I.Q. Project Management Pty Ltd

Project 96527.00
February 2019

Douglas Partners
Geotechnics / Environment / Groundwater

Document History

Document details

Project No.	96527.00	Document No.	R.001.Rev0
Document title	Report on Geotechnical Investigation Proposed Local Structure Plan		
Site address	Briggs & Larsen Roads, Byford		
Report prepared for	I.Q. Project Management Pty Ltd		
File name	96527.00.R.001.Rev0.Proposed LSP, Byford - best version		

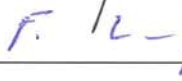
Document status and review

Status	Prepared by	Reviewed by	Date issued
Revision 0	Damian Jagoe-Banks	Fred Verheyde	26 February 2019

Distribution of copies

Status	Electronic	Paper	Issued to
Revision 0	1	1	Nick Di Lello, I.Q. Project Management 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		26/2/2019
Reviewer		26/2/2019

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Douglas Partners
Geotechnics / Environment / Groundwater

Table of Contents

Report on Geotechnical Investigation
Proposed Local Structure Plan
Briggs & Larsen Roads, Byford

1. Introduction

This report presents the results of a geotechnical investigation undertaken for a proposed local structure plan at Lots 53, 57, & 58 Briggs Road and Lots 53, 70, 81, 83, 100, & 105 Larsen Road, Byford. The investigation was commissioned in an email dated 4 January 2019 from Nick Di Lello of I.Q. Project Management Pty Ltd and was undertaken in accordance with Douglas Partners' proposal PER180511 dated 19 December 2018.

A concept plan provided to Douglas Partners indicates that the future development may comprise around 150 residential lots with associated roads and public open space along the existing water course.

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

- A general description of the sub-soil conditions and identification of problematic soils, if encountered.
- Preliminary comments on likely site classification in accordance with AS 2870-2011.
- Comments on likely site preparation requirements
- Comment on the reuse potential for the encountered soils.
- Likely appropriate foundation system(s) for one to two story structures and design parameters for the recommended foundation system(s).
- Preliminary comments on likely California bearing ratio for the encountered shallow materials based on site observations and our previous experience.
- General comments on the encountered soil suitability for stormwater infiltration.
- Depth to groundwater, if encountered.

The investigation included the excavation of ten test pits, in situ permeability testing at two locations and laboratory testing of selected samples. The details of the field work are presented in this report, together with comments and recommendations on the issues listed above.

2. Site Description

The site encompasses Lots 53, 57, & 58 Briggs Road and Lots 53, 70, 81, 83, 100, & 105 Larsen Road, Byford, WA. It is bound by Briggs Road to the west, Larsen Road to the south and creek along the northern and eastern boundaries (refer to Drawing 1, Appendix B).

At the time of the investigation, the site comprised multiple rural residential properties. Test locations were undertaken within grassed areas, away from vegetation and other structures such as sheds and greenhouses.

Figure 1: Typical Site Conditions at the time of the Investigation

Survey data provided by The Civil Group indicates the surface levels generally fall from a high point of approximately RL 38.5 m AHD in the south-eastern corner to approximately RL 33.0 m AHD in the north-western corner.

The 1:50,000 Armadale geology mapping indicates that the site is underlain by sandy clay of the Guildford Formation.

The 2004 Perth Groundwater Atlas indicates that the groundwater level was 30 m AHD, approximately 400 m west of the site western boundary (the extent of the Atlas' coverage) in May 2003.

3. Field Work Methods

Field work was carried out on 22 January 2018 and comprised:

- The excavation of ten test pits (Pit 1 to Pit 10);

- Dynamic cone penetrometer (DCP) test adjacent to each test pit location; and
- Two in-situ permeability tests.

The test pits were excavated to depths of between 1.0 m and 1.65 m, using a 5.5 tonne excavator with a 450 mm wide toothed bucket. Ground conditions were logged in general accordance with AS 1726:2017 by a geotechnical engineer from Douglas Partners. Soil samples were recovered for subsequent laboratory testing.

Two in-situ permeability tests were carried out at test locations 1 and 11 at depths of 0.14 m and 0.35 m respectively. Both tests were undertaken using the constant head method in accordance with AS 1547:2012 Appendix G.

The DCP testing was carried out in accordance with AS 1289.6.3.2, adjacent to each test pit location, to assess the in situ density of the shallow soils. The results of these DCP tests are presented on the test pit log sheets in Appendix B.

Test locations were determined using a hand held GPS and site features, and are presented on Drawing 1 in Appendix B. Surface elevations at each test location were interpolated from the Harley Dykstra Feature and Contour Survey plan (Drawing No 21645-01A) dated 4 September 2018.

4. Field Work Results

4.1 Ground Conditions

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

The encountered ground conditions generally comprised sandy topsoil overlying clayey sands and sandy gravels.

A summary of the ground conditions encountered at the test locations is given below:

- **Topsoil (SILTY SAND, SM)** – brown, fine to medium grained, silty sand topsoil, with trace roots, encountered from surface to depths of between 0.1 m and 0.2 m all test locations. The topsoil material at test location Pit 8 is considered to be fill.
- **FILL (GRAVELLY CLAY, GC)** - stiff gravelly clay with sand fill underlying the topsoil fill at test location Pit 8 to a depth of 0.4 m.
- **CLAYEY SAND, SANDY CLAY (SC, CI)** – generally hard, orange-brown clayey sand and sandy clay underlying the topsoil at test locations Pit 1 to Pit 7 and Pit 9 to depths of between 0.4 m and test pit termination depths up to 1.65 m.
- **SANDY GRAVEL (GP-GC)** – generally dense, sandy gravel underlying clayey sand at Pits 1 and Pit 5 and fill and topsoil at Pit 8 and Pit 10 respectively, to test pit termination depths of between 1.0 and 1.3 m. An exception to this was encountered at Pit 8, where clayey sand was encountered below the sandy gravel between depths of 1.0 m and termination depth of 1.5 m.

No groundwater was observed at any test locations excavated to depths of up to 1.65 m at the time of the investigation on 22 January 2018.

It should be noted that groundwater levels are affected by climatic conditions and soil permeability, and will therefore vary with time.

4.2 Permeability Testing

Two in situ permeability tests using the constant head method were carried out in accordance with AS 1547:2012 at test locations 1 and 11 at depths of 0.14 m and 0.35 m respectively. Field permeability values were estimated using the test results in accordance with AS 1547:2012. The results of the in situ permeability test are presented in Table 1.

Table 1: Summary of Constant Head Permeability Analysis

Test Location	Depth (m)	Measured Permeability[1]		In situ Conditions of Tested Material
		m/s	m/day	
1	0.14	1.1×10^{-4}	9.5	SILTY SAND (topsoil)
11	0.35	4.2×10^{-5}	3.6	Stiff GRAVELLY CLAY (FILL)

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 three samples; and
- The Atterberg limits of three samples.

The detailed test certificates are given in Appendix C, with the results summarised in Table 2.

Table 2: Results of Laboratory Testing for Soil Identification and Site Classification

Test	Depth (m)	Gravel (%)	Sand (%)	Fines (%)	LL (%)	PL (%)	PI (%)	LS (%)	Material
Pit 1	0.6	26	44	30	37	15	22	7.6	CLAYEY SAND with gravel, medium plasticity (SC)
Pit 5	0.9	66	25	9	29	12	17	4.0	SANDY GRAVEL with clay (GP-GC)
Pit 7	0.4	3	46	51	44	18	26	8.0	SANDY CLAY, trace gravel, medium plasticity (CI)

Notes on Table 2:

- % fines is the amount of particles smaller than 75 µm.
- % gravel is the amount of particles larger than 2.36 mm.

Notes on Table 2 (continued):
- LL: liquid limit.
- PL: plastic limit
- '-' means 'Not Tested'
- LS: linear shrinkage
- PI: plasticity Index

6. Comments

6.1 Likely Site Classification

The site is generally underlain by reactive clayey soils with variable sand and gravel content. Fill was encountered at one locations and is considered to be uncontrolled. Uncontrolled filling is considered likely to be located elsewhere on this site based on previous experience with site similar in nature to this one, however it is typically surficial and can be addressed with conventional earthworks and site preparation.

Based on the encountered conditions and the results of the investigation, it is considered that the site is generally 'Class M' in accordance AS 2870-2011 (provided the encountered uncontrolled filling encountered at Pit 8 was addressed during site preparation), with zones of 'Class S'. Class M would be anticipated within zones underlain by clayey sand and sandy clay (such as encountered at test locations 2 to 4, 6, 7 and 9). Typically, Class S would be anticipated within zones underlain by sandy gravel (such as encountered at test locations 1, 5, 8 and 10).

The addition of non-reactive filling (e.g. sand), typically undertaken for residential subdivision around the Perth area could improve the site classification. Preliminary analysis indicated that amending anticipated areas of Class M to Class S would require enough non-reactive fill to produce a separation of at least 0.8 m from the finished surface level to reactive material. Improving the site classification to Class A would require enough non-reactive fill to produce a separation of at least 1.8 m from the finished surface level to reactive material. Reactive material generally was encountered immediately below the silty sandy topsoil and therefore, approximately 1.7 to 1.8 m of compacted sand filling would be required to achieve lots with a site classification of Class A.

Trees alter the natural shrinking and swelling characteristics of soil due to their effect on the moisture content within the soil. The above classification comments apply to areas outside of the influence of trees. If trees are retained for the future subdivision is recommended that site classification is reassessed for any foundations proposed within 20 m of trees.

Preliminary analysis indicated that foundations within 20 m of trees at this site may be subject to surface movement equivalent to Class H1 conditions (i.e. greater than 40 mm of surface movement), however this should be checked on a case by case basis as the soil and characteristics of the trees factor into the ground surface movement. It is noted however, that the site classification (and ground surface movement) can be altered with the placement of sand above the reactive soil (i.e. a building pad).

6.2 Likely Site Preparation Requirements and Reuse Potential of On-site Soils

Site preparation requirements would typically require stripping to remove topsoil, vegetation and any surficial debris (e.g. demolition debris if any of the existing structures are removed). The underlying soils were found to be generally very stiff becoming hard and as such, the requirement of compaction of the existing material is not anticipated to be extensive. Areas of uncontrolled filling such as that encountered at Pit 8 and possibly elsewhere on site, would require further assessment of their suitability as structural filling, and assuming such suitability to stay in situ, a limited thickness (say less than 0.4 m thick) would require proof rolling and suitable control testing of their density.

Following proof compaction of the required areas, any filling should be undertaken in layers placed in thickness suitable to the type of material being placed and the compaction plant being used to compact the fill.

The reactive material could be reused for either structural or non-structural fill. However, its impact on site classification would need to be considered if it were placed within 1.8 m of the finished surface below areas supporting structures because the use of reactive filling generally exacerbates seasonal soil movements. The topsoil would be suitable for reuse in landscaped areas or alternatively, could be blended with imported material for re-use in other areas.

6.3 Suitable Foundations Systems

Shallow foundation systems comprising slab, pad and strip footings are considered suitable to support typical residential structures up to two storeys in height at this site.

A preliminary allowable bearing pressure of 150 kPa is suggested for foundation design of strip footings between 0.5 m and 1.0 m wide and 200 kPa for pad footings 0.5 m to 1.5 m wide founded at a minimum depth of 0.5 m in at least very stiff or medium dense ground.

Foundation systems design in accordance with AS 2870-2011 are anticipated to be suitable for residential buildings (and other similar buildings) covered by this standard.

6.4 Pavement Design Parameters and Subgrade Preparation

Generally, the near surface materials comprise a clayey sands, sandy clays and sandy gravels. California bearing ratio (CBR) testing undertaken on similar soils for previous investigations in the Byford area have indicated soils with CBRs between 7% and 25%. A preliminary presumptive CBR value of 5% is recommended for the natural clayey materials. It is considered that areas where pavement subgrade has higher gravel content could have higher CBR values attributed to them (i.e. Pit 10), however at this stage, the test location frequency is not suitable to delineate any such areas.

Filling to increase the distance between the base of the pavement and the natural subgrade could be used to increase the design CBR for the pavement. Assuming such filling material comprises ‘typical Perth sand’, Table 3 provides indicative CBR values for varying amount of filling.

Table 3: Suggested Preliminary CBR Values

Granular Filling Separating Base of Pavement and Existing Material (m)	Suggested CBR Value (%)
0	5
0 – 0.5	8
0.5 – 1.0	10
≥ 1.0	Value of the granular fill (e.g. 12%)

6.5 Soil Permeability

The soil types noted at test pit locations across the site are predominantly clayey and are not considered suitable for on-site stormwater disposal by infiltration.

Because sufficient penetration into the hard clayey soils was not practicable with hand tools, the results of the in situ permeability tests undertaken at test locations 1 and 11 are considered to be influenced by the sandy topsoil. As such, it is suggested that that representative permeability values of the very stiff to hard clayey soils at this site are lower than the results from the in situ testing.

Based on the observed conditions and our experience with similar ground conditions a preliminary permeability value in the order or 1 x 10^{-6} m/s (<0.1 m/day) or less is suggested for the clayey soils underlying at the site.

7. References

1. Australian Standard AS 1289-2000, Methods of Testing Soils for Engineering Purposes.
2. Australian Standard AS 1289.6.3.2-1999, Soil Strength and Consolidation Tests-Determination of the Penetration Resistance of a Soil – Dynamic Cone Penetrometer Test.
3. Australian Standard AS 1726-2017, Geotechnical Site Investigation.
4. Australian Standard AS 2870-2011, Residential Slabs and Footings.
5. Australian Standard AS 1547:2012, On-site Domestic-wastewater Management.
6. Armadale 1:50,000 Environmental Geology Sheet
7. Department of Environment, Perth Groundwater Atlas, Second Edition, December 2004.

8. Limitations

Douglas Partners (DP) has prepared this report for this project at Lots 53, 57, & 58 Briggs Road and Lots 53, 70, 81, 83, 100, & 105 Larsen Road, Byford, WA in accordance with DP's proposal PER180511 dated 19 December 2018 and acceptance received from I.Q. Project Management Pty

Ltd dated 4 January 2019. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of I.Q. Project Management Pty Ltd and their agents 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.

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.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the (geotechnical / environmental / groundwater) components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

Appendix A

About This Report

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.

Copyright

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.

Sampling Methods

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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 AS 1726-2017, 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

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

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.

Symbols & Abbreviations

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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

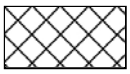
Graphic Symbols for Soil and Rock

General


Asphalt


Road base


Concrete


Filling

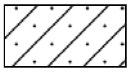
Soils


Topsoil

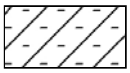

Peat


Clay

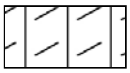

Silty clay

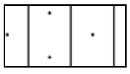

Sandy clay

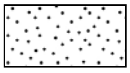

Gravelly clay

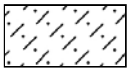

Shaly clay

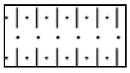

Silt


Clayey silt

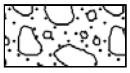

Sandy silt


Sand


Clayey sand


Silty sand


Gravel


Sandy gravel


Cobbles, boulders

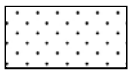

Talus

Sedimentary Rocks

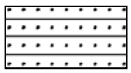

Boulder conglomerate

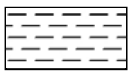

Conglomerate


Conglomeratic sandstone

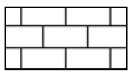

Sandstone


Siltstone


Laminite

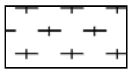

Mudstone, claystone, shale

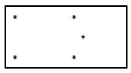

Coal


Limestone

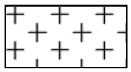
Metamorphic Rocks

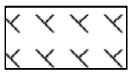

Slate, phyllite, schist

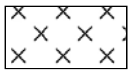

Gneiss

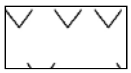

Quartzite

Igneous Rocks


Granite


Dolerite, basalt, andesite

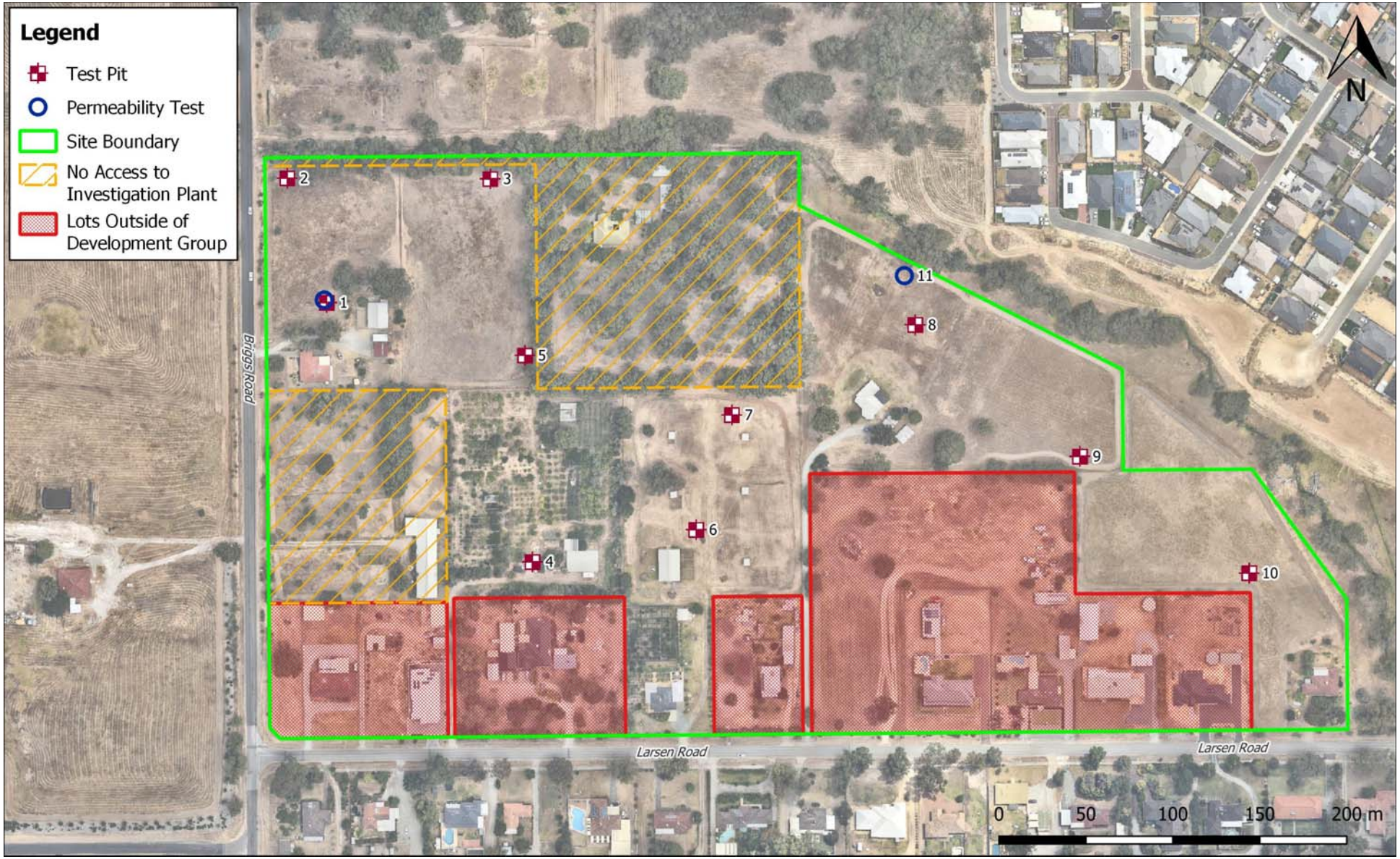

Dacite, epidote


Tuff, breccia


Porphyry

Appendix B

Test Location Plan
Test Pit Logs



Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: I.Q Poject Management Pty Ltd	**Test Location Plan**	PROJECT No: 96527.00
	OFFICE: Perth	**Proposed Local Structure Plan**	DRAWING No: 1
	DATE: 21-2-2019	**Briggs and Larson Road, Byford, WA**	REVISION: 0

TEST PIT LOG

CLIENT: I.Q. Project Management Pty Ltd
PROJECT: Proposed Local Structure Plan
LOCATION: Corne rof Briggs & Larsen Roads, Byford

SURFACE LEVEL: 33.9 AHD
EASTING:
NORTHING:

PIT No: 1
PROJECT No: 96527.00
DATE: 22/1/2019
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 150mm)
33	0.15	TOPSOIL (SM) - light brown, fine to medium grained, silty sand, trace roots, dry.							
		CLAYEY SAND (SC) - hard, orange brown, fine to medium grained, medium plasticity, clayey sand with gravel, dry.		D	0.6				
1	0.9	SANDY GRAVEL (GP-GC) - dense, green-brown, fine to medium sized, sandy gravel with clay, dry. Gravel is laterite. Low plasticity fines.		D	1.1				
	1.3	Pit discontinued at 1.3m *Refusal on hard clay		D	1.3				

5 10 15 20

>

1

RIG: 5.5T Yanmar Excavator with backhoe

LOGGED: PJ

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: *Surface levels interpolated from Harley Dykstra survey plan. Drawing No 21645-01A (04/09/18)

☐ 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: I.Q. Project Management Pty Ltd
PROJECT: Proposed Local Structure Plan
LOCATION: Corne rof Briggs & Larsen Roads, Byford

SURFACE LEVEL: 32.9 AHD
EASTING:
NORTHING:

PIT No: 2
PROJECT No: 96527.00
DATE: 22/1/2019
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 150mm)
32	0.2	TOPSOIL (SM) - light brown, fine to medium grained, silty sand, trace roots, dry.							
		CLAYEY SAND (SC) - hard, orange brown, fine to medium grained, medium plasticity, clayey sand, dry.							
		- with gravel from 0.5 m.		D	0.6				
		- becoming green/grey mottled orange-brown from 0.7 m.		D	0.95				
31	1.1	Pit discontinued at 1.1m *Refusal on hard clay							

RIG: 5.5T Yanmar Excavator with backhoe

LOGGED: PJ

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: *Surface levels interpolated from Harley Dykstra survey plan. Drawing No 21645-01A (04/09/18)

☐ 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: I.Q. Project Management Pty Ltd
PROJECT: Proposed Local Structure Plan
LOCATION: Corne rof Briggs & Larsen Roads, Byford

SURFACE LEVEL: 33.9 AHD
EASTING:
NORTHING:

PIT No: 3
PROJECT No: 96527.00
DATE: 22/1/2019
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 150mm)
33	0.2	TOPSOIL (SM) - light brown, fine to medium grained, silty sand, trace roots, dry.		D	0.1				
		CLAYEY SAND (SC) - hard, orange brown, fine to medium grained, medium plasticity, clayey sand trace gravel, dry.		D	0.7				
		- with gravel from 0.8 m.							
1		- becoming green-grey mottled orange-brown from 1.0 m.		D	1.0 1.05		pp = 500		1
	1.3	Pit discontinued at 1.3m *Refusal on hard clay		D	1.3				

5 10 15 20

RIG: 5.5T Yanmar Excavator with backhoe

LOGGED: PJ

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: *Surface levels interpolated from Harley Dykstra survey plan. Drawing No 21645-01A (04/09/18)

☐ 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: I.Q. Project Management Pty Ltd
PROJECT: Proposed Local Structure Plan
LOCATION: Corne rof Briggs & Larsen Roads, Byford

SURFACE LEVEL: 35.1 AHD
EASTING:
NORTHING:

PIT No: 4
PROJECT No: 96527.00
DATE: 22/1/2019
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 150mm)
35	0.15	TOPSOIL (SM) - light brown, fine to medium grained, silty sand, trace roots, dry.							
		CLAYEY SAND (SC) - hard, orange brown, fine to medium grained, medium plasticity, clayey sand trace gravel, dry.			0.5		pp = 500		
		- low plasticity, with gravel from 0.6 m.		D	0.9				
34	1.1	Pit discontinued at 1.1m *Refusal on hard clay			1.0		pp = 500		

RIG: 5.5T Yanmar Excavator with backhoe

LOGGED: PJ

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: *Surface levels interpolated from Harley Dykstra survey plan. Drawing No 21645-01A (04/09/18)

☐ 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: I.Q. Project Management Pty Ltd
PROJECT: Proposed Local Structure Plan
LOCATION: Corne rof Briggs & Larsen Roads, Byford

SURFACE LEVEL: 34.6 AHD
EASTING:
NORTHING:

PIT No: 5
PROJECT No: 96527.00
DATE: 22/1/2019
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 150mm)
34	0.1	TOPSOIL (SM) - light brown, fine to medium grained, silty sand, trace roots, dry.							
		SANDY CLAY (SC) - hard, orange brown, low plasticity, sandy clay, with gravel, dry.		D	0.3				
	0.4	SANDY GRAVEL (GP-GC) - dense, green-brown, fine to medium sized, sandy gravel with clay, dry. Gravel is laterite. Low plasticity fines.		D	0.9				
33	1.3	Pit discontinued at 1.3m *Refusal on hard clay		D	1.3				

RIG: 5.5T Yanmar Excavator with backhoe

LOGGED: PJ

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: *Surface levels interpolated from Harley Dykstra survey plan. Drawing No 21645-01A (04/09/18)

☐ 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: I.Q. Project Management Pty Ltd
PROJECT: Proposed Local Structure Plan
LOCATION: Corne rof Briggs & Larsen Roads, Byford

SURFACE LEVEL: 35.4 AHD
EASTING:
NORTHING:

PIT No: 6
PROJECT No: 96527.00
DATE: 22/1/2019
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 150mm)
35	0.2	TOPSOIL (SM) - light brown, fine to medium grained, silty sand, trace roots, dry.							
		SANDY CLAY (CI) - very stiff, orange-brown, medium plasticity, sandy clay, trace gravel, dry		D	0.4				
	0.6	CLAYEY SAND (SC) - hard, orange brown, fine to medium grained, medium plasticity, clayey sand trace gravel, dry.		D	0.7				
1		- becoming orange-brown mottled green-grey from 0.8 m.							
				D	1.2				
	1.3	Refusal							
34		Pit discontinued at 1.3m *Refusal on hard clay							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20

RIG: 5.5T Yanmar Excavator with backhoe

LOGGED: PJ

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: *Surface levels interpolated from Harley Dykstra survey plan. Drawing No 21645-01A (04/09/18)

☐ 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: I.Q. Project Management Pty Ltd
PROJECT: Proposed Local Structure Plan
LOCATION: Corne rof Briggs & Larsen Roads, Byford

SURFACE LEVEL: 35.5 AHD
EASTING:
NORTHING:

PIT No: 7
PROJECT No: 96527.00
DATE: 22/1/2019
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 150mm)
	0.1	TOPSOIL (SM) - light brown, fine to medium grained, silty sand, trace roots, dry.							
		SANDY CLAY (CI) - stiff, orange-brown, medium plasticity, sandy clay, trace gravel, dry		D	0.4				
35					0.5		pp = 400		
		- becoming very stiff from 0.7 m.							
	0.9	CLAYEY SAND (SC) - very stiff, green-grey mottled red-brown, low plasticity, clayey sand trace gravel, dry.			1.0		pp = 180		1
1		- becoming hard from 1.1 m.		D	1.2				
34				D	1.6				
	1.65	Pit discontinued at 1.65m *Refusal on hard clay							

RIG: 5.5T Yanmar Excavator with backhoe

LOGGED: PJ

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: *Surface levels interpolated from Harley Dykstra survey plan. Drawing No 21645-01A (04/09/18)

☐ 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: I.Q. Project Management Pty Ltd
PROJECT: Proposed Local Structure Plan
LOCATION: Corne rof Briggs & Larsen Roads, Byford

SURFACE LEVEL: 35.8 AHD
EASTING:
NORTHING:

PIT No: 8
PROJECT No: 96527.00
DATE: 22/1/2019
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 150mm)
	0.1	FILL (SILTY SAND, SM) - light brown, fine to medium grained, silty sand, trace roots, dry.							
		FILL (GRAVELLY CLAY, GC) - stiff, light brown, low plasticity, fine to medium sized, gravelly clay, with sand, dry. Gravel is laterite.							
	0.4	SANDY GRAVEL (GP-GC) - medium dense to dense dense, orange-brown and red, fine to coarse sized, sandy gravel with clay, dry. Gravel is laterite. Low plasticity fines.		D	0.5				
35									
1	1.0	CLAYEY SAND (SC) - hard, orange-brown mottled green-grey, low plasticity, clayey sand trace gravel, dry to moist.		D	1.0		pp = 500		1
				D	1.3		pp = 500		
	1.5	Pit discontinued at 1.5m *Refusal on hard clay							

Dynamic Penetrometer Test (blows per 150mm): 5, 10, 15, 20

RIG: 5.5T Yanmar Excavator with backhoe

LOGGED: PJ

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: *Surface levels interpolated from Harley Dykstra survey plan. Drawing No 21645-01A (04/09/18)

☐ 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: I.Q. Project Management Pty Ltd
PROJECT: Proposed Local Structure Plan
LOCATION: Corne rof Briggs & Larsen Roads, Byford

SURFACE LEVEL: 36.9 AHD
EASTING:
NORTHING:

PIT No: 9
PROJECT No: 96527.00
DATE: 22/1/2019
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 150mm)
		TOPSOIL (SM) - light brown, fine to medium grained, silty sand, trace roots, dry.							
	0.2	CLAYEY SAND (SC) - hard, orange-brown and red, low plasticity, clayey sand trace gravel, dry to moist. Gravel is fine to medium sized, laterite.		D	0.5		pp = 500		
36		- becoming orange-brown and grey from 0.8 m.							
	1			D	1.0		pp = 500		1
	1.2	Pit discontinued at 1.2m *Refusal on hard clay							

RIG: 5.5T Yanmar Excavator with backhoe

LOGGED: PJ

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: *Surface levels interpolated from Harley Dykstra survey plan. Drawing No 21645-01A (04/09/18)

☐ 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: I.Q. Project Management Pty Ltd
PROJECT: Proposed Local Structure Plan
LOCATION: Corne rof Briggs & Larsen Roads, Byford

SURFACE LEVEL: 37.8 AHD
EASTING:
NORTHING:

PIT No: 10
PROJECT No: 96527.00
DATE: 22/1/2019
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 150mm) 5 10 15 20
	0.15	TOPSOIL (SM) - light brown, fine to medium grained, silty sand, trace roots, dry.							
		SANDY GRAVEL (GP-GC) - medium dense to dense dense, orange-brown and red, fine to coarse sized, sandy gravel with clay, dry. Gravel is laterite. Low plasticity fines.		D	0.4				
		- becoming orange-brown and grey from 0.4 m.			0.5		pp = 500		
37				D	0.8				
	1 1.0	Pit discontinued at 1.0m *Refusal on hard clay							1

RIG: 5.5T Yanmar Excavator with backhoe

LOGGED: PJ

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: *Surface levels interpolated from Harley Dykstra survey plan. Drawing No 21645-01A (04/09/18)

☐ 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

Appendix C

Laboratory Results

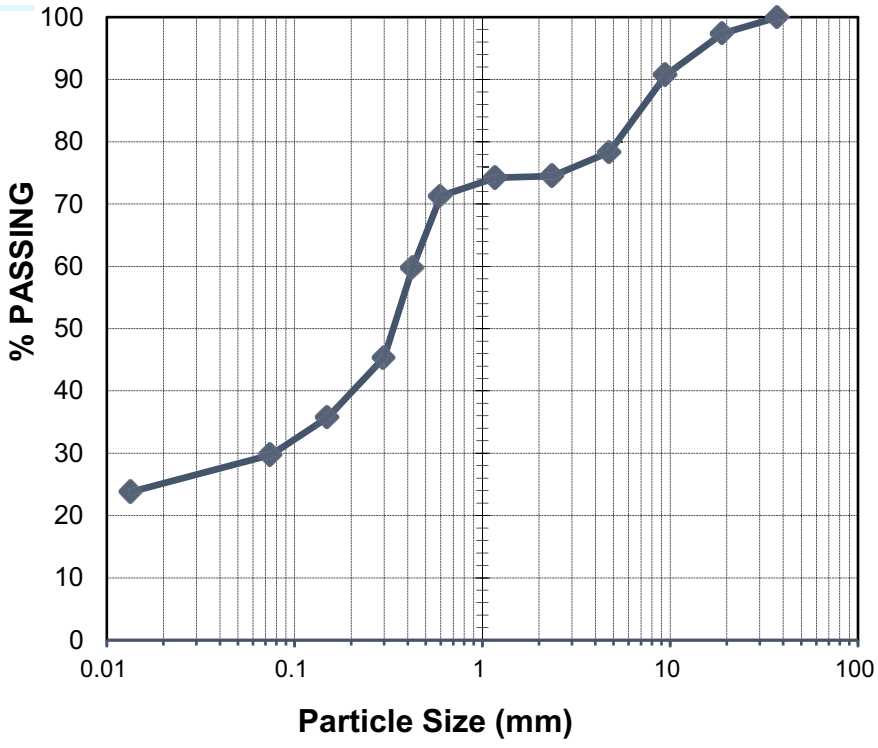
Liquid Labs WA
08 94723349
16B/81 Briggs Street
Carlisle, WA 6101

SOIL CLASSIFICATION - TEST REPORT

WA 110.1, 115.1, 120.2, 121.1, 122.1, 123.1
AS 1289.2.1.1,3.1.1,3.1.2,3.2.1,3.3.1, 3.4.1

Client	**I.Q. Project Management Pty Ltd**	Ticket No.	**S2897**
Client Address	**-**	Report No.	**LLS19/564_1_PSDPI**
Project	**Briggs & Larsen Roads Precinct**	Sample No.	**LLS19/564**
Sampling Location	**Byford**	Sampled By	**Client**
Sample Identification	**Pit 1 - 0.6m - 96527**		
Sampling Method	**Sampled by Client, Tested as Received**	Preparation Method	**WA105.1**
Sample History	**Oven Dried**	Wet or dry sieved	**Dry Sieved**

PARTICLE SIZE DISTRIBUTION - ANALYSIS BY SIEVING



Sieve Size (mm)	Percent Passing Sieve (%)
75.0	
37.5	100
19.0	97
9.50	91
4.75	78
2.36	74
1.18	74
0.600	71
0.425	60
0.300	45
0.150	36
0.075	30
0.0135	24

CONSISTENCY LIMITS

AS 1289.3.1.1	AS 1289.3.2.1	AS 1289.3.3.1	AS 1289.3.4.1		
Liquid Limit (%)	**Plastic Limit (%)**	**Plasticity Index (%)**	**Linear Shrinkage (%)**	**Mould Length (mm)**	**Condition of Dried Specimen**
37	**15**	**22**	**7.6**	**250**	**-**

Comments:

NATA WORLD RECOGNISED ACCREDITATION

Accredited for compliance with ISO/IEC 17025 - Testing

Accreditation No. 19872

Approved Signatory

Name	Matt van Herk
Function	Laboratory Manager
Issue Date	13-February-2019

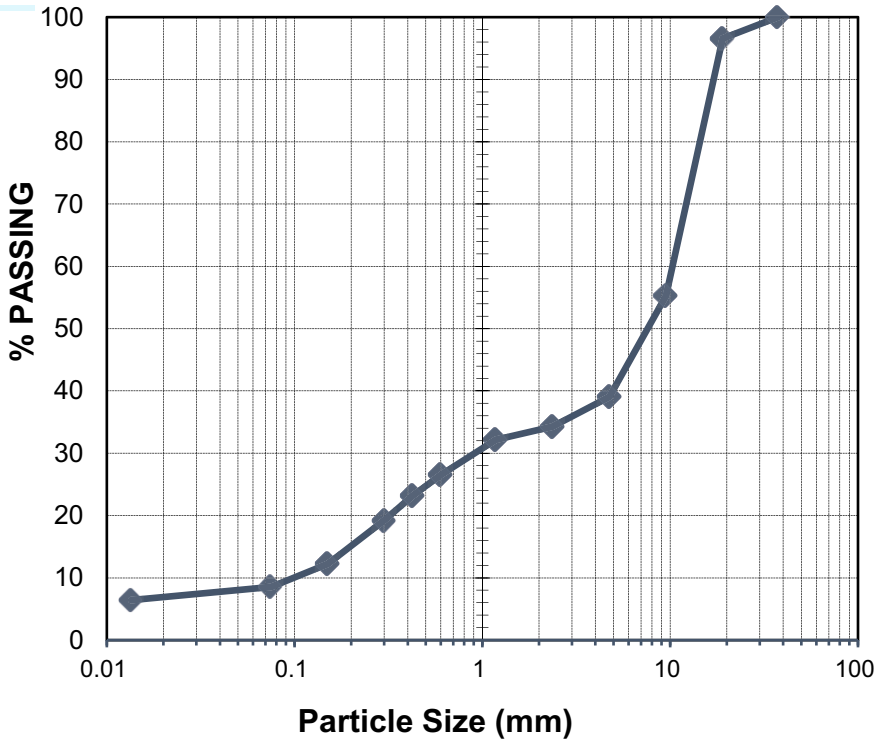
Liquid Labs WA
08 94723349
16B/81 Briggs Street
Carlisle, WA 6101

SOIL CLASSIFICATION - TEST REPORT

WA 110.1, 115.1, 120.2, 121.1, 122.1, 123.1
AS 1289.2.1.1,3.1.1,3.1.2,3.2.1,3.3.1, 3.4.1

Client	**I.Q. Project Management Pty Ltd**	Ticket No.	**S2897**
Client Address	-	Report No.	**LLS19/565_1_PSDPI**
Project	**Briggs & Larsen Roads Precinct**	Sample No.	**LLS19/565**
Sampling Location	**Byford**	Sampled By	**Client**
Sample Identification	**Pit 5 - 0.9m - 96527**		
Sampling Method	**Sampled by Client, Tested as Received**	Preparation Method	**WA105.1**
Sample History	**Oven Dried**	Wet or dry sieved	**Dry Sieved**

PARTICLE SIZE DISTRIBUTION - ANALYSIS BY SIEVING



Sieve Size (mm)	Percent Passing Sieve (%)
75.0	
37.5	100
19.0	97
9.50	55
4.75	39
2.36	34
1.18	32
0.600	27
0.425	23
0.300	19
0.150	12
0.075	9
0.0135	6

CONSISTENCY LIMITS

AS 1289.3.1.1	AS 1289.3.2.1	AS 1289.3.3.1	AS 1289.3.4.1		
Liquid Limit (%)	**Plastic Limit (%)**	**Plasticity Index (%)**	**Linear Shrinkage (%)**	**Mould Length (mm)**	**Condition of Dried Specimen**
29	**12**	**17**	**4.0**	**250**	**-**

Comments:

NATA WORLD RECOGNISED ACCREDITATION

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Accreditation No. 19872

Approved Signatory

Name	Matt van Herk
Function	Laboratory Manager
Issue Date	13-February-2019

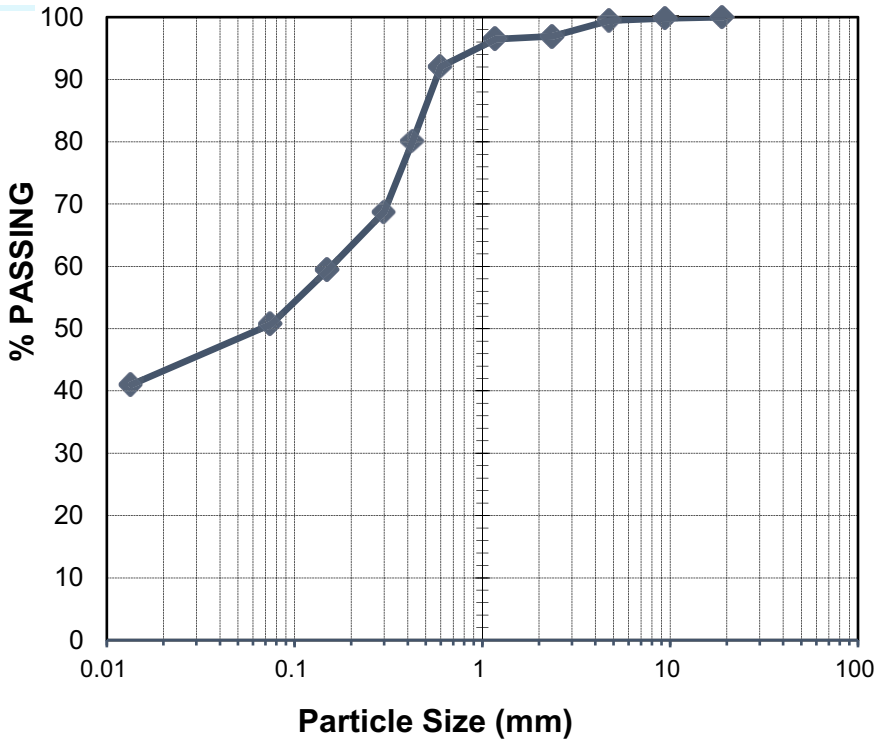
Liquid Labs WA
08 94723349
16B/81 Briggs Street
Carlisle, WA 6101

SOIL CLASSIFICATION - TEST REPORT

WA 110.1, 115.1, 120.2, 121.1, 122.1, 123.1
AS 1289.2.1.1,3.1.1,3.1.2,3.2.1,3.3.1, 3.4.1

Client	**I.Q. Project Management Pty Ltd**	Ticket No.	**S2897**
Client Address	**-**	Report No.	**LLS19/566_1_PSDPI**
Project	**Briggs & Larsen Roads Precinct**	Sample No.	**LLS19/566**
Sampling Location	**Byford**	Sampled By	**Client**
Sample Identification	**Pit 7 0.4m - 96527**		
Sampling Method	**Sampled by Client, Tested as Received**	Preparation Method	**WA105.1**
Sample History	**Oven Dried**	Wet or dry sieved	**Dry Sieved**

PARTICLE SIZE DISTRIBUTION - ANALYSIS BY SIEVING



Sieve Size (mm)	Percent Passing Sieve (%)
75.0	
37.5	
19.0	
9.50	100
4.75	99
2.36	97
1.18	96
0.600	92
0.425	80
0.300	69
0.150	59
0.075	51
0.0135	41

CONSISTENCY LIMITS

AS 1289.3.1.1	AS 1289.3.2.1	AS 1289.3.3.1	AS 1289.3.4.1		
Liquid Limit (%)	**Plastic Limit (%)**	**Plasticity Index (%)**	**Linear Shrinkage (%)**	**Mould Length (mm)**	**Condition of Dried Specimen**
44	**18**	**26**	**8.0**	**250**	**Cracked, Curled,**

Comments:

NATA WORLD RECOGNISED ACCREDITATION

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Accreditation No. 19872

Approved Signatory

Name	Matt van Herk
Function	Laboratory Manager
Issue Date	13-February-2019

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