LOCAL WATER MANAGEMENT STRATEGY

WEST KARNUP - LOT 805 LSP ADDENDUM

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Executive Summary

The West Karnup Local Structure Plan (LSP) area consists of Lots 805, 806 and 3 Mandurah Road, Karnup and is situated 54 km south west of Perth CBD, within the City of Rockingham (CoR). Gold Right Pty Ltd (the 'proponent') landholdings in Karnup include Lot 806 and 805 Mandurah Road. Lot 3 (located between Lot 805 and 806) is owned by the CoR.

Planning was progressed over Lots 806 and 3 whilst planning within Lot 805 was deferred due to some outstanding issues with local road alignments, intersections and implications of the future Transit Oriented Development (TOD) proposed to the north of the West Karnup LSP area. Planning for Lot 805 has now progressed and as such an amendment to the West Karnup LSP has been prepared to support changes within Lot 805.

A Local Water Management Strategy (LWMS) was prepared detailing the proposed water management approach to support the structure planning for Lots 3 and 806 Mandurah Road (Emerge Associates 2012b). This LWMS addendum has been prepared to support the amendment to the West Karnup LSP to reflect the addition of Lot 805. For the purposes of this document 'the site' consists of Lot 805 Mandurah Road only.

The LWMS addendum has been developed in accordance with *Better Urban Water Management* (WAPC 2008a), *State Planning Policy 2.9 Water Resources* (WAPC 2006) and *Planning Bulletin 92 Urban Water Management* (WAPC 2008b). Water will be managed using an integrated water cycle management approach, which has been developed using the philosophies and design approaches described in the *Stormwater Management Manual for Western Australia* (DoW 2007) and the approved *West Karnup LSP Local Water Management Strategy* (Emerge Associates 2012b) developed for Lots 3 and 806.

The first step in applying integrated water cycle management in urban catchments is to establish agreed environmental values for receiving waters and their ecosystems. Characteristics of both the existing and past environment within the site have been investigated. In summary, the environmental investigations conducted to date indicate that:

- The site receives 756 mm of average annual rainfall with the majority of rainfall received between June and August.
- The site ranges from 5 m Australian height datum (AHD) to 28 m AHD in elevation, with the lowest areas in the centre of the site resulting from extensive quarry works.
- The soil types encountered during investigations were generally uniform consisting of limestone and sand.
- Acid sulfate soils (ASS) risk maps classify the entire site as having no known risk of encountering ASS within 3 m of the surface.
- Modelling conducted using XPStorm indicates that surface water is retained within the site except for a small outflow into the railway reserve to the east.
- Surface water quality monitoring has not been possible due to there being no defined surface water bodies within the site.
- Groundwater underlying the site flows towards the Indian Ocean.
- Measured groundwater levels underlying the site range between 4 m below ground level (BGL) and 27 m BGL. Maximum referenced groundwater level is approximately 1.85 m AHD across the site.

- Groundwater quality underlying the majority of the site has low nutrient concentrations with Total Nitrogen (TN) and Total Phosphorous (TP) below *National Water Quality Management Strategy* (NWQMS) default trigger values (ANZECC 2000).
- Vegetation condition across the site varies from 'Very Good' and 'Good' in the southern portion of the site to 'Completely degraded' and 'Degraded' within the quarry extraction zone.
- The *Geomorphic Wetlands of the Swan Coastal Plain* dataset indicates that there are no wetlands within the site.
- The site has historically been used as a limestone quarry.

The site covers an area of 22 ha. Once developed, the Lot 805 LSP will provide a range of housing choices ranging in density from R24 to R40, and allows for 3.5 ha of public open space (POS), achieving balance between useable passive and active open space, as well as recognising vegetation retention where possible and drainage requirements.

The overall objective for integrated water cycle management for the site is to maintain the existing hydrological regime and minimise pollution. The LWMS addendum design objectives seek to deliver best practice outcomes using a Water Sensitive Urban Design (WSUD) approach, including management approaches for:

- Water conservation
- Stormwater quality management
- Flood mitigation
- Groundwater management.

The criteria proposed within this LWMS addendum are based on the characteristics of the existing environment and a contemporary best-practice approach to integrated water cycle management and are consistent with those presented in the overarching *West Karnup LWMS* (Emerge Associates 2012b).

The water conservation approach is to reduce the amount of water required within the development at both a lot and an estate scale. Water conservation measures proposed include fit-for-purpose water sources, including groundwater for POS irrigation, scheme water for potable uses within lots and harvested rainwater to supplement potable water use within dwellings. Scheme water use within lots will be reduced by use of water efficient fixtures. Additional water efficient practices including waterwise gardens, installation of water efficient appliances and rainwater tanks are to be promoted at point of sale to further reduce lot scale scheme water usage. Estate scale irrigation requirements will be met by groundwater, and this will be used efficiently to ensure that the long term use is within licensed allocation limits.

Stormwater management focuses on stormwater runoff quantity and quality. The guiding principle for stormwater quantity is to maintain the existing hydrology by retaining surface flows and to infiltrate the stormwater runoff as close to source as possible. All runoff (up to the 100 year average recurrence interval (ARI) event) will be retained and infiltrated on site.

Surface water quality will be addressed using a treatment train approach, which incorporates lot scale retention (via soak wells), vegetated treatment swales and bio-retention areas (BRAs) within POS (for small events), and flood storage areas (FSA) and verge swales (for major events). Further non-structural measures will also be adopted and will be detailed in the future Urban Water Management Plan (UWMP).

The groundwater management approach is passive and aims to avoid any intersection with groundwater, and therefore any modification or manipulation of existing groundwater levels. Depth to groundwater across the site is significant and no subsoil drains are proposed within the West Karnup LSP.

Groundwater quality will be maintained by managing nutrient inputs within surface runoff and will aim to ensure that the quality of groundwater leaving the site is ideally better than the quality of groundwater entering it. Measures to address groundwater quality are consistent with those proposed for surface water quality.

The proposed criteria and the manner in which they are proposed to be achieved are presented in **Table E 1**. This table provides a readily auditable summary of the required outcomes which can be used in the future detailed design stage to demonstrate that the agreed objectives for water management at the site have actually been achieved.

This LWMS addendum demonstrates that by following the recommendations detailed in the report the site is capable of being developed.

Table E 1 Water Management criteria and compliance summary

Management Aspect	Criteria Number	Criteria Description	Manner in which compliance will be achieved	Responsibility for implementation	When implemented
Water Conservation	WC 1	Consumption target of 100 kL/person/year with no more than 40 – 60 kL/person/year of scheme water.	Promotion of rainwater tanks	Proponent	Point of sale
			Use of rainwater tanks	Lot owner	Ongoing
			Promotion of waterwise gardening practices	Proponent	Point of sale
			Use of waterwise gardening practices	Lot owner	Ongoing
			Promotion of Water efficient appliances	Proponent	Point of sale
			Use of Water efficient appliances	Lot owner	Ongoing
			Water efficient fittings	Lot owner	Building construction
	WC 2	Maintain a maximum irrigation rate of 7,500 kL/ha/yr in POS areas	Use of waterwise plant species in POS	Proponent	Landscape implementation
			Irrigation system to be designed and installed according to best water efficient practices	Proponent	Landscape implementation
			The amount of turfed areas will be minimised	Proponent	Landscape implementation
			Garden beds will utilise mulch where required	Proponent	Landscape implementation
			Use of soil conditioner for turf and garden beds where required	Proponent	Landscape implementation
			Retention and use of native vegetation in landscaped areas	Proponent	Landscape implementation
Stormwater Management	SW1	All runoff up to the 100 year ARI event is to be retained on site	Lots will retain small event runoff (15 mm) within soakwells and garden areas	Lot owner	Building construction
			Road reserve runoff from the small event will be retained in treatment swales and BRAs in POS	Proponent	Detailed drainage design
			All additional runoff (up to the 100 year ARI event) to be retained in FSAs in POS and verge swales in road verge	Proponent	Detailed drainage design

Management Aspect	Criteria Number	Criteria Description	Manner in which compliance will be achieved	Responsibility for implementation	When implemented
	SW2	The finished floor levels must have a minimum of 500 mm clearance above the 100 year ARI event flood levels in drainage basins	Landscape concept plans presented in **Appendix C** confirm that lots adjacent to storage infrastructure will be at least 500 mm above the top water level (TWL) in 100 year ARI events	Proponent	Detailed drainage design
	SW3	Ensure minor roads remain passable in a 5 year ARI event	The pipe network will be sized to convey the 5 year ARI event, thus ensuring minor roads will remain passable in a 5 year ARI event	Proponent	Detailed drainage design
Surface Water Quality	SWQ1	Retain and treat the small rainfall event (first 15 mm) as close as possible	Lots will retain small event runoff within soakwells and garden areas	Proponent	Detailed drainage design
			Road reserve runoff will be retained within treatment swales and BRAs within POS	Proponent	Detailed drainage design
	SWQ2	The surface area of BRAs is to be at least 2% of the connected impervious area.	The minimum treatment area per catchment is 2.2% of the corresponding contributing impervious catchment area	Proponent	Detailed drainage design
	SWQ3	Reduce nutrient loads by applying appropriate structural and non-structural measures	Structural measures include soakwells, verge and treatment swales, BRAs and FSAs	Proponent	Detailed drainage design
			Minimising fertiliser use to establish and maintain vegetation within POS areas and road verges	Landscape contractor	Landscape implementation and maintenance
			Maintenance of POS and drainage areas	Proponent, local government	Ongoing
			Street sweeping	Proponent, local government	Ongoing
			Education of residents regarding WWG, fertiliser use and nutrient absorbing vegetation species within lots	Proponent	Point of sale
Groundwater	GW1	Inverts of stormwater storage areas (including swales, BRAs and FSAs) must have a minimum clearance of 500 mm from the MGL	Indicative landscape sections and the concept earthworks plan presented in **Appendix E** and **Appendix F** respectively confirm that inverts of all retention structures will have a minimum clearance of 8 m from MGL	Proponent	Detailed drainage design
	GW2	Downstream groundwater quality should be	Treatment of surface water runoff through infiltration and	Proponent	

Management Aspect	Criteria Number	Criteria Description	Manner in which compliance will be achieved	Responsibility for implementation	When implemented
		at least the same as or better than upstream groundwater quality	adsorption of nutrients to underlying soils within soakwells , treatment swales and BRAs		
			Treatment of surface water runoff through interaction with nutrient removing vegetation within treatment swales and BRAs	Proponent	Landscape implementation
			Provision of GPTs prior to discharge of runoff to swales and BRAs	Proponent	Detailed drainage design
			Provision of educational material to lot owners in relation to minimising fertiliser use and plant species selection	Proponent	Point of sale

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1 Introduction

1.1 Background

The West Karnup Local Structure Plan (LSP) area is situated 54km south west of Perth CBD and 8 km north of Mandurah, within the City of Rockingham (CoR) and lies between the Perth to Mandurah Railway to the east and the Mandurah Road to the west. Gold Right Pty Ltd landholdings in Karnup include Lots 805 and 806 Mandurah Road, Karnup. Lot 3 (located between Lots 805 and 806) is owned by the CoR.

Planning was previously progressed over Lots 806 and 3. Planning within Lot 805 was deferred due to some outstanding issues with local road alignments, intersections and implications of the future Transit Oriented Development (TOD) proposed to the north of the West Karnup LSP area. Planning for Lot 805 has now progressed and as such an amendment to the West Karnup LSP has been prepared to support changes within Lot 805.

For the purposes of this document 'the site' consists of Lot 805 Mandurah Road. The location of the site is shown in **Figure 1** with an aerial photograph illustrating the cadastral boundaries provided in **Figure 2**.

1.2 Town planning context

The site is currently zoned 'Urban' under the Metropolitan Region Scheme (MRS) (WAPC 2012) and 'Development' under the CoR Town Planning Scheme (TPS) 2 (CoR 2004).

1.3 Purpose of this report

It is important that the manner in which stormwater runoff from urban zoned areas is to be managed to avoid flooding and protect the environment are clearly documented early in the planning process. This approach provides the framework for actions and measures to achieve the desired outcomes at subdivision and development stages.

A Local Water Management Strategy (LWMS) was prepared detailing the proposed water management approach to support the structure planning for Lots 3 and 806 Mandurah Road (Emerge Associates 2012b) (discussed further in **Section 1.5.2**). This LWMS addendum has been prepared to detail the water management approach to be used within Lot 805 of the West Karnup LSP to support the LSP amendment application. The LWMS addendum is consistent with the approved LWMS for Lots 806 and 3 (Emerge Associates 2012b)and with the principles outlined in *Better Urban Water Management* (WAPC 2008a).

1.4 Policy framework

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

- *State Water Strategy* (Government of WA 2003)
- *State Water Plan* (Government of WA 2007)
- *State Planning Policy 2.9 Water Resources* (WAPC 2006)

- *Environmental Protection (Swan Coastal Lakes) Policy* (Government of WA 1992)
- *Guidance Statement No. 33: Environmental Guidance for Planning and Development* (EPA 2008)
- *Liveable Neighbourhoods Edition 4* (WAPC 2007)
- *Planning Bulletin No. 64: Acid Sulfate Soils* (WAPC 2009)
- *Planning Policy Procedure 1.8 Water Sensitive Urban Design* (CoR 2010)
- *Planning Policy 3.4.1 Public Open Space* (CoR 2011).

The site falls outside the physical and administrative boundaries of the Peel-Harvey Estuary surface water catchment and therefore does not sit within the area covered by either *Statement of Planning Policy No. 2.1: The Peel-Harvey Coastal Plain Catchment* (WAPC 2003) or the *Environmental Protection (Peel Inlet-Harvey Estuary) Policy* (EPA 1992).

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

- *Better Urban Water Management* (WAPC 2008a)
- *Decision Process for Stormwater Management in Western Australia* (DoW 2009)
- *Stormwater Management Manual for Western Australia* (DoW 2007)
- *National Water Quality Management Strategy* (ANZECC 2000)
- *Australian Runoff Quality* (Engineers Australia 2006)
- *Australian Rainfall and Runoff* (Engineers Australia 1987).

The guidance documents listed indicate a need for accurate baseline data prior to urban development. This will ensure that any future development is able to fulfil the stormwater management requirements of Department of Water (DoW) and engineering standards specified by the CoR, but will also ensure that realistic water management criteria that are practically achievable are adopted.

1.5 Previous studies

1.5.1 West Karnup LSP District and Local Water Management Strategy

An overarching District and Local Water Management Strategy (D/LWMS) was prepared by Emerge Associates and approved by the CoR and DoW in August 2012 (Emerge Associates 2012a). The D/LWMS included the site and the adjacent Lots 806 and 3 to the south. Objectives for the district (outlined in the State Water Plan (Government of WA 2007)) that were intended to be addressed in the D/LWMS include:

- Water conservation
  - Ensure the efficient use of all water resources in newly developing urban form, ensuring scheme water is used efficiently wherever possible.
  - Consumption target of 7500 kL/ha/year for public open space (POS) areas with no more than 50 ML/year total.
  - Consumption target of 100 kL/person/year for residential areas with no more than 40-60 kL/person/year of scheme water.
- Groundwater management
  - Groundwater quality downstream of the development should be at least the same as or better than upstream groundwater quality.

- Soils underlying bio-retention areas should have a band of material that is a minimum of 150 mm deep with a Phosphorous Retention Index (PRI) of at least 15. It is acceptable for this to be achieved with a thicker layer of lower PRI soils.

- Stormwater management
  - Retain the 1 year 1 hour duration annual recurrence interval (ARI) rainfall event at source, or as close to source as practicable.
  - For those areas of the site that currently discharge from the site, the post-development critical 5 year and 100 year ARI peak flows leaving the development shall not exceed those calculated for the pre-development environment.
  - For those areas of the study area which currently retain all runoff provide adequate land area for the 100 year ARI rainfall event to be retained onsite.
  - Detention/retention areas should have 1:6 side slopes and be a maximum depth of 1.2 m
  - The pipe network will be designed to convey the 5 year ARI rainfall event (and therefore roads will be passable in the 5 year ARI event).
  - Finished floor levels of lots must have a 300 mm clearance from the 100 year ARI event flows being conveyed within road reserves.
  - Finished floor levels must have a minimum of 500 mm clearance above the 100 year ARI flood levels in the onsite detention areas.
  - Retain the 1 year 1 hour duration ARI rainfall event at source or as close as practicable
  - The surface area of bio-retention areas (BRA) is to be at least 2% of the connected impervious areas.
  - BRAs must have maximum 1:3 side slopes and a maximum water depth no greater than 500 mm.
  - Reduce nutrient loads by applying appropriate structural and non-structural measures.

1.5.2 West Karnup LSP Local Water Management Strategy

As discussed in **Section 1.3**, a Local Water Management Strategy (LWMS) was prepared by Emerge Associates to support the structure planning of Lots 806 and 3 Mandurah Road (Emerge Associates 2012b). Lot 805 was not included in the LWMS to allow progression of structure planning for Lots 3 and 806 while outstanding planning issues relating to Lot 805 were resolved. The LWMS was approved by the CoR and DoW in May 2013 (Emerge Associates 2012b). The water management principles outlined in the LWMS are consistent with the D/LWMS and are detailed below.

- Water conservation
  - Ensure the efficient use of all water resources in newly developing urban form, ensuring scheme water is used efficiently wherever possible.
  - Consumption target for POS of no more than 33.8 ML/year total.
  - Consumption target of 100 kL/person/year for residential areas with no more than 40-60 kL/person/year of scheme water.
- Groundwater management
  - Groundwater quality downstream of the development should be at least the same as or better than upstream groundwater quality.
  - Soils underlying bio-retention areas should have a brand of material that is a minimum of 150 mm deep with a Phosphorous Retention Index (PRI) of at least 10.
  - Inverts of stormwater storage areas (including swales, bio-retention areas and Flood Storage Areas (FSAs) must have a minimum clearance of 300 mm from the referenced MGL.

- Stormwater management
  - Retain the 1 year 1 hour duration ARI rainfall event at source, or as close to source as practicable.
  - For those areas of the site which currently retain all runoff provide adequate land area for the 100 year ARI rainfall event to be retained onsite.
  - Detention/retention areas should have 1:6 side slopes and be a maximum depth of 1.2 m
  - The pipe network will be designed to convey the 5 year ARI rainfall event (and therefore roads will be passable in the 5 year ARI event)
  - Finished floor levels of lots must have a 300 mm clearance from the 100 year ARI event flows being conveyed within road reserves
  - Finished floor levels must have a minimum of 500 mm clearance above the 100 year ARI flood levels in the onsite detention areas.
  - Retain the 1 year 1 hour duration ARI rainfall event at source or as close as practicable.
  - The surface area of bio-retention areas is to be at least 2% of the connected impervious area.
  - Bio-retention areas must have maximum 1:3 side slopes and a maximum water depth no greater than 500 mm.
  - Reduce nutrient loads by applying appropriate structural and non-structural measures.

1.6 LWMS addendum objectives

This LWMS addendum has been developed in consideration of the objectives and principles detailed in *Better Urban Water Management* (WAPC 2008a) and the criteria presented in the *West Karnup LSP LWMS* (Emerge Associates 2012b). It is intended to support the West Karnup LSP amendment detailing the changes within Lot 805 and is further based on the following major objectives:

- Provide a broad level stormwater management framework to support future urban development.
- Incorporate appropriate best management practices (BMPs) into the drainage systems that address the environmental and stormwater management issues identified.
- Minimise development construction costs, which will result in reduced land costs for future home owners.
- Minimise ongoing operation and maintenance costs for the land owners and CoR.
- Develop a water conservation strategy for the site that will accommodate existing groundwater allocation constraints for the area.
- Gain support from DoW and CoR for the proposed method to manage stormwater within the site and potential impacts on downstream areas.

Detailed objectives for water management within the site are further discussed in **Section 4**.

2 Proposed Development

The site covers 22 ha and is bordered by Mandurah Road to the west, the Perth-Mandurah Railway to the east, Lot 3 Mandurah Road to the south and a designated road reserve to the north, as shown in **Figure 2**. The LSP over Lot 805 allows for 3.5 ha of POS, achieving balance between useable passive and active open space, as well as recognising vegetation retention (where possible) and drainage requirements. Once developed, the Lot 805 LSP will provide a range of housing choices with lot densities ranging between R25 and R40.

The water management approach described in **Sections 4** through **7** of this LWMS addendum has been designed to recognise the pre-development hydrology of the site and nearby hydrological features.

This LWMS addendum demonstrates and confirms that the Lot 805 LSP area can be readily serviced, with essential infrastructure already available in the area. Further information in this regard is also provided in the West Karnup LSP Servicing Report (JDSi 2015).

The West Karnup LSP is shown in **Appendix A**.

3 Pre-development Environment

3.1 Sources of information

The following sources of information were used to provide a broad regional environmental context to the site:

- *Rockingham-Stakehill Groundwater Management Plan (Draft)* (DoW 2008a)
- *National Water Quality Management Strategy* (ANZECC 2000)
- *Regional 1:50 000 Geology Map Sheet* (Gozzard 1983)
- *WA Atlas* (Landgate 2015)
- *Perth Groundwater Atlas* (DoW 2015)
- *Water Register* (DoW 2015)
- *Weather and Climate Statistics Data* (Bureau of Meteorology 2015).

In addition to the above information, site-specific investigations have been conducted. These have aimed at providing more detail to the existing regional information. These site-specific investigations include:

- *Lots 3, 805 & 806 Mandurah Road, Karnup Servicing Report (JDSi 2015)*
- *Lot 805 & 806 Mandurah Road – Urban Deferment Lifting Report* (DPS 2011)
- *Lots 805 & 806 Mandurah Road – Karnup Geotechnical Karst Risk Assessment* (Coffey Geotechnics 2011)
- *Test Pits and Permeability Testing, Lots 805 and 806 Mandurah Road, Karnup* (Galt Geotechnics 2010)
- *Lots 3, 805, 806 and 807 Mandurah Road, Karnup - Flora and Vegetation Survey* (Emerge Associates 2011)
- *Flora and Vegetation Survey of Singleton Quarry Expansion Area* (Mattiske Consulting 2008)
- *West Karnup Local Structure Plan District and Local Water Management Strategy* (Emerge Associates 2012a)
- *West Karnup Local Structure Plan Local Water Management Strategy* (Emerge Associates 2012b)
- *Lots 3, 805 and 806 Mandurah Road, Karnup Environmental Assessment and Justification Report* (Emerge Associates 2015).

The above studies have been consulted to determine any potential integration requirements with local surface water flow paths (i.e. those within the CoR) and existing groundwater levels. This is important, as both can have implications for the stormwater management measures and the extent of earthworks that may be required to facilitate subdivision.

3.2 Climate

The site experiences a dry Mediterranean climate of hot dry summers and cool wet winters. Long term climatic averages indicate that the site is located in an area of moderate to high rainfall, receiving an average of 756 mm annually (Bureau of Meteorology 2015) with the majority of rainfall received between June and August. The region receives 90 days of rainfall per annum on average.

3.3 Geotechnical conditions

3.3.1 Topography

The natural topography of the site ranges from a maximum height of 28 m Australian height datum (AHD) in the south of the site to a minimum 5 m AHD. The majority of the low lying areas are in the centre of the site where historical limestone quarrying has reduced natural levels. The steepest slopes within the site are also located within this quarried area.

The remaining natural levels of the site grade from Mandurah Road in the west to the Perth-Mandurah Railway line rail reserve in the east.

Topographic contours of the site are shown in **Figure 3**.

3.3.2 Soils and geology

The Rockingham sheet of the 1:50,000 scale Environmental Geology series map (Gozzard 1983) indicates that the area is largely underlain with Tamala Limestone and Safety Bay Sand. This is in accordance with the findings of investigations by Galt Geotechnical (Galt Geotechnics 2010, 2011).

Subsurface conditions across the site were generally uniform and comprised:

- SAND (SP): grey and brown, fine to coarse grained, sub-rounded, dry to moist, loose, with trace organics (roots) generally present from the surface to depth varying from 0.1 m to greater than 3 m (maximum depth excavated at TP09).
- LIMESTONE: excavated as sandy gravel, grey, with weakly to well cemented cobbles and boulders, fine to coarse sand and shell fragments, present from depths between 0.1 m and 1.0 m.

The limestone material was generally found at shallow depth across the southern half of the site beneath the sand material. The northern portion of the site has sand to depth, as shown in **Figure 4**.

The site has generally good permeability with an average infiltration rate of 8.4 m/day (Galt Geotechnics 2010, 2011). Permeability testing results varied between the two site investigations carried out which is considered to be due to the higher moisture content of soils at the time of testing during the second investigation (Galt Geotechnics 2011).

A shallow geophysical investigation to locate limestone bedrock and possible karstic formations was undertaken by GBG Maps and analysed by Coffey Geotechnical (Coffey Geotechnics 2011). The investigation concluded that there is little to no risk of areas being of karstic nature.

The distribution of these soil types throughout the site and test pit locations are shown in **Figure 4**. The test pit bore logs are provided in **Appendix B**.

3.3.3 Acid sulphate soils

The *WA Atlas* (Landgate 2015) acid sulfate soil (ASS) risk mapping classifies the entire site as a having ‘no known risk’ of ASS occurring within 3 m of natural soil surface or deeper.

3.4 Flora and vegetation

A number of flora and vegetation surveys have been carried out over Lot 805, the most recent of which was undertaken by Emerge Associates in 2010.

Vegetation within Lot 805 was found to have been heavily impacted by historical land uses and associated clearing, and subsequently the extent of remnant vegetation is limited to areas surrounding the historical quarrying footprint (discussed in **Section 3.3.1**).

Vegetation condition in the southern portion of the site ranges from “Good” to “Very Good” and is primarily comprised of native shrubland. The remaining area of the site is characterised by remnant vegetation in “Completely Degraded” to “Degraded” condition, incorporating the cleared historical quarry extraction zone and an area of *Eucalyptus* woodland across the north-eastern extent of the site.

The flora and vegetation survey did not record any Threatened Flora species or Threatened Ecological Communities within the site. Overall, the flora and vegetation values of the site are not considered to be regionally or locally significant.

3.5 Wetlands

The *Geomorphic Wetlands of the Swan Coastal Plain* (Landgate 2015) dataset indicates that there are no wetlands within the site.

3.6 Hydrology

Surface water infiltrates freely across the site due to the underlying, highly permeable sands and limestone. Surface runoff from the area would occur infrequently and only in response to intense events. With infiltration occurring locally, almost all surface runoff remains within the site.

There are no flood corridors within the site, no nearby water courses and depth to groundwater is significant. The 100 year ARI flood levels are therefore only relevant to the post-development scenario.

3.6.1 Surface water quantity

Surface runoff flow rates and volumes are estimated using accurate data on topography, infiltration rates, vegetation and existing surface channels. This information is used in a hydraulic and hydrologic model to calculate discharges, volume of runoff and flow paths. A site specific pre-development model (XPStorm) was created for the West Karnup DWMS/LWMS (Emerge Associates 2012a) to provide a basis from which a comparison with the post-development peak discharges and volumes can be made.

3.6.1.1 Pre-development sub-catchments

The pre-development model is based on assumptions informed by the existing environment investigations. Sub-catchments and related slopes were developed according to the topography of the site and analysis of aerial photography. The site contains 4 of the 8 sub-catchments identified in the pre-development modelling (Emerge Associates 2012a) with 2 extending south into Lot 3 and Lot 806, as shown in **Figure 5**. For the purposes of modeling all catchments are assumed to consist of the same sandy soils, derived from limestone with constant infiltration and roughness characteristics.

The sub-catchment attributes are summarised in the hydrological modeling assumptions report provided in **Appendix C**.

3.6.1.2 Pre-development modelling parameters

An 'initial loss - continual loss' infiltration model was adopted to generate stormwater runoff hydrographs in XPStorm. The infiltration rates for the different soil and land types are presented in **Appendix C**.

3.6.1.3 Pre-development modelling results

A multi-storm analysis was conducted to determine the critical duration storm event. This analysis indicated that the critical duration storm event was 6 hours for the 100 year ARI event. The pre-development peak catchment volumes are indicated in **Table 1** with the pre-development catchments illustrated in **Figure 5**.

Table 1 Pre-development catchment peak volumes

Catchment	5yr 6hr (m^3)	10 yr 6hr (m^3)	100yr 6hr (m^3)	Discharge Location
7	675	1105	5830	Retained onsite
8	365	605	2295	Retained onsite
9	480	805	4185	Railway Reserve
10	205	340	1280	Retained onsite
Total	**4945**	**8135**	**33530**	

The modelling indicates that the only catchment with a potential outflow is Catchment 9, as shown in **Figure 5**. This outflow occurs during major storm events as sheet flow being conveyed to the localised low point in the adjacent railway reserve where it accumulates and infiltrates.

3.6.2 Surface water quality

Given that there are no defined surface water bodies or channels, there is no surface water quality data available for the site.

3.6.3 Groundwater levels

Information on the regional groundwater obtained from the *Rockingham-Stakehill Groundwater Area Management Plan – Draft* (DoW 2008a) indicates the groundwater beneath the site is a multi-layered system comprised of the following:

- Perth - Superficial (unconfined) aquifer
- Rockingham Sand (unconfined) aquifer
- Leederville (confined) aquifer
- Yarragadee (confined) aquifer.

The Superficial aquifer is considered to be the primary aquifer of interest in relation to this LWMS addendum as this is the aquifer most likely impacted by water management practices within the site, and also most likely accessed for local use.

Groundwater monitoring was carried out by Emerge Associates to confirm the depth to groundwater and groundwater flow direction. Six monitoring bores were installed across the greater West Karnup LSP area to identify levels with one bore located within the site (shown in **Figure 3**).

Monitoring was carried out over an 18 month period from July 2011 to January 2013 with ground water levels being measured monthly and water quality samples taken every three months.

Characteristics of the superficial aquifer in the vicinity of the site, as indicated by the *Perth Groundwater Atlas* (DoW 2015) include:

- The elevation of the aquifer is approximately 1.0 m AHD across the site. Groundwater levels have been measured between 5 m Below Ground Level (BGL) to the north of the site and 27 m BGL in the south.
- Depth of the aquifer is approximately -15.00 m AHD (between 20 m BGL and 43m BGL).
- Regional groundwater flow direction is east to west.

There is no surface water expression of the groundwater within the site. The nearest groundwater discharge location based upon the inferred regional groundwater flow direction referred to above is the Indian Ocean.

The recorded groundwater levels for the site have been referenced to historical groundwater data for the local area by calibration to DoW bore 61410027 (shown in **Figure 3**). The DoW bore record shows a marked decrease in groundwater levels from 1994 onwards, therefore the referenced MGL has been calibrated to the record from 1994 to 2013.

The Maximum Groundwater Level (MGL) recorded for the site was identified from groundwater monitoring in September 2012, as illustrated in the groundwater hydrograph provided in **Appendix D**. The MGL recorded at the DoW bore since 1994 is 1.86 m AHD in September 1999. The groundwater level recorded in September 2012 at the DoW bore is 1.34 m AHD, giving a difference to the MGL of 0.52 m. The referenced MGL for the site has been calculated by assuming the MGL is 0.52 m higher than the September 2012 readings onsite.

The MGL across Lot 805 and the immediately adjacent area varies between 1.82 m AHD (at MW1 at the north of Lot 806) and 1.93 m AHD (at MW6 at the north of Lot 805) with levels in the DoW monitoring bore adjacent to the north of Lot 805 at 1.86 m AHD as shown in **Figure 3**. Groundwater contours have not been shown due to groundwater levels being generally flat across the site and surrounding area i.e. there would be only one contour to the east of the site.

3.6.4 Groundwater quality

As discussed in **Section 3.6.3**, groundwater quality monitoring was carried out on a quarterly basis between July 2011 and January 2013 within six bores across the greater West Karnup LSP area. Bore MW6 is located within the site with MW6 located to the south. The full groundwater monitoring water quality dataset is provided in **Appendix D**.

Groundwater quality analyses indicates that the local groundwater pH is 'neutral' across the site (pH 7.3). The recorded values for pH and Electrical conductivity (EC) are within the *National Water Quality Management Strategy* (NWQMS) default trigger values (for lowland rivers in south west Australia) (ANZECC 2000).

Laboratory analysis data from initial groundwater samples indicates that Total Nitrogen (TN) concentrations and Total Phosphorous (TP) concentrations beneath the site are also within the NWQMS default trigger valies. The groundwater quality monitoring results are summarised in **Table 2**.

Table 2 Groundwater quality monitoring results

Bore ID	pH	EC mS/cm	TP (mg/L)	TN (mg/L)	NO_x (mg/L)	NH_4 (mg/L)	TKN (mg/L)
MW1	7.88 (0.19)	0.34 (0.09)	0.020 (0.01)	0.95 (0.37)	0.82 (0.37)	0.02 (0.008)	0.20 (0.10)
MW6	7.25 (0.27)	1.28 (0.09)	0.02 (0.014)	0.35 (0.07)	0.15 (0.13)	0.08 (0.01)	0.2 (0.00)
NWQMS	*6.5-8.0*	-	*0.065*	*1.2*	*0.15*	*0.08*	-

[Average and (Standard Deviation)]

3.7 Current and historical land use

The West Karnup LSP area was, until recently, a working sand and limestone quarry managed by Cemex.

3.8 Summary of existing environment

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

- The site receives 756 mm of average annual rainfall with the majority of rainfall received between June and August.
- The site ranges from 5 m AHD to 28 m AHD in elevation.
- The soil types encountered during investigations were generally uniform consisting of limestone and sand.
- ASS risk maps classify the entire site as having no known risk of encountering ASS within 3 m of the surface.
- Modelling conducted using XPStorm indicates that surface water is retained within the site except for a small outflow into the railway reserve to the east.
- Surface water quality monitoring has not been possible due to there being no defined surface water bodies within the site.
- Groundwater underlying the site flows towards the Indian Ocean.
- Measured groundwater levels underlying the site range between 4 m BGL and 27 m BGL. Maximum referenced groundwater level is approximately 1.85 m AHD across the site.
- Groundwater quality underlying the majority of the site has low nutrient concentrations with TN and TP below NWQMS default trigger values.
- Vegetation condition across the site varies from ‘Very Good’ and ‘Good’ in the southern portion of the site to ‘Completely degraded’ and ‘Degraded’ within the quarry extraction zone.
- The *Geomorphic Wetlands of the Swan Coastal Plain* dataset indicates that there are no wetlands within the site.
- The site has historically been used as a limestone quarry.

4 Design Criteria and Objectives

This section outlines the objectives and design criteria that this LWMS addendum and the future UWMPs must achieve. This water management strategy addresses stormwater management, groundwater management and water consumption.

4.1 Integrated water cycle management

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

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

- Water conservation
- Groundwater management
- Flood mitigation
- Stormwater quality management.

The first step in applying integrated water cycle management in urban catchments is to establish agreed environmental values for receiving waters and their ecosystems. The existing environmental context of the site has been discussed in **Section 3** of this document. Guidance regarding environmental values and criteria is provided by a number of National and State policies and guidelines and site specific studies undertaken in and around the site development. These were detailed in **Sections 1.4** and **3.1**.

The overall objective for preparing integrated water cycle management plans for proposed residential developments is to minimise pollution and maintain an appropriate water balance. This objective is central to the water management approach for the site.

4.2 Water conservation

Water conservation design criteria have been determined in line with the guidelines presented in *Better Urban Water Management* (WAPC 2008a) and the LWMS (Emerge Associates 2012b). The following water conservation criteria are proposed:

Criteria WC 1 Consumption target of 100 kL/person/year with no more than 40 – 60 kL/person/year of scheme water.

Criteria WC 2 Maintain a maximum irrigation rate of 7,500 kL/ha/yr in POS areas.

The manner in which the above objectives will be achieved is further detailed in **Section 5**.

4.3 Stormwater management

The stormwater management principles and the guidance documents discussed in **Section 1.4** have guided the stormwater management criteria. Stormwater management design criteria include:

Criteria SW1 All runoff up to the 100 year ARI event is to be retained on site.

Criteria SW2 Finished floor levels must have a minimum of 500 mm clearance above the 100 year ARI flood levels in drainage basins.

Criteria SW3 Minor roads will remain passable in a 5 year ARI event.

Criteria SWQ1 Retain and treat runoff from the small rainfall event (first 15 mm) as close to source as possible.

Criteria SWQ2 Size treatment areas to at least 2% of the connected impervious area.

Criteria SWQ3 Reduce nutrient loads by applying appropriate non-structural measures.

The manner in which these objectives will be achieved is further detailed in **Section 6**.

4.4 Groundwater management

The principle behind the groundwater management strategy is to maintain the existing groundwater hydrology. The groundwater management criteria include:

Criteria GW1 Inverts of stormwater storage areas (including swales, BRAs and FSAs) to maintain a minimum clearance of 500 mm from MGL.

Criteria GW2 Groundwater quality leaving the site will be maintained or, where possible, improved.

The manner in which these objectives will be achieved is further detailed in **Section 7**.

5 Water Source Allocation, Infrastructure, Fit-for-Purpose and Water Use

5.1 Fit-for-purpose water use

Conservation of water through fit-for-purpose use and best management practices is encouraged so that scheme water is not wasted. Fit-for-purpose describes the use of water that is of a quality suitable for the required use of the water. Fit-for-purpose principles have been utilised in the water conservation strategy for the West Karnup LSP and will achieve **Criteria WC1**.

5.1.1 Scheme water

The site is located within the Water Corporation (WC) Tamworth-Karnup Reservoir Scheme. There is an existing 600 mm diameter distribution main feeding the area which extends from Warnbo, north of the site, for 16 km south to Singleton where it terminates. There are water pressure limitations on this main that increase as it runs south and the system can only serve up to approximately 20 m AHD in the Singleton area (JDSi 2015).

A recent 250 mm diameter extension has been installed along Singleton Beach Rd into Lot 806. Ultimately this 250 mm main would be extended through Lot 3 to provide supply for development on Lot 805. WC have also indicated that they will be installing a 300 mm water main within Mandurah Road adjacent to the site, north of Singleton Beach Road. This will improve supply pressures and provide security of supply to the site (JDSi 2015).

Scheme water is proposed to be used for all in-house potable uses, and where ex-house uses cannot be serviced by other supplies or approaches, it would also satisfy ex-house requirements.

5.1.2 Groundwater

The DoW 'Water Register' indicates that the site is located in the Stakehill groundwater area, within the Karnup East sub-area. There is an existing groundwater abstraction licence in place for the Gold Right Pty Ltd landholdings for the purposes of dust suppression for 97,500 kL/year from the Perth-Superficial and Rockingham Sands (licence #GWL164062(7)). This licence will be part-transferred for use in ongoing irrigation of POS (39,525 kL/year). An additional allocation of 20,550 kL/year (licence #GWL175845(3)) has been provided under 'exceptional circumstances' for the purpose of irrigating the school oval in Lot 806.

Emerge Associates has prepared a project irrigation schedule (provided in **Appendix E**) which details the permanent ongoing irrigation requirement for each POS across Lot 805 and Lot 806 (discussed further in **Section 5.4**). The schedule assumes an average rate for irrigated areas of 7,500 kL/ha/year as required by CoR with a total use for irrigation of 60,050 kL/year across the wider Vista Estate (Lot 805 and 806), with 16,685 kL/year required within Lot 805. This estimate will be reviewed at UWMP stage once the POS landscape design is complete and the proportion of POS proposed to be turfed and native vegetation retention/conservation areas have been finalised. Groundwater use for POS irrigation is further discussed in **Section 5.4**.

5.1.3 Rainwater tanks

Collection of stormwater runoff from roof surfaces in lot can potentially be undertaken, with this water stored within rainwater tanks for later use.

Stored rainwater may be used for some irrigation requirements however this will need to be supplemented with scheme water during the lower rainfall months. During the higher rainfall months, the majority of the stored rainwater can be used to supplement internal building non-potable uses. This water efficiency strategy recommends that the rainwater is used in washing machines, toilets and hot water systems.

The above measures will assist in achieving **Criteria WC1** and **WC2**.

5.2 Water conservation measures

The development will utilise water wise garden (WC 2003) principles for lot gardens and within estate landscaping and water efficient fixtures and appliances (WEFA) to ensure that the development minimises the use of water. These measures are further discussed in the following Sections.

5.2.1 Water efficient fixtures and appliances

Significant reductions in in-house water uses can be achieved with the use of WEFA. Water efficient devices can provide between 30% and 50% reduction in water use within houses (Melbourne Water 2003). Reduced water use rates have been used in the water balance analysis discussed in **Section 5.3**.

The water conservation strategy proposes that all dwellings use WEFA. Water efficient fittings will be implemented by the lot owner during building construction, while uptake of water efficient appliances can be encouraged by state and local government rebates, as well as education from the proponent at point of sale.

The above measures will assist in achieving **Criteria WC1**.

5.2.2 Water wise gardens

Reductions in water use for irrigation by employing water efficiency measures can significantly reduce the total water usage (WC 2003). The development will undertake a variety of measures to limit water use into the future within POS and the private residential landscape works under the control of the developer. A variety of methods and approaches will be considered including any or all of the following:

- The adoption of water wise species, with a focus on using local native water wise species or if necessary species from regions with similar climates.
- Where required, existing site soil may be improved with soil conditioner certified to Australian Standard AS 4454 to a minimum depth of 150 mm where turf is to be planted and a minimum depth of 300 mm for garden beds.
- The irrigation system is proposed to be designed and installed according to best water efficient practices including consideration of hydro zone design solutions.
- The amount of turfed areas will be controlled while also being designed to meet community needs.
- Garden beds will be mulched to 75 mm with a product certified to Australian Standard AS 4454.
- The landscape design will cater for efficient water requirements during POS maintenance. Implementation of an appropriate management and maintenance program for POS areas will be further detailed at the UWMP stage.

- Community awareness of water conservation will be promoted at the point of sale and during the projects sales lifespan. This will reference the project as a whole and focus on private gardens by providing educational literature to lot owners.

Waterwise gardens will not be mandated for the West Karnup LSP, however they will be promoted by the proponent at point of sale by providing educational literature regarding the benefits of waterwise gardening practices. It is assumed that 50% of future residents will utilise WWG, based on typical uptake rates provided by Australian Bureau of Statistics (ABS) (ABS 2013a, b)

The above measures will assist in achieving **Criteria WC1** and **WC2**.

5.3 Lot water balance

A water balance analysis has been undertaken to demonstrate the effectiveness of the water conservation strategy proposed for the development.

The water balance analysis has been based on the rates and calculation methodology presented in the Water Corporation Spreadsheet *AltWaterSupply_Water_Use_Model.xls* (WC 2011). The water balance analysis assumes an average of 2.6 people per lot for single dwellings, a value calculated from data provided by the ABS for new housing developments in Perth (ABS 2013a). The spreadsheet has been adapted to model the effects of using RWT, WWG and WEFA, with approximate update rates of each (detailed in **Sections 5.1.3, 5.2.1 and 5.2.2**) informed by ABS data (ABS 2013b, 2014).

The results of the water balance indicate that on average if households in the development adopt the proposed water conservation measures at typical uptake rates they will use on average 34.1 kL/year/person. This achieves the state water consumption target of no more than 100 kL/year/person and the *Better Urban Water Management* aspirational goal of 40-60 kL/year/person, and satisfies **Criteria WC1**.

5.4 Estate scale water usage

Water use at an estate scale is determined by the amount of POS provided that requires irrigation, the amount of road verge that will require irrigation and the rates at which these are irrigated. Not all of the POS areas will be irrigated at the same rates as some areas consist of native vegetation (new and retained), while others will utilise turf or hard surfaces to provide active recreation areas. Once established, irrigation provided to POS areas will be reduced in order to minimise the long-term irrigation demand. This results in a temporary peak water use that is higher than the long-term requirement.

The detailed irrigation schedule provided in **Appendix E** indicates a long-term irrigation requirement for Lot 805 of 16,685 kL/year, with a total development irrigation requirement of 39,232 kL/year (excluding the school oval which is provided for under its own groundwater allocation (GWL GWL175845(3)). The permanent ongoing irrigation requirement is based on an average irrigation rate of 7,500 kL/ha/year as required by CoR. As discussed in **Section 5.1.2**, the proponent has secured a permanent groundwater allocation for Lots 805 and 806 of 39,525 kL/year (GWL164062(7)).

The above measures will assist in achieving **Criteria WC2**.

5.5 Wastewater management

The site is situated within the catchment of the East Rockingham Waste Water Treatment Plant (ERWWTP).

JDSi has recently completed an Engineering Summary Report which details the preliminary solution to service the site. This involves construction of a Type 40 Pump Station (PS) within Lot 806, installation of 3,435 m of DN200 PN16 PVC-O pressure main running through Lot 806, Lot 3 and Lot 805 then north along Mandurah Road and west along Dampier Drive/Warnbro Sound Avenue to a proposed DN600 GRP gravity main on Warnbro Sound Avenue. The Engineering Summary Report has been formally endorsed by the Water Corporation on 24th February 2015 and it is anticipated that construction of the above infrastructure will be completed in March 2016 (JDSi 2015).

Wastewater from the site will therefore discharge to the ERWWTP.

5.6 Water conservation criteria compliance summary

A summary of the proposed water conservation design criteria and how these are addressed within the Lot 805 LSP is provided in **Table 3**.

Table 3 Water conservation criteria compliance

Criteria Number	Criteria Description	Manner in which compliance will be achieved
WC1	Consumption target of 100 kL/person/year with no more than 40-60 kL/person/year of scheme water	Mandated use of water efficient fittings
		Promotion/use of water efficient appliances
		Promotion/use of WWG principles
		Promotion/use of rain water tanks
WC2	Maintain a maximum irrigation rate of 7,500 kL/ha/yr in POS areas	Use of waterwise plant species in POS
		Irrigation system to be designed and installed according to best water efficient practices
		The amount of turfed areas will be minimised while also being designed to meet community needs
		Garden beds will utilise mulch where required
		Use of soil conditioner for turf and garden beds where required

6 Stormwater Management Strategy

The principle behind the stormwater management strategy for the West Karnup LSP is to maintain the existing hydrology by retaining surface flows and to infiltrate the stormwater runoff as close to source as possible. The development drainage system has been designed to achieve the objectives and criteria stated in **Section 4.3**. The stormwater management measures, discussed below and shown in **Figure 6**, are proposed considering the stormwater management requirements of the entire West Karnup LSP area including Lot 805.

6.1 Stormwater management approach

Surface runoff modelling undertaken using XPStorm has been used to inform the design of stormwater infrastructure as detailed below. A summary of the modelling assumptions is provided in **Appendix C**.

6.1.1 Lot storage

All lots will retain runoff from the small event (i.e. the first 15 mm) from roof and rear areas in soakwells, RWTs (where implemented) and through infiltration in pervious areas.Front of lot areas only will discharge to the road network and downstream POS in small events.

Minor and major event runoff (up to the 100 year ARI event) will be retained on lot or directed downstream via the road network, depending on the proposed lot size. Specific retention requirements for each lot size include:

- Lots < 350 m^2 will convey all runoff from roof and rear (above the first 15 mm) downstream via overland flow.
- Lots ≥ 350 m^2 will retain up to the 100 year ARI event runoff from roof and rear areas within soakwells and permeable garden areas.

This approach responds to the good permeability of underlying soils across the site, use of fill in previously quarried areas, significant clearance to groundwater (>5 m) and proposed lot sizes.

The lot retention approach proposed will assist in achieving **Criteria SW1**, **SWQ1** and **SWQ4**.

6.1.2 Verge swales

Runoff from catchment CtI-1 will be retained in a verge swale located in the widened road verge along the eastern boundary of the site (as shown in **Figure 6**). The verge swale will be designed with 1:6 side slopes and a maximum inundation depth of 500 mm. The base of the swale will be vegetated with plant species with nutrient removal capabilities in order to provide treatment to the small rainfall event (first 15 mm) prior to infiltration to groundwater, as illustrated in the landscape plans provided in **Appendix E**. Storage requirements within the verge swale for all rainfall events are provided in **Table 4** and **Table 5**, with associated inundations areas shown in **Figure 7** through **Figure 10**.

6.1.3 Bio-retention areas

The small rainfall event (first 15 mm) runoff from road reserves and that not retained on lot will be retained in treatment swales and BRAs located in POS, as shown in **Figure 6**. Storage requirements for the small rainfall event are provided in **Table 4** with associated inundation areas shown in **Figure 7**.

Table 4 Small rainfall event storage requirements

Catchment	Sub-catchment	Retention area	Depth (m)	Length (m)	Surface Area (m^2)	Volume (m^3)	Connected impervious catchment area (ha)	% treatment area
H	H1	Swale	0.3	65	234	35	0.80	2.6
	H2	BRA	0.5	-	139	40	0.61	
I	I1	Swale	0.3	145	562	13	0.70	3.6
	I2	BRA	0.5		106	28	0.57	
	I3	BRA	0.5		241	80	1.29	
J	J	BRA	0.5		97	25	0.44	2.2
K	K1	Swale	0.3	235	846	127	2.33	3.7
	K2	BRA	0.5		40	7	0.14	
	K3	Swale	0.3	60	216	32	0.52	
	K4	Swale	0.3	20	72	11	0.21	

BRAs and treatment swales will be designed with side slopes no greater than 1 in 6 and a maximum depth of 500 mm. BRAs and treatment swales will be densely vegetated with species known for their nutrient uptake capacity.

Gross pollutant traps (GPT) will be installed in the pipe network prior to discharge to verge swales, treatment swales and BRAs to provide removal of gross pollutants and reduce the ongoing maintenance requirements.

The total treatment area provided (including verge swales, treatment swales and BRAs) equates to a minimum of 2.2 % of the total connected impervious area per catchment as detailed in **Table 4**, thus exceeding the 2% requirement.

6.1.4 Flood storage areas

All surface runoff above the small event (up to and including the 100 year ARI event) will be retained within FSAs (located in POS) and verge swales (located in road verge, detailed in **Section 6.1.2**) resulting in no off-site discharge. FSAs will be designed with side slopes no greater than 1 in 6 and an overall maximum depth of 1.2 m. **Figure 5** shows the indicative locations of FSAs and verge swales.

The pre-development modelling detailed in **Section 3.6.1** indicated a discharge of 0.42 m^3/s from the site, along the eastern boundary (shown in **Figure 5**). Flows currently discharge via sheetflow into the railway reserve where it accumulates and infiltrates to groundwater. The proposed development removes the discharge with flows retained and infiltrated in FSA I (shown in **Figure 6**).

Retaining the surface runoff within the site adjacent to the existing low does not significantly change the surface water hydrology of the site or impact on any water dependent ecosystems and therefore this approach is considered to be appropriate.

Storage details of the FSAs and verge swales for the 5, 10 and 100 year ARI events are provided in **Table 5** with associated inundation areas shown in **Figure 8**, **Figure 9** and **Figure 10** respectively. The critical duration for all rainfall events is 6 hours, as detailed in the modelling summary report provided in **Appendix C**.

Where BRAs and treatment swales are not located directly adjacent to the associated FSA (detailed in **Section 6.1.4**) flows above the first 15 mm will be conveyed via pipe or overland flow to the FSA. Specific design details will be provided within the future UWMP in which the POS is located following detailed design.

The CoR require drainage up to the 10 year ARI event to be within 25% of the POS area. As shown in **Table 5**, the maximum 10 year ARI event in any POS is 20%, thus meeting this requirement.

6.1.5 Drainage design parameters

Inverts of all drainage structures (including verge and treatment swales, BRAs and FSAs) will maintain a minimum 500 mm clearance from MGL to ensure they drain following a rainfall event (as shown in the landscape sections provided in **Appendix E**).

Final lot levels will be designed to maintain a 500 mm clearance from the 100 year ARI event top water levels (TWL) in all retention structures. Specific design details of each structure will be provided in future UWMPs in compliance with CoR guidelines and expectations.

The maximum inundation time for all storage areas is approximately 5.16 hours, assuming an average infiltration rate of 4 m/day.

The use and design of verge swales, treatment swales, BRAs and FSAs will assist in achieving **Criteria SW1**, **SW2**, **SW4**, **SWQ1** and **SWQ3**.

Table 5 Minor and major event retention storage

Catchment	Retention area	5 year ARI			10 year ARI			100 year ARI				Infiltration time (hours)	Total 100 year ARI event drainage in POS (m^2)	10 year ARI event drainage (% in POS)
		Depth (m)	Surface Area (m^2)	Volume (m^3)	Depth (m)	Surface Area (m^2)	Volume (m^3)	Depth (m)	Length (m)	Surface Area (m^2)	Volume (m^3)			
H	FSA H	0.6	479	206	0.7	555	277	1.2	-	840	590		979	13
I	Swale I1	0.3	1,027	227	0.3	1,098	270	0.5	145	1,392	479		1,392	-
	FSA I	0.6	868	390	0.7	967	516	1.2	-	1,368	1,085		1,715	14
J	FSA J	0.7	320	133	0.8	375	176	1.2	-	583	365		680	7
K	FSA K	0.4	1,156	441	0.6	1,292	639	1.2	-	1,850	1,560		3,024	20

6.2 Non-structural stormwater management measures

The structural measures proposed within the site provide both a storage and treatment function to stormwater runoff, as detailed in **Sections 6.1**. A number of non-structural measures will also be implemented across the site to help reduce nutrient loads within stormwater runoff. These measures include:

- Street sweeping.
- Minimising fertiliser use to establish and maintain vegetation within POS areas and road verges.
- Use of drought tolerant turf species that require minimal water and nutrients.
- Education of residents regarding fertiliser use and nutrient absorbing vegetation species within lots through provision of educational material at point of sale.

These measures will assist in achieving **Criteria SWQ2** and **GW3**.

6.3 Stormwater criteria compliance summary

A summary of the proposed stormwater design criteria and how these are addressed for the site are shown in **Table 6**.

Table 6 Stormwater criteria compliance summary

Criteria Number	Description	Manner in which compliance is achieved
SW1	All runoff up to the 100 year ARI event is to be retained on site	Lots will retain small event runoff (first 15 mm) within soakwells and garden areas
		Small event runoff from road reserves will be retained within treatment swales and BRAs in POS
		All additional flows, up to the 100 year ARI event, will be retained within verge swales and FSAs in POS
SW2	Finished floor levels must have a minimum of 500 mm clearance above the 100 year ARI flood levels in drainage basins.	Drainage areas will be designed to ensure adjacent finished floor levels will have a minimum clearance of 500 mm above the 100 year ARI TWL
SW3	Ensure minor roads remain passable in a 5 year ARI event	The pipe network will be sized to convey the 5 year ARI event, thus ensuring minor roads will remain passable in a 5 year ARI event
SWQ1	Retain and treat the small rainfall event (first 15 mm) as close to source as possible	Lots will retain small rainfall event runoff within soakwells and garden areas
		Small event runoff from road reserves will be retained within treatment swales and BRAs in POS
		Provision of GPTs prior to discharge of runoff into swales and BRAs
SWQ2	Size treatment areas to (at least) 2% of the connected impervious area	The surface area of treatment areas provided equates to a minimum of 2.2 % of the total connected impervious area per catchment
SWQ3	Reduce nutrient loads by applying appropriate	Street sweeping

Criteria Number	Description	Manner in which compliance is achieved
	non-structural measures	Education of residents regarding WWG, fertiliser use and nutrient absorbing vegetation species within lots
		Minimising fertiliser use to establish and maintain vegetation within POS areas and road verges
		Use of WWG in POS and road verges

7 Groundwater Management Strategy

The development drainage system has been designed to achieve the objectives and criteria stated in **Section 4.4**.

7.1 Groundwater level management

The primary objective for groundwater level management is to ensure that the stormwater retention areas have adequate clearance to groundwater (see **Section 4.3**).

All stormwater retention areas (including swales, BRAs and FSAs) will be designed such that invert levels have a minimum clearance of 500 mm from the referenced MGL (detailed in **Section 3.6.3**). A landscape concept plan and cross-sections for swales, BRAs and FSAs are provided within **Appendix E**, with MGL also shown. A minimum clearance to MGL from the invert of retention basins is 3.45 m AHD. Detailed designs of all stormwater retention areas will be presented within future UWMPs.

The preliminary earthworks and lot levels are shown in **Appendix F**; however the final earthworks levels for the development will be presented within the UWMP.

The above measures will ensure that **Criteria GW1** is achieved.

7.2 Groundwater quality management

The main objective of the management of the groundwater quality is to maintain or improve the existing groundwater quality. This can be achieved by reducing the total nutrient load to groundwater from sources within the development and by providing treatment of the surface runoff prior to infiltrating to groundwater.

The reduction of nutrient loads to groundwater will be achieved by:

- Direct stormwater to vegetated (with native wetland species) treatment swales and BRAs.
- Infiltration of stormwater through underlying parent soils with greater than 5 m clearance to groundwater.
- Minimising fertiliser use to establish and maintain vegetation within POS areas and road verges.
- Utilising drought tolerant turf species that require minimal water and nutrients.
- Roll-on turf will be used within POS areas to prevent the high nutrient input requirement during establishment of turf.
- Education of residents as to appropriate use of fertilisers and nutrient absorbing plant species within lots.

The above measures will improve the quality of the water prior to it infiltrating into the underlying groundwater, and will assist in achieving **Criteria GW2**.

7.3 Groundwater criteria compliance summary

A summary of the proposed groundwater management design criteria and how these are addressed within the site are provided in **Table 7**.

Table 7 Groundwater management criteria compliance

Criteria Number	Criteria description	Manner in which compliance will be achieved
GW1	Inverts of stormwater storage areas (including swales, BRAs and FSAs) to maintain a minimum clearance of 500 mm from MGL	Indicative landscape sections and the concept earthworks plan presented in **Appendix E** and **Appendix F** respectively confirm that inverts of all retention structures will have a minimum clearance of 8 m from MGL
GW2	Groundwater quality leaving the site will be maintained or, where possible, improved	Treatment of surface water runoff through infiltration and adsorption of nutrients to underlying soil media within soakwells, swales and BRAs
		Treatment of surface water runoff through interaction with nutrient removing vegetation within swales and BRAs
		Provision of GPTs prior to discharge of runoff to swales and BRAs
		Provision of educational material to lot owners in relation to minimising fertiliser use and plant species selection

8 Subdivision and Urban Water Management Plans

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

While strategies have been provided within this LWMS addendum that address planning for water management within the site, it is a logical progression that future subdivision designs and the supportive UWMP will clarify details not provided within the LWMS addendum. The main areas that will require further clarification within the future UWMP include:

- Detailed drainage design
- Non-structural water quality improvement measures
- Management and maintenance requirements
- Construction period management strategy
- Monitoring and evaluation program.

These are further detailed in the following sections.

8.1 Detailed drainage design

While the Lot 805 development drainage catchments have been defined based on the earthworks model presented in **Appendix F**, it is possible that these could undergo some change to accommodate stakeholder feedback prior to final subdivision design. It is also expected that the civil drainage designs will be progressed to a level that provides detailed cross-sections, sizes of storage areas, pipe sizes, inverts, etc. The ultimate aim of revising the hydrological model will be to confirm that the site retains the 100 year ARI event as stated within criteria proposed in **Section 4** of this LWMS addendum. The design of the drainage system to date has been undertaken at an appropriate level for local structure planning and runoff-routing computer modelling of the stormwater drainage system will be reviewed once detailed drainage design has commenced for the area. The exact location and shape of the stormwater management infrastructure will need to be specified and presented within the future UWMPs.

The exception to the requirement to revise the surface runoff modelling is if the catchment details and basin designs are consistent with the assumptions made in this LWMS addendum. If this were the case it would be acceptable to provide design calculations for the concrete pipe and retention areas to demonstrate compliance with the LWMS addendum.

8.2 Non-structural water quality improvement measures

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

8.3 Management and maintenance requirements

The management measures to be implemented to address surface water quality, such as BRAs, will require ongoing maintenance. It is therefore expected that future UWMPs will provide detailed management and maintenance plans that will set out maintenance actions (e.g. gross pollutant removal), timing (e.g. how often it will occur), locations (e.g. exactly where it will occur) and responsibilities (e.g. who will be responsible for carrying out the actions). Given that approval from the CoR and DoW will be sought for the proposed measures, it is anticipated that consultation with these agencies will be undertaken and referral to guiding policies and documents will be made.

8.4 Construction period management strategy

It is anticipated that the construction stage will require some management of various aspects (e.g. dust, surface runoff, noise, traffic etc.). The management measures undertaken for construction management will be addressed either in future UWMPs or a separate Construction Management Plan (CMP).

8.5 Monitoring and evaluation program

It will be necessary to confirm that the management measures that are implemented are able to fulfil their intended management purpose, and are in a satisfactory condition at a point of management hand-over to the CoR. A post-development monitoring program will be developed to provide this confirmation, and it will include details of objectives of monitoring, relevant issues and information, proposed methodology, monitoring frequency and reporting obligations. These monitoring programs are discussed in **Section 9** of this LWMS addendum and will be further detailed at UWMP stage.

9 Monitoring

9.1 Condition monitoring

It is proposed that the overall condition of the development will be monitored on a bi-annual basis. This monitoring will be implemented after the completion of the civil and landscaping works and will continue for a period of two years.

A visual assessment will be undertaken to monitor the overall condition of the development, with the aim to ascertain that the maintenance activities are achieving the overall management objectives for the development. The parameters that will be monitored include:

- Gross pollutants
- Terrestrial weeds
- Irrigation
- Vegetation density
- Paths, benches, walkways and other infrastructure.

The management and maintenance objectives will be detailed within future UWMPs.

9.2 Groundwater monitoring

It is anticipated that the post-development monitoring would be consistent with the pre-development monitoring of hydrological conditions (as documented in earlier sections), with the addition that the BMPs should also be monitored to ensure their continued effectiveness. It will be necessary to confirm that the structural management measures that are implemented are able to fulfil their intended management purpose and are in a satisfactory condition at a point of management hand-over to the CoR. These monitoring programs will be further detailed at UWMP stage.

9.2.1 Post development trigger values

Groundwater quality targets have been derived from background levels measured during monitoring prior to development, provided in **Table 2** detailed in **Section 3.6.4**. Trigger values have been chosen to be consistent with readings taken at Bore MW6 located near the proposed post-development monitoring site and in consideration of the water quality aims and objectives provided in the *NWQMS* (ANZECC 2000). The trigger criteria proposed are shown in **Table 8**.

Table 8 Post-development trigger values

Analyte	TN (mg/L)	TP (mg/L)	TKN (mg/L)	NH_4 (mg/L)	NO_X (mg/L)	pH	EC (mS/cm)
Trigger Value	1.2	0.065	0.20	0.08	0.15	7.0-8.0	1.28
NWQMS	1.2	0.065	-	0.08	0.15	6.5-8.0	-

9.2.2 Recommended program for UWMP

Given that there will be no surface water discharge from the site during a small rainfall event it will be very difficult to collect a water quality sample for treated surface runoff. Rather, post-development monitoring will instead focus on groundwater quality.

The locations of existing groundwater bores need not necessarily be maintained post-development. It is proposed that post-development monitoring will reference both a derived water quality target, and an upstream/downstream comparison of water quality at key locations within the development site. The indicative proposed location for groundwater monitoring is shown in **Figure 6** and has been selected to provide an indication of the results of POS management at one key representative POS area where MGL is within 5 m of the surface. Note that upstream/downstream locations are proposed, and given that the location of BRAs are nominally shown, these locations should be revised at UWMP to ensure that an upstream/downstream comparison is available.

Groundwater quality monitoring will be conducted on a quarterly basis. A summary of the post-development monitoring program is shown in **Table 9**. The post-development monitoring will be conducted for two years which will commence when at least 80% of the development is complete.

Table 9 Monitoring program summary

Monitoring Type	Locations	Frequency	Parameters
Groundwater	Bores upstream and downstream of key representative POS area	Quarterly (typically Jan, April, July, Oct).	*In situ* pH, electrical conductivity (EC), temperature. Sample total dissolved solids (TSS), total nitrogen (TN), total kjehdahl nitrogen (TKN), ammonia (NH_4), nitrogen oxides (NO_x), total phosphorous (TP), filterable reactive phosphorous (FRP).

9.2.3 Contingency Action Plan

A Contingency Action Plan (CAP) will be detailed and implemented as a part of each UWMP. The CAP is effectively a plan of steps that will be undertaken should certain water quality criteria be reached.

9.2.3.1 Trigger criteria

As indicated, the groundwater trigger values proposed in **Section 9.2.1** have been derived from groundwater quality levels measured during pre-development monitoring within the site. These values should be reviewed for each UWMP to include additional data gained from continued monitoring.

9.2.3.2 Contingency actions

If the results from the initial monitoring occasion indicate that nutrient concentrations exceed the nominated trigger values, a number of contingency measures will be employed.

The first action that will be undertaken if groundwater trigger criteria are exceeded is to repeat the monitoring within two weeks of the exceedance to remove the potential for sampling error. If the repeat monitoring still shows results which breach the trigger value, the next action will be to compare the upstream (incoming) nutrient concentrations with the outgoing (downstream) nutrient concentrations. The comparison monitoring should be carried out within a month of the initial exceedance.

If the downstream nutrient concentrations are >20% higher than the upstream nutrient concentrations, the following actions will be undertaken:

1. Review POS nutrient application practices to identify source if possible
2. Conduct surveillance of subdivision area to determine any other potential and obvious nutrient inputs
3. Remove source if possible (e.g. fertiliser input, etc.)
4. Remove sediment-bound nutrients by removing basin sediments
5. Manual removal of plant material from bio-retention areas to facilitate further nutrient uptake.

If the downstream nutrient concentrations are found to be generally consistent with the upstream concentrations the next action will be to conduct a site-specific comparison of background data collected within the site prior to development. There is some amount of variability (both spatially and temporally) in nutrient concentrations experienced across the West Karnup LSP area and the trigger values may need to be modified following additional monitoring. This information should then be used as a management tool in consultation with DoW to determine if the trigger values should be revised.

Following implementation of the above contingency measures the groundwater quality will be re-sampled within one month of the implementation of the required contingency measures. If the results of the analysis still show water quality characteristics which breach the trigger values an additional set of upstream/downstream monitoring bores will be installed at another key representative POS area. The additional bores will be sampled as per the ongoing sampling regime already being undertaken for the first two bores. If the results from the second POS area demonstrate results consistent with the first POS area, DoW and CoR will be informed of the results, and the proponent will seek to work with DoW and CoR to determine if the results are representative of a broader catchment management issue, and whether any additional contingency actions need to be implemented onsite.

9.3 Reporting

A post-development monitoring report will be prepared annually and on conclusion of the two year monitoring period, and will be provided to the CoR. Interim results (spreadsheet) can be provided to CoR or DoW on request during the monitoring program.

10 Implementation

The LWMS addendum is a key supportive document for the West Karnup LSP, along with the *West Karnup LSP LWMS* (Emerge Associates 2012b). The development of the LWMS addendum has been undertaken with the intention of providing a structure within which subsequent development can occur consistent with an integrated water cycle management approach. It is also intended to provide overall guidance to the general stormwater management principles for the area and to guide the development of future UWMPs.

10.1 Roles and responsibility

The LWMS addendum provides a framework that the proponent can utilise to assist in establishing stormwater management methods that have been based upon site-specific investigations, are consistent with relevant State and Local Government policies, and have been endorsed by the CoR. The responsibility for working within the framework established within the LWMS addendum rests with the subdivider, although it is anticipated that future UWMPs will be developed in consultation with the CoR and DoW and in consideration of other relevant policies and documents.

Due to the size of the LSP area it is most likely that the area will not be developed as a single parcel. Staged development will therefore be required. It will be the responsibility of the proponent to prepare detailed subdivision designs and a supportive UWMP at the appropriate time (i.e. at subdivision stage). It is also the responsibility of the proponent to demonstrate that the proposed subdivision designs and the supportive UWMP not only complies with the objectives and management approaches provided in this LWMS addendum, but that they can also achieve the water quantity and quality criteria proposed by this LWMS addendum.

10.2 Funding

The site is a single landholding owned by the proponent and therefore all works will be funded by the proponent.

10.3 Review

The surface runoff calculations contained herein would not need to be revised unless additional land parcels/lots are added to the LSP area prior to subdivision, or the LSP undergoes significant change post-lodgement of the LWMS addendum. If the LSP is substantially modified surface runoff modelling undertaken for this LWMS addendum will need to be reviewed and the criteria proposed revised to ensure that all are still appropriate.

The next stages of water management are anticipated to be lot planning through subdivision. Subdivision approvals will be supported by a UWMP. The UWMP is largely an extension of the LWMS as it should provide detail to the designs proposed within this LWMS addendum, and will demonstrate compliance with the criteria proposed in **Section 4**.

In addition to the issues detailed in **Section 8**, the UWMP will address:

- Compliance with design objectives within the LWMS addendum
- Detailed stormwater management design

- Specific structural and non-structural methods to be implemented and their manner of implementation
- Non-potable water requirements and supply confirmation
- Details of proposed roles and responsibilities for the above measures.

The next stage of development following the UWMP is single lot or multiple dwelling developments. It is recognised that certain elements of the LWMS addendum and the UWMP will not be implemented until this late stage, and that there is little or no statutory control that can be applied to ensure the implementation of any remaining measures. While the remaining measures are unlikely to be enforced at this stage, their implementation could be encouraged by the CoR through policy (or modification of these where necessary), building licence or awareness programs (such as the WC Waterwise program).

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FIGURES

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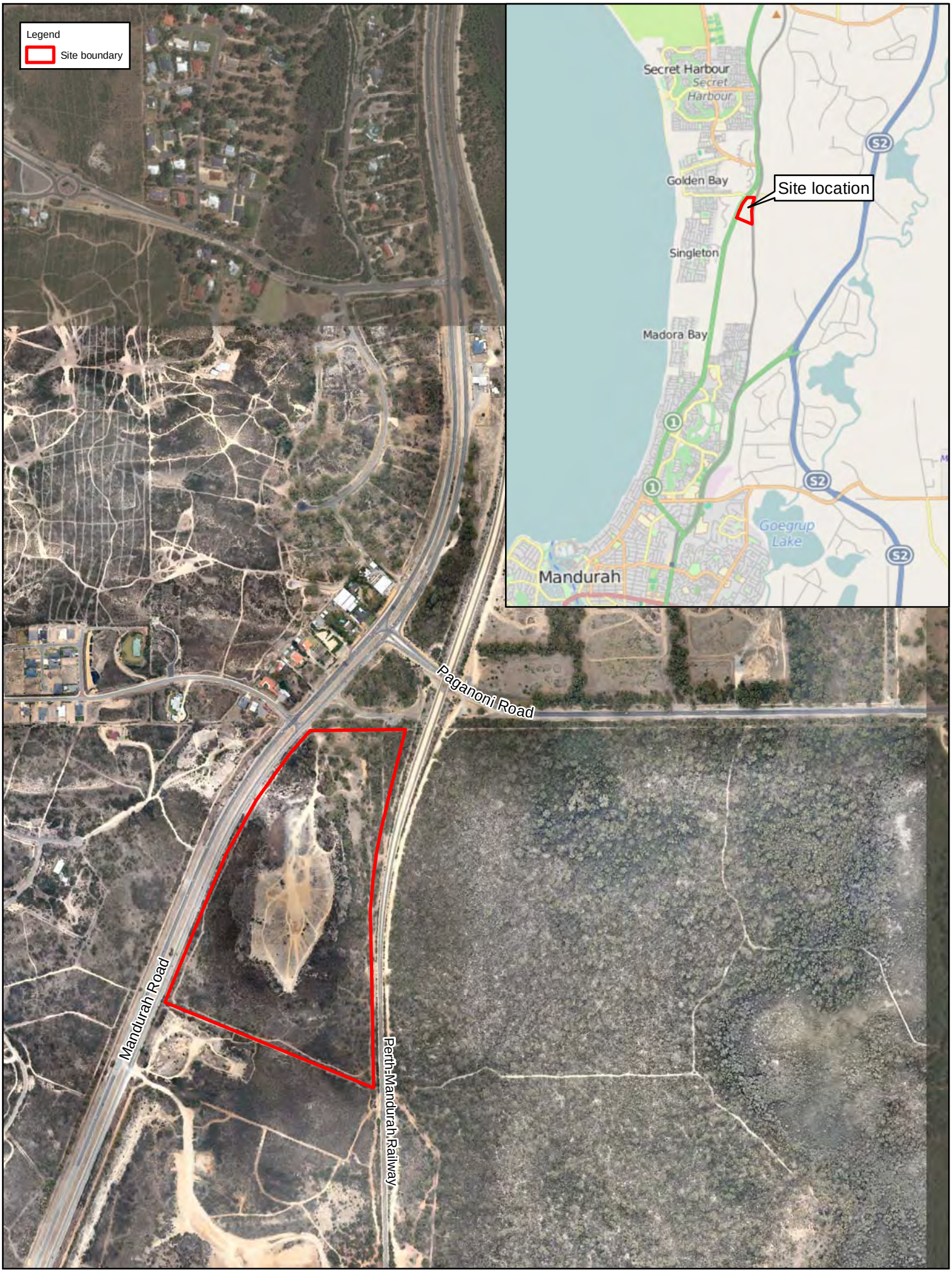

Figure 1:	**Site Location**	**Plan Number: EP14-047(06)--F19**	
Project:	LWMS Addendum West Karnup - Lot 805 LSP	Drawn: GRO	Date: 09/02/15
		Approved: DPC	Date: 27/03/15
Client:	Gold Right Pty Ltd	Checked: RLE	Scale: 1:10,000@A4

0 100 200 400 Metres

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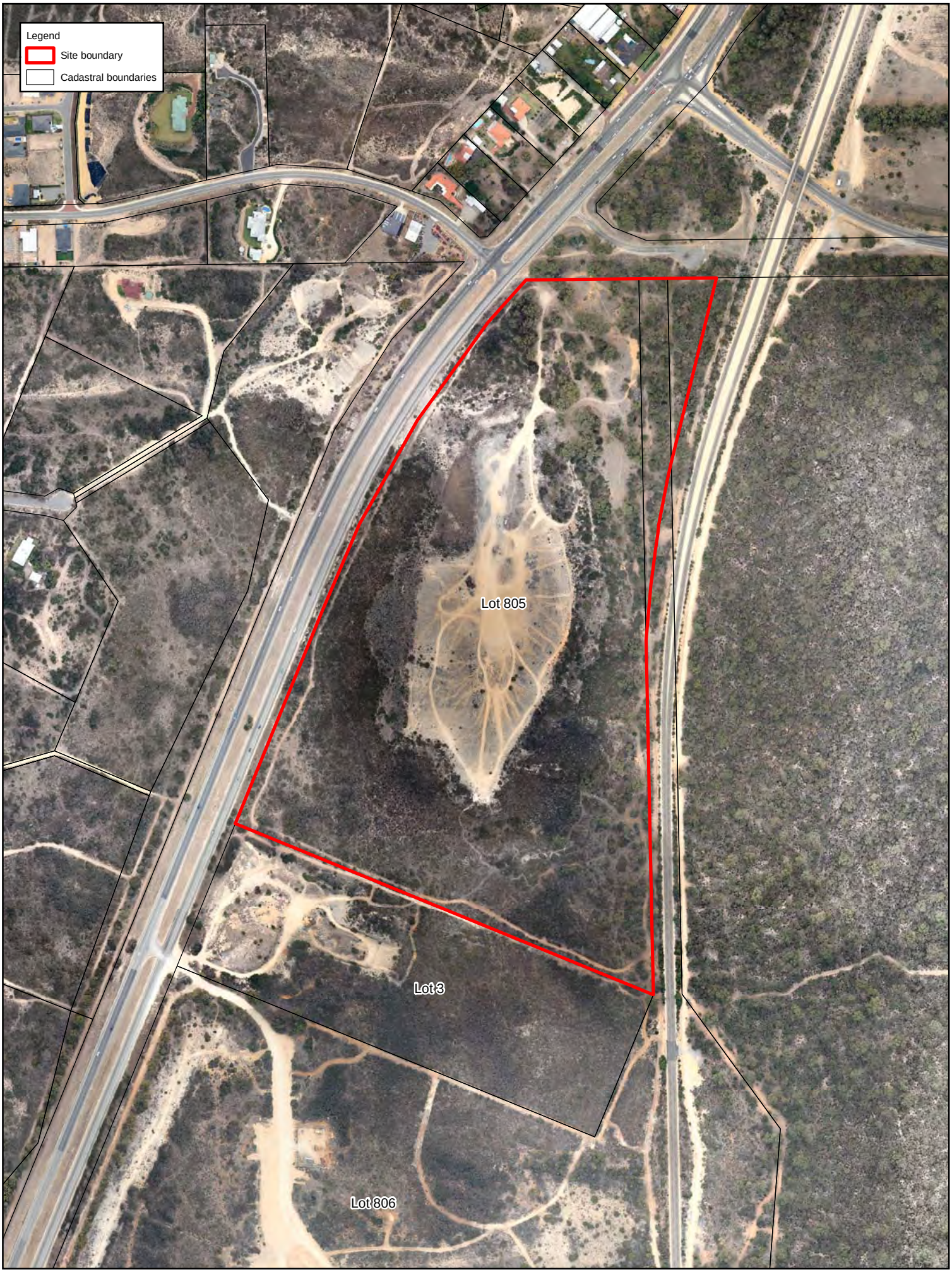

Figure 2: **Site Boundary**

Project: LWMS
West Karnup - Lot 805 LSP

Client: Gold Right Pty Ltd

Plan Number: EP14-047(06)--F20

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Approved:	DPC	Date:	27/03/15
Checked:	RLE	Scale:	1:5,000@A4

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Figure 3:	**Topography and MGL**	**Plan Number: EP14-047(06)--F21**	
Project:	LWMS Addendum West Karnup - Lot 805 LSP	Drawn: GRO	Date: 09/02/15
		Approved: DPC	Date: 27/03/15
Client:	Gold Right Pty Ltd	Checked: RLE	Scale: 1:3,500@A4

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Figure 4: Soil Types

Project: LWMS Addendum
West Karnup - Lot 805 LSP

Client: Gold Right Pty Ltd

Plan Number: EP14-047(06)--F22a

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Approved:	DPC	Date:	19/02/2016
Checked:	RLE	Scale:	1:3,500@A4

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Figure 5: Pre-development Catchments

Project: LWMS Addendum
West Karnup - Lot 805 LSP

Client: Gold Right Pty Ltd

Plan Number: EP14-047(06)--F33

Drawn:	GRO	Date:	20/02/15
Approved:	DPC	Date:	27/03/15
Checked:	RLE	Scale:	1:3,500@A4

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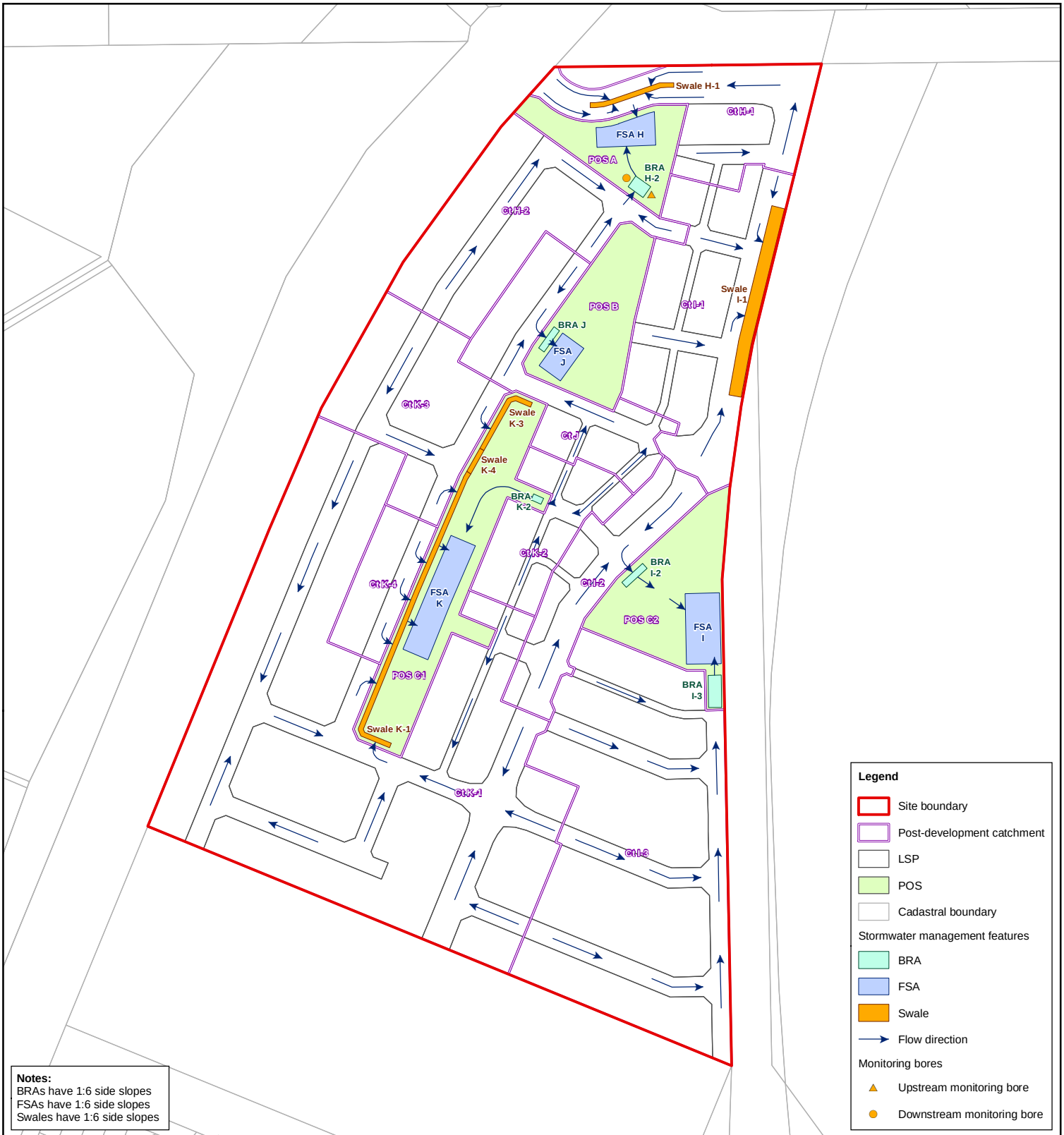

Notes:
BRAs have 1:6 side slopes
FSAs have 1:6 side slopes
Swales have 1:6 side slopes

Catchment	POS/road reserve	Total Area (m^2)	Sub-catchment	Storage area	First 15 mm (treatment area) depth (m)	length (m)	area (m^2)	volume (m^3)	5 year ARI depth (m)	area (m^2)	volume (m^3)	10 year ARI depth (m)	area (m^2)	volume (m^3)	100 year ARI depth (m)	length (m)	area (m^2)	volume (m^3)	Total 100 year ARI drainage area (m^2)	10 year ARI % drainage in POS
H	Median	TBC	H-1	Swale H1	0.3	65	234	35											234	
	A	5,316		FSA H					0.6	479	206	0.7	555	277	1.2		840	590	979	13
			H-2	BRA H2	0.5		139	40												
I	Verge	1,423	I-1	Swale I1	0.02	145	562	13	0.3	1,027	227	0.3	1,098	270	0.5	145	1,392	479	1,392	
	C2	9094	I-2	BRA I2	0.5		106	28											1,715	14
			I-3	BRA I3	0.5		241	80												
				FSA I					0.6	868	390	0.7	967	516	1.2		1,368	1,085		
J	B	7,166	J	BRA J	0.5		97	25											680	7
				FSA J					0.7	320	133	0.8	375	176	1.2		583	365		
K	C1	12,130	K-1	Swale K1	0.3	235	846	127											3,024	20
			K-2	BRA K2	0.5		40	7												
			K-3	Swale K3	0.3	60	216	32												
			K-4	Swale K4	0.3	20	72	11												
				FSA K					0.4	1,156	441	0.6	1,292	639	1.2		1,850	1,560		

Figure 6: Stormwater Management Features

Project: LWMS Addendum
West Karnup - Lot 805 LSP

Client: Gold Right Pty Ltd

Plan Number: EP14-047(06)--F24b

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Approved:	RLE	Date:	15/06/17
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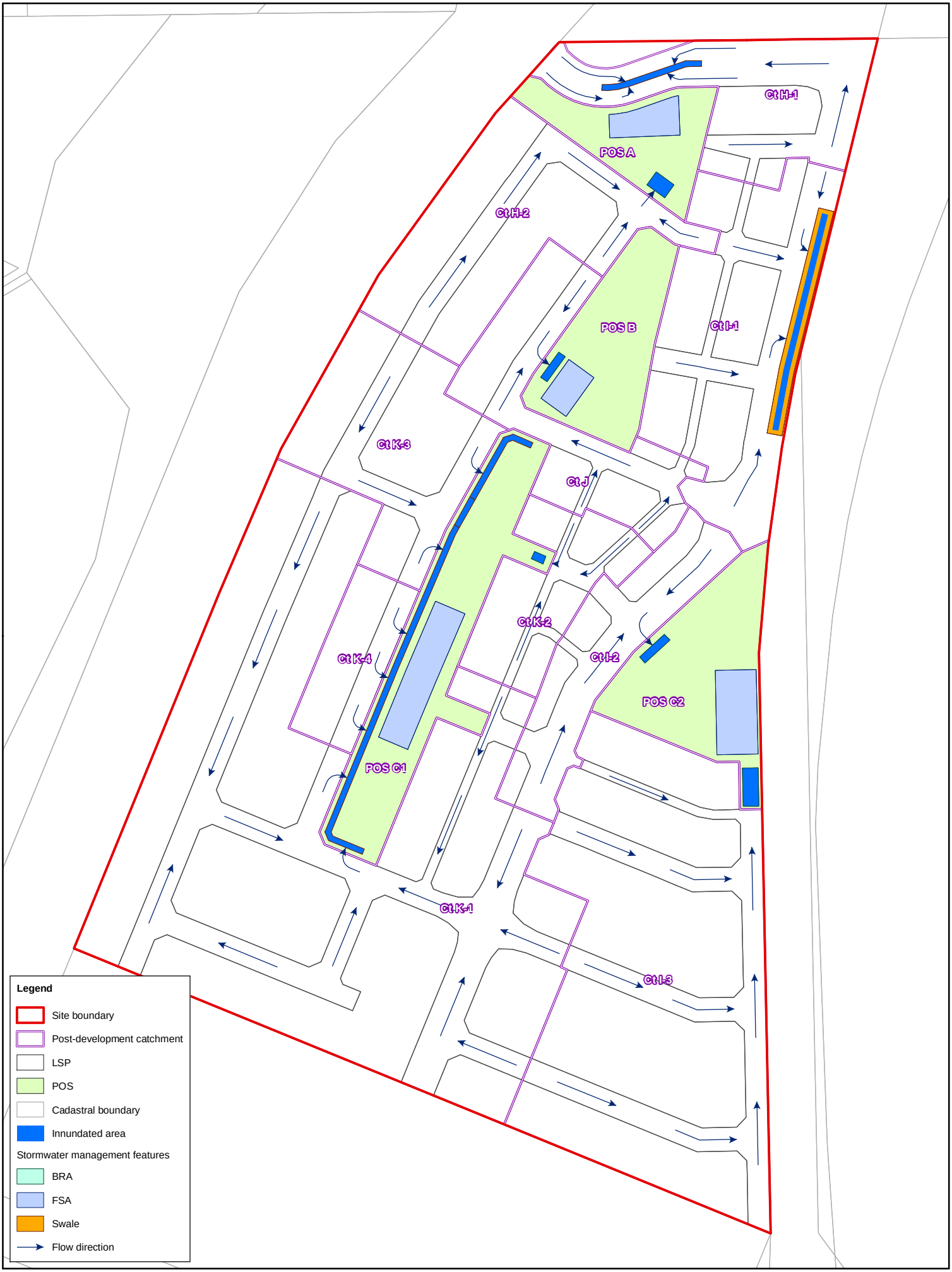

Figure 7: Small Event (First 15 mm) Inundation

Project: LWMS Addendum
West Karnup - Lot 805 LSP

Client: Gold Right Pty Ltd

Plan Number: EP14-047(06)--F25b

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Approved:	RLE	Date:	15/06/17
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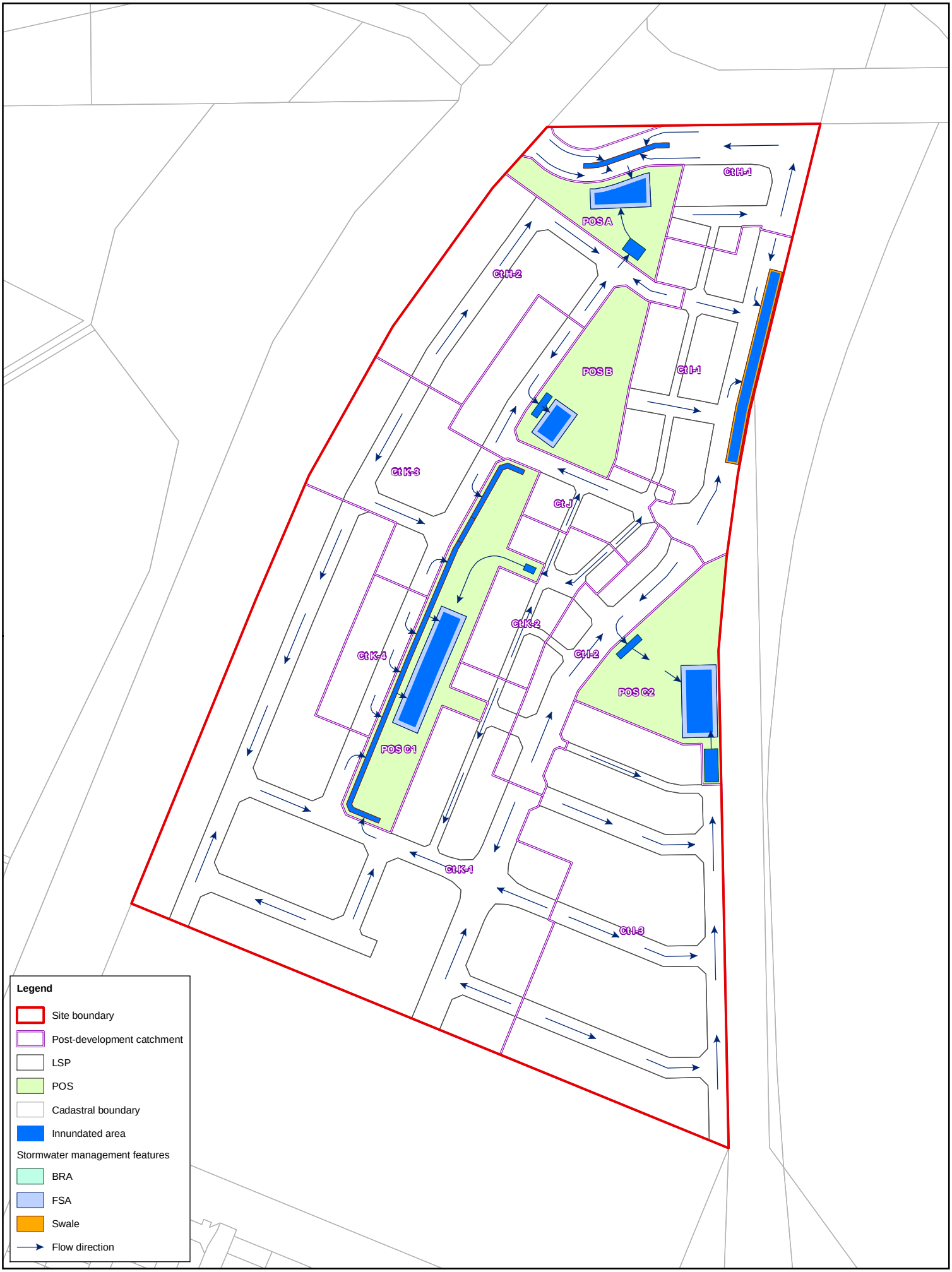

Figure 8: 5 Year ARI Inundation

Project: LWMS Addendum
West Karnup - Lot 805 LSP

Client: Gold Right Pty Ltd

Plan Number: EP14-047(06)--F26b

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Approved:	RLE	Date:	15/06/2017
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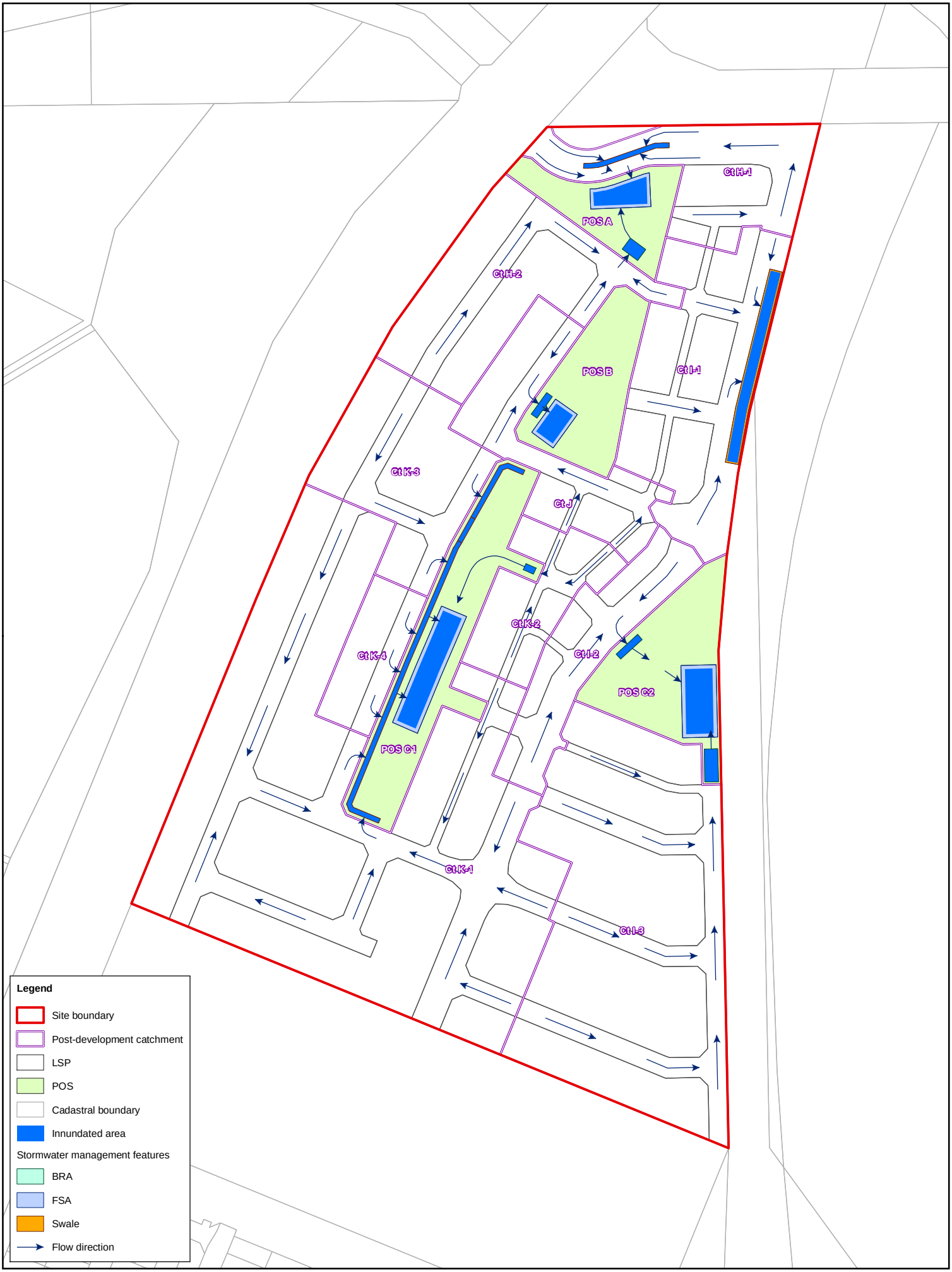

Figure 9: 10 Year ARI Inundation

Project: LWMS Addendum
West Karnup - Lot 805 LSP

Client: Gold Right Pty Ltd

Plan Number: EP14-047(06)--F27b

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Approved:	RLE	Date:	15/06/2017
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0 50 100 Metres

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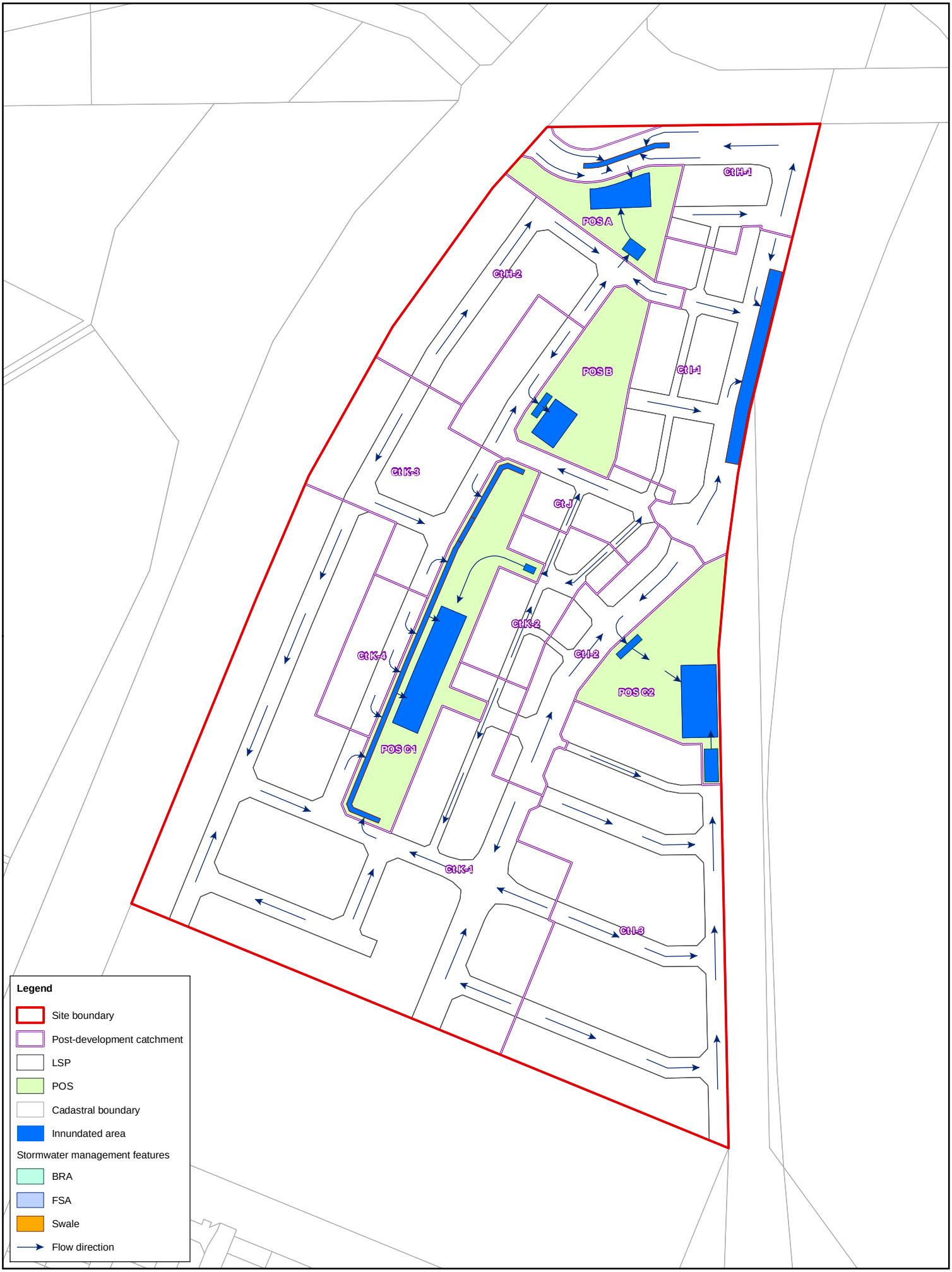

Figure 10: 100 Year ARI Inundation

Project: LWMS Addendum
West Karnup - Lot 805 LSP

Client: Gold Right Pty Ltd

Plan Number: EP14-047(06)--F28b

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Approved:	RLE	Date:	15/06/2017
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0 50 100 Metres

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APPENDIX A

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LOCAL STRUCTURE PLAN

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LEGEND :

- Subject Site

ZONES

- Residential 25
- Residential 30
- Residential 40
- Residential 60
- Commercial
- RMD **

RESERVES

- Road Reserve
- (A) Public Open Space/Ref Number
- Reserve for Conservation
- Public Purposes
  - PS - Primary School
  - PU - Public Utilities

ROAD HIERARCHY

- Integrator B
- Neighbourhood Connector A
- Neighbourhood Connector B
- Access Street B
- Light Controlled Intersection
- Full Movement Intersection

PATH NETWORK

- Dual Use Paths

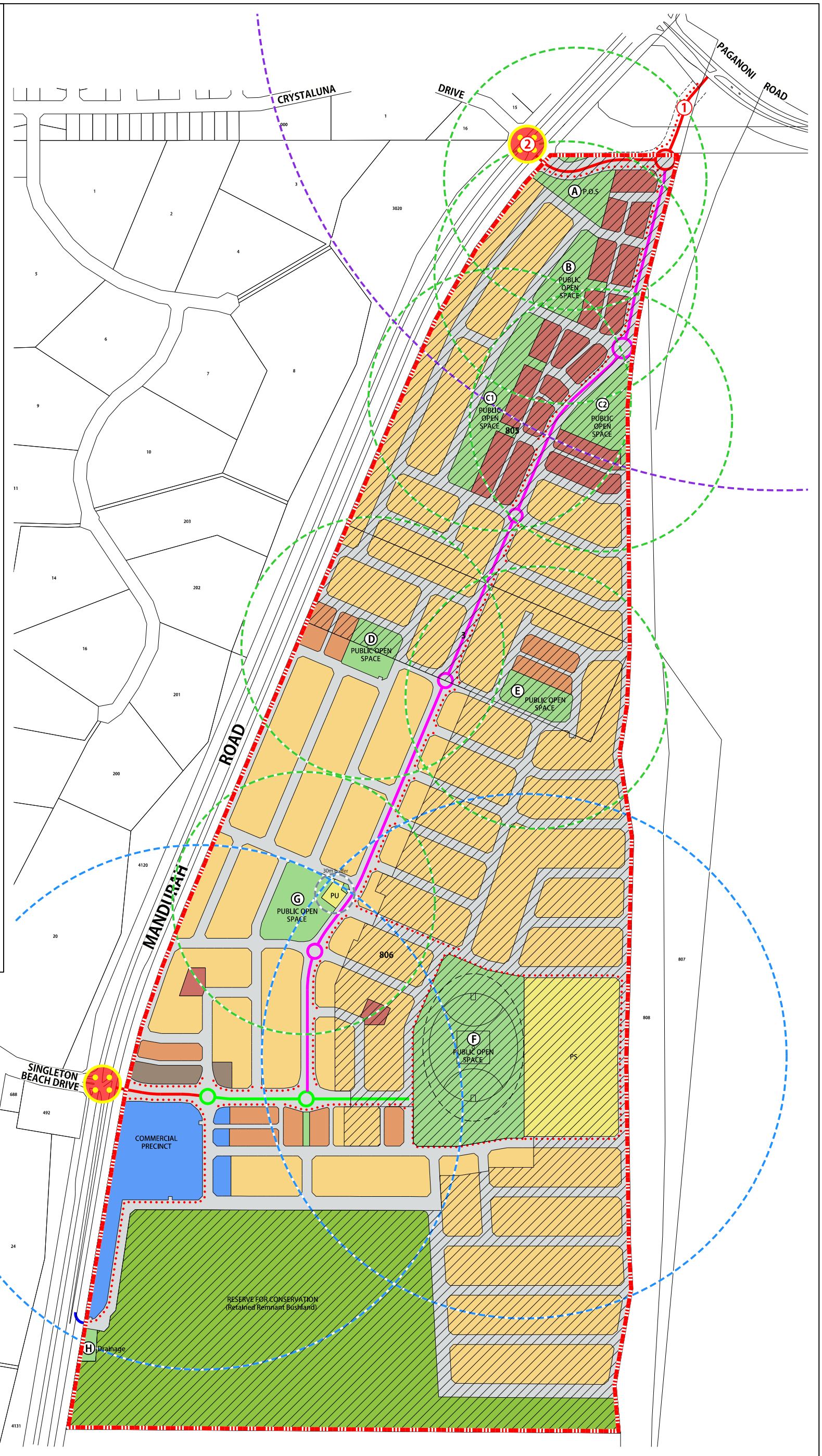
WALKABLE CATCHMENTS

- 200m POS walkable catchment
- 400m Major Community Node walkable catchment
- 800m TOD walkable catchment

** Planning Policy No.3.3.22 Medium-Density Single House Development Standards-Development Zones

① Alignment of road connection to Paganoni Road through Lot 172 shall be such that it minimises loss of vegetation

② A 'Seagull' intersection and 'Left-in/Left-out' access point on Mandurah Road (opposite Crystaluna Drive). The intersection shall be such that a reconfiguration to a four way 'Light Controlled' intersection is possible in the future



Revised Local Structure Plan

The Vista Karnup

NORTH

Scale 1: 6000 @ A3

25 0 50 100 150 200 250 metres

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APPENDIX B

emerge ASSOCIATES
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GEOTECHNICAL REPORTS

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Report on

GEOTECHNICAL INVESTIGATION
PROPOSED RESIDENTIAL SUBDIVISION
LOTS 3, 805 & 806 MANDURAH ROAD
KARNUP

Submitted to:
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J1001085 002 R Rev0

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03 August 2011

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1. INTRODUCTION

This report presents the results of Galt Geotechnics Pty Ltd's (Galt's) geotechnical investigation for the proposed development of Lots 3, 805 and 806 Mandurah Road, Karnup. The location of the site relative to the surrounding area is shown on Figure 1, Location Plan.

The work was requested by Mr Steven Foley of JDSi Consulting Engineers, and authorised in a client authorisation form signed by Tom Kroyer of Gold Right Pty Ltd on 14 June 2011.

A preliminary investigation of the site was undertaken by Galt in October 2010 (refer Galt letter reference J1001085 001 L Rev0 dated 1 November 2010).

2. SITE DESCRIPTION AND PROPOSED DEVELOPMENT

2.1 Site Description

The site lies to the east of Mandurah Road. The total area is roughly triangular in shape, about 2.1 km along Mandurah Road and about 840 m along the southern boundary. There are three limestone quarries on the site, one in each of the Lots. The largest quarry (on Lot 806) was still operational at the time of the investigation.

The site is densely vegetated with shrubs and grass. In the north-east corner, there is a low-lying area with large trees. There are several tracks throughout the site but access is relatively difficult due to the presence of loose surficial sands, limestone outcrop, surface cobbles and boulders, and the steeply undulating terrain.

Typical photographs showing the various surface features are presented in Attachment A. Site plans are included as Figure 2 (overlain on aerial photograph) and 3 (overlain on concept layout plan).

2.2 Proposed Development

We understand that the proposed development will comprise a series of low and medium density residential lots plus associated roads, public open space (POS), a shopping centre and a primary school.

In the southern part of the site (Lot 806), the natural ground levels vary from RL 10 m to 12 m AHD. The floor of the quarry is at about RL 7 m AHD.

Over the northern part of the site (Lot 3, Lot 805 and the northeast part of Lot 806), natural ground levels vary from about RL 10 m to 29 m AHD. The northeastern corner of Lot 805 is at about RL 6 m to 8 m AHD. The floor level of the northern quarry is at RL 7.0 m.

We understand that the quarries will be filled (the fill will be between about 3 m and 5 m thick). The fill material will be obtained from the higher-lying areas (mainly in the area of Lot 3).

3. OBJECTIVES

The objectives of the study were to:

- assess subsurface soil and groundwater conditions across the site;
- provide a site classification for the lots in accordance with AS2870-2011, "Residential Slabs and Footings";
- provide advice on how to improve the site classification, if required;
- collect representative samples for laboratory testing;

- provide design subgrade California Bearing Ratio (CBR) values for pavement thickness design of the roads;
- assess the suitability of the materials for use as structural fill for house lots;
- assess the suitability of the limestone for use as base and subbase in the construction of the residential roads within the development;
- assess excavatability of the surficial and near-surface soils and rock at the site;
- provide geotechnical design parameters for retaining structures;
- provide allowable bearing pressure for shallow footings; and
- recommend appropriate subgrade preparation procedures including compaction criteria.

4. FIELDWORK

Fieldwork was conducted between 28 June and 13 July 2011 and comprised;

- Excavation and logging of 46 test pits (TP1 to TP48 excluding TP37 and TP45) to depths of between 0.3 m and 3.0 m;
- Dynamic cone penetration testing (DCP) adjacent to each test pit to a maximum depth of 0.9 m;
- Drilling and logging of 8 boreholes (BH1 to BH8) to depths of 8.0 m each;
- Permeability tests, using the inverse auger hole method, at 4 locations, at a depth of between 0.5 m and 1.0 m.

The test locations are shown on Figures 2 and 3. Test locations were located using a handheld GPS accurate to about 5 m in the horizontal plane.

The tests were positioned by an engineering associate from Galt who observed the test pitting and drilling, logged the materials encountered in the test pits and boreholes, undertook the field testing and collected representative samples for laboratory testing.

The results of the fieldwork done as part of the preliminary investigation in November 2010 have also been included in this report.

Test Pits

The test pits were excavated using a Komatsu 9.5 tonne backhoe fitted with a 500 mm wide toothed bucket supplied and operated by Erskine Earthmoving. Test pit records along with sheets providing explanatory notes, the methods of soil description and cementation classification used on the reports are presented in Appendix B1[1].

Details of the test pits are presented in Table 1.

Table 1: Summary of Test Pits

Test Name	Test Depth (m)	Reason for Termination	Comments
TP01	0.5	Refusal	Sandy gravel
TP02	0.7	Refusal	Sandy gravel
TP03	2.5	Target Depth	Sand, over limestone excavated as sandy gravel
TP04	1.5	Refusal	Sand, over limestone excavated as sandy gravel
TP05	0.3	Refusal	Limestone excavated as sandy gravel
TP06	2.5	Target Depth	Fill: sandy gravel
TP07	1.8	Refusal	Sandy gravel

[1] Test pit reports from the preliminary investigation have also been included in Appendix B2 of this report for completeness.

Test Name	Test Depth (m)	Reason for Termination	Comments
TP08	1.0	Refusal	Sandy gravel
TP09	0.2	Refusal	Limestone excavated as sandy gravel
TP10	3.0	Target Depth	Fill: sandy gravel
TP11	1.7	Refusal	Sandy gravel
TP12	1.8	Refusal	Sandy gravel
TP13	2.5	Target Depth	Sandy gravel
TP14	2.5	Target Depth	Sandy gravel
TP15	0.8	Refusal	Sand, over sandy gravel
TP16	2.5	Target Depth	Sandy gravel
TP17	2.5	Target Depth	Sand, over limestone excavated as sandy gravel
TP18	1.1	Refusal	Sandy gravel
TP19	2.5	Target Depth	Fill: sandy gravel
TP20	2.6	Target Depth	Fill: sandy gravel, over sand
TP21	1.0	Refusal	Sand, over limestone excavated as sandy gravel
TP22	2.5	Target Depth	Sand, over limestone excavated as sandy gravel
TP23	2.6	Target Depth	Sand, over limestone excavated as sandy gravel
TP24	1.9	Refusal	Fill: sandy gravel, over sand, over sandy gravel
TP25	2.2	Refusal	Sandy gravel
TP26	2.8	Target Depth	Gravelly sand, over sandy gravel
TP27	1.8	Refusal	Sand, over sandy gravel
TP28	2.5	Target Depth	Sand, over limestone excavated as sandy gravel
TP29	1.0	Refusal	Sand, over sandy gravel
TP30	1.5	Refusal	Sand, over limestone excavated as sandy gravel
TP31	2.8	Target Depth	Sand
TP32	2.5	Target Depth	Sand, over sandy gravel
TP33	1.8	Refusal	Sand, over limestone excavated as sandy gravel
TP34	2.0	Refusal	Sand, over limestone excavated as sandy gravel
TP35	1.4	Refusal	Sand, over limestone excavated as sandy gravel
TP36	0.7	Refusal	Sandy gravel
TP38	2.5	Target Depth	Sand
TP39	2.5	Target Depth	Sand
TP40	2.5	Target Depth	Sandy gravel
TP41	2.5	Target Depth	Sandy gravel
TP42	1.0	Refusal	Sand, over limestone excavated as sandy gravel
TP43	1.0	Refusal	Sand, over limestone excavated as sandy gravel
TP44	2.5	Target Depth	Fill: sandy gravel
TP46	2.5	Target Depth	Sand
TP47	2.5	Target Depth	Fill: gravelly sand – inclusions of concrete rubble, wire and plastic
TP48	2.5	Target Depth	Sand

Note: Test pits TP37 and TP45 were not excavated

DCP Tests

DCP tests were carried out adjacent to each test pit. These tests were conducted in accordance with AS 1289.6.3.2.

The results of the DCP tests are provided in Table 2.

Table 2: DCP Test Results

Depth (m)	Test Number/Blows per 0.1m Penetration											
	TP1	TP2	TP3	TP4	TP5	TP6	TP7	TP8	TP9	TP10	TP11	TP12
0.0 – 0.1	2	1	1	3	2	3	3	5HB	10HB	5	5	9
0.1 – 0.2	9HB	3	2	1	10HB	7	12HB			8	12HB	12HB
0.2 – 0.3		6	1	2		12HB				10HB		
0.3 – 0.4		6	1	1								
0.4 – 0.5		7	1	2								
0.5 – 0.6		5	1	4								
0.6 – 0.7		6	1	2								
0.7 – 0.8		5	4	1								
0.8 – 0.9		7	4	3								

Depth (m)	Test Number/Blows per 0.1m Penetration											
	TP13	TP14	TP15	TP16	TP17	TP18	TP19	TP20	TP21	TP22	TP23	TP24
0.0 – 0.1	10	2	3	1	0	3	2	3	1	9	1	2
0.1 – 0.2	12	6	8	2	1	9	4	17HB	1	15HB	3	3
0.2 – 0.3	15HB	12	12	5HB	1	15HB	5		3		4	6
0.3 – 0.4		15HB	10HB		1		5		3		4	6
0.4 – 0.5					1		9		8HB		4	8
0.5 – 0.6					1		9				6	7
0.6 – 0.7					2		11				6	7
0.7 – 0.8					1		10				15HB	8
0.8 – 0.9					1		13					9

Depth (m)	Test Number/Blows per 0.1m Penetration											
	TP25	TP26	TP27	TP28	TP29	TP30	TP31	TP32	TP33	TP34	TP35	TP36
0.0 – 0.1	4	2	1	0	3	1	1	1	1	18HB	0	2
0.1 – 0.2	15HB	2	1	1	6	2	2	3	2		1	8
0.2 – 0.3		2	1	2	8HB	5	3	5HB	2		1	12HB
0.3 – 0.4		1	2	2		7	3		6HB		1	
0.4 – 0.5		10HB	3	2		6	5				3	
0.5 – 0.6			2	3		6	8HB				5	
0.6 – 0.7			3	3		6					8HB	
0.7 – 0.8			3	4		6						
0.8 – 0.9			4	4		7						

Depth (m)	Test Number/Blows per 0.1m Penetration									
	TP38	TP39	TP40	TP41	TP42	TP43	TP44	TP46	TP47	TP48
0.0 – 0.1	1	1	1	3	0	1	1	1	1	8
0.1 – 0.2	4	1	10	4	2	1	1	3	2	9
0.2 – 0.3	7	2	15HB	9HB	6	2	3	2	4	11
0.3 – 0.4	7	2			9HB	4	3	2	8	15HB
0.4 – 0.5	7	3				6	3	3	10HB	
0.5 – 0.6	8	3				8	2	3		
0.6 – 0.7	7	2				6	1	2		
0.7 – 0.8	5	3				6	7	3		
0.8 – 0.9	5	3				4	9	3		

R: Refusal
HB: Hammer bouncing (Refusal)

Boreholes

Drilling and logging of geotechnical boreholes was undertaken at 8 locations. The purpose of these was to assess the excavatability and quality of the limestone in the higher-lying areas.

The boreholes were drilled using a reverse air blast truck mounted drill rig fitted with a 100 mm diameter corer, supplied and operated by Proline Drilling. Borehole records along with sheets providing explanatory notes, the methods of soil description and cementation classification used on the reports are presented in Appendix C.

The locations of the boreholes are shown on Figures 2 and 3. Details of the boreholes are presented in Table 3.

Table 3: Summary of Boreholes

Test Name	Test Depth (m)	Reason for Termination	Comments
BH1	8.0	Target Depth	Siliceous calcarenite (limestone)
BH2	8.0	Target Depth	Siliceous calcarenite (limestone)
BH3	8.0	Target Depth	Sandy gravel, over siliceous calcarenite (limestone)
BH4	8.0	Target Depth	Sand, over siliceous calcarenite, over calcareous sandstone (limestone)
BH5	8.0	Target Depth	Sandy gravel, over siliceous calcarenite with layers of sand
BH6	8.0	Target Depth	Sand, over siliceous calcarenite (limestone)
BH7	8.0	Target Depth	Sand, over siliceous calcarenite (limestone)
BH8	8.0	Target Depth	Sand, over calcareous sandstone, over siliceous calcarenite (limestone)

Permeability Tests

Permeability testing was carried out at four locations using the inverse auger hole method described by Cocks[2]. The locations of the tests are shown on Figure 2, Site Plan. The results of the permeability testing are presented in Appendix D1[3] and summarised in Table 4.

Table 4: Permeability Test Results

Test ID	Description	Depth to Base of Test (m)	Minimum Permeability[1], k (m/day)		
			Test 1	Test 2	Test 3
P1	In natural sand	0.6	5.9	6.0	4.8
P2	In natural sand	0.6	5.6	2.1	0.8
P3	In natural sandy gravel	0.6	0.7	1.5	1.2
P4	In natural sandy gravel	0.65	3.4	3.3	2.3

Notes: 1. Minimum permeability measured towards the end of each test, with pressure head typically varying from approximately 0 m to 0.60 m.

The recorded permeabilities are all less than those measured in the preliminary investigation (October 2010) which ranged from 8.3 to 23.8 m/day. The reason for this may the higher moisture content of the soil at the time of the recent testing.

5. LABORATORY TESTING

Laboratory testing on soil and rock samples were undertaken by Mining and Civil Geotest and GB Testing, both of which are NATA-accredited laboratories. Testing comprised the determination of:

- particle size distribution (PSD) on 8 samples;
- dry density-moisture content relationship using Modified compactive effort on 6 samples;
- soaked California bearing ratio (CBR) on 6 samples;
- Calcium Carbonate ($CaCO_3$) content of limestone on 10 samples;

2 Cocks, G (2007), "Disposal of Stormwater Runoff by Soakage in Perth Western Australia", Journal and News of the Australian Geomechanics Society, Volume 42 No. 3, pp 101-114

3 The results of permeability tests done for the preliminary investigation are included in Appendix D2 for completeness.

- Maximum dry compressive strength on 2 samples of limestone (borehole core)
- Los Angeles Abrasion on 1 sample of limestone (borehole core)
- uniaxial compressive strength (UCS) on 5 samples of limestone (borehole core); and
- point load index (PLI) on 8 samples of limestone (borehole core).

Laboratory test results along with the test methods followed are presented in Appendix E. The laboratory test results are summarised in Table 5.

Table 5: Summary of Laboratory Test Results

Test Pit / Borehole	Sample Depth (m)	(%)	(%)	(%)	MDCS (kPa)	$CaCO_3$ (%)	PLI (I_{s50}) MPa	UCS (MPa)	MDD (t/m^3)	OMC (%)	CBR (%)	LA Abrasion
		Gravel	Sand	Fines								
TP6	1.0	42	52	6	-	-	-	-	-	-	-	-
TP12	0.5-1.0	44	52	4	-	-	-	-	1.821	11.0	60	-
TP14	0.5-1.0	32	65	3	-	-	-	-	1.495	19.6	60	-
TP17	0.3	0	97	3	-	-	-	-	1.727	13.9	35	-
TP20	2.0	7	90	3	-	-	-	-	-	-	-	-
TP25	0.5-1.0	50	46	4	-	-	-	-	1.593	16.4	60	-
TP31	0.5	0	97	3	-	-	-	-	1.652	13.8	30	-
TP40	1.0	29	69	2	-	-	-	-	1.736	10.4	45	-
BH1	3.5-3.6	-	-	-	-	56.9	1.00	-	-	-	-	-
BH1	5.4-5.5	-	-	-	-	52.8	1.40	-	-	-	-	-
BH3	1.0-1.2	-	-	-	-	73.7	-	3.31	-	-	-	-
BH3	1.3-1.5	-	-	-	-	72.0	0.37	-	-	-	-	-
BH3	0.0-8.0	-	-	-	1250	76.4	-	-	-	-	-	51.4
BH4	3.7-3.8	-	-	-	-	54.6	-	-	-	-	-	-
BH5	0.4-0.5	-	-	-	-	-	0.92	-	-	-	-	-
BH5	5.8-6.0	-	-	-	-	-	-	7.01	-	-	-	-
BH5	6.0-6.3	-	-	-	-	73.8	-	6.75	-	-	-	-
BH5	6.3-6.5	-	-	-	-	-	-	3.92	-	-	-	-
BH5	7.1-7.3	-	-	-	-	-	0.42	-	-	-	-	-
BH7	1.5-8.0	-	-	-	750	74.5	-	-	-	-	-	-
BH7	5.0-5.3	-	-	-	-	-	0.68	-	-	-	-	-
BH7	6.0-6.2	-	-	-	-	81.6	-	15.4	-	-	-	-
BH8	4.9-5.0	-	-	-	-	66.2	0.69	-	-	-	-	-
BH8	6.7-6.8	-	-	-	-	-	0.85	-	-	-	-	-

PLI: Point Load Strength Index UCS: Uniaxial Compressive Strength MDCS: Maximum Dry Compressive Strength
$CaCO_3$: Calcium Carbonate Content MDD: Maximum dry density OMC: Optimum moisture content
CBR: California bearing ratio (test done on soaked samples compacted to 95% MDD and under a 4.5 kg surcharge)

Note that the UCS and PLI tests were necessarily done on intact samples of the limestone. These are therefore from the more cemented zones and do not reflect the full range of rock strengths present on the site, particularly the weaker material.

6. SITE DESCRIPTION

6.1 Geology

The Rockingham sheet of the 1:50,000 scale Environmental Geology series map indicates that the area is largely underlain by Tamala Limestone which is described as: *pale yellowish brown, fine to coarse-grained, sub-angular to well rounded quartz, trace of feldspar, shell debris, variably lithified, surface kankar, of eolian origin.*

The north-east corner of Lot 805 is underlain by sand derived from Tamala Limestone which is described as: *pale yellowish brown, medium to coarse grained, sub-angular quartz, trace of feldspar, moderately sorted, of residual origin.*

From our experience with Tamala Limestone and experience in the vicinity of the site (the nearby Secret Harbour development), there is a possibility that karst features (i.e. sinkholes and dolines) are present.

6.2 Sub-surface Conditions

Subsurface conditions typically comprise the following layers:

Fill

Fill was encountered in several areas, mainly within and adjacent to the quarries. This generally comprises sandy gravel, fine to coarse grained with some cobbles and with pale yellow fine to coarse sand. The thickness ranged from 0.2 m to over 3 m.

In the north-east corner (TP47), inclusions of rubbish (concrete rubble, wire, metal and polystyrene) were also noted.

Aeolian Sand

The aeolian sand blankets the site and has infilled between the limestone pinnacles. The sand is fine to medium grained, yellow-orange and yellow, dry, loose and medium dense. Occasional limestone gravels and cobbles are present. There is a thin (0.2 m) upper layer of topsoil containing rootlets. The thickness of the sand is highly variable, ranging from 0.3 m to over 2.5 m. It appears that the deepest zones of sand are located in the north-eastern part of the site.

Limestone

The term "limestone" as used in this report is the local term of a variety of calcium carbonate cemented sediments, varying from calcarenite and sandstone.

The limestone is typically cobbly or bouldery, weakly to moderately cemented intact particles of siliceous calcrete or calcareous sand in a sand matrix (sand comprising 20% to 70% of the mass). Pinnacles and outcrops occur in several areas.

The limestone was typically excavatable by the 9.5 tonne Komatsu backhoe to 1.5 m to 2 m depth. Refusal was often encountered due to awkward / confined excavation conditions, not because of the excessive hardness of the limestone.

The boreholes drilled also showed that most of the limestone material is not consistently cemented and is frequently bouldery or layered. More consistently cemented layers were encountered at some locations however these layers are generally relatively thin and are moderately to well cemented, rather thick, than very well cemented "caprock".

6.3 Groundwater

No water was noted in the quarries (RL 6 m to 7 m AHD) nor in any of the test pits or boreholes. From experience in the area, we expect the water table to be at around sea level.

We consider that the presence of groundwater is unlikely to have an adverse effect on the proposed development. We understand that construction water is likely to be sourced from on-site bores.

7. DISCUSSION

7.1 Site Classification

We consider that the entire development is suitable for a site classification of "Class A" in accordance with AS2870-2011, "Residential Slabs and Footings", provided that the site preparation requirements outlined in Section 7.6 are followed.

7.2 Pavement Design

Where pavement subgrades are constructed according to the site preparation requirements outlined in Section 7.6, the thickness of pavements built upon them may be calculated using a subgrade California bearing ratio, CBR = 12% in areas of *in situ* sand and where sand fill is used.

Where a mixture of limestone gravels and sand is used as fill and in areas where the *in situ* limestone is exposed, a CBR value of the order of 20 % may be adopted.

7.3 Site Subsoil Class

We have assessed the site subsoil class in accordance with AS1170.4-2007, "Earthquake Design Actions – Australia". We consider that a site subsoil class of 'Ce' is appropriate for the site.

7.4 Stormwater Disposal

We understand that consideration is being given to disposal of stormwater on-site by means of infiltration, both in infiltration basins and in soakwells located on individual residential lots.

We note that the permeabilities measured vary between about 0.8 m/day and 20 m/day at the tested locations. The lower end of these values is relatively low (although not unprecedented) for Perth sands, and may be due to the relatively fine grading of the materials encountered at the particular test locations.

We recommend design of soakage systems assuming a permeability no greater than 2 m/day. Local areas may have lower permeabilities than this, as shown in the tests above. In addition, areas where compacted fill (sand and limestone) and *in situ* limestone are present, are likely to exhibit lower permeabilities than the *in situ* sand in its natural state.

We note that the effectiveness of infiltration systems is expected to degrade over time due to the clogging of voids with fines, organic material, etc.

If the permeability values adopted by the drainage designers are critical, we recommend that the achieved permeability be confirmed by undertaking large scale permeability tests (i.e. in test pits) in the proposed drainage basins to measure the actual permeabilities.

7.5 Excavatability

We do not expect that difficulty will be encountered in the "sand areas" with excavations undertaken using conventional earthmoving equipment (e.g. 10-tonne and larger excavators, scrapers, etc). Some difficulty may be encountered in merely gaining access to higher-lying areas to excavate them down.

We expect that limestone can be excavated with low to moderate difficulty to about 2 m depth using either a 20-tonne (or larger) excavator with a narrow (900 mm or narrower) toothed bucket or a D9 (or larger) dozer equipped with a single or triple tine ripper.

Below 2 m and in other areas of the site where deeper limestone is present, we anticipate that the limestone would be rippable by a D9 or similar dozer equipped with a single tine or a three-tine ripper. The difficulty of ripping is likely to vary between easy and moderately difficult. Localised, more consistently cemented layers may require cross-ripping. Some variably cemented (gravelly/cobbly) material can probably be pushed directly with the dozer blade without ripping (or dug with an excavator of, say, 20 tonnes or greater mass, equipped with a toothed 0.9 m bucket).

About 75% of the limestone we observed during the investigation is likely to be relatively easy to break down to relatively small (<200 mm) particles by track-rolling with a large (say D9 or D10) dozer or grid roller. Some areas may be harder than others and less easy to break down – the density of testing possible in this investigation did not allow an exhaustive assessment of the limestone excavatability.

It is important to note that Tamala limestone is very variable over very short distances (both vertically and horizontally), and more highly cemented zones (including zones of more consistent cementation) may be present in areas between or outside the investigated points. We therefore advise that allowance is also made for hydraulic breaking.

7.6 Site Preparation

The site preparation measures outlined below are aimed at improvement of the site in preparation for construction of buildings including on-ground slabs and shallow footings, retaining walls and pavement subgrades.

The following site preparation measures must be followed:

- Strip vegetation from the site including grubbing out of tree roots and removal of rubbish;
- Strip and stockpile topsoil from the site for potential re-use in non-structural applications

  We note that there is very little organic-rich topsoil unsuitable for structural fill present across the site. Stripping of the vegetation should be sufficient in most areas to remove any unsuitable organic rich topsoil. We consider that, after vegetation is stripped (including grubbing out of roots), all underlying sand is suitable for re-use as structural fill. True topsoil should be readily identifiable by its dark colour (as opposed to the pale coloured sands present at the site). Where doubt exists, we must be engaged to comment;
- Cut to the desired finished level.

  We note that unless there are different subsurface conditions (e.g. part-sand, part-limestone) on any given lot, there is no geotechnical requirement (in the contexts of AS2870-2011) to have a sand layer present at the site overlying limestone. However, a sand layer is commonly desired over a site to facilitate construction of

footings and service trenches. Accordingly, over-excavation may be required on some lots where limestone is present.

- Compact the exposed sandy ground to achieve the level of compaction specified in Section 7.7 to at least 0.9 m depth below areas where structures are proposed – any areas of very loose to loose soil, etc must be removed and replaced with approved fill as outlined in Section 7.8.

  Proof rolling of limestone (say 4 passes of a 10 tonne or larger padfoot roller) is recommended, however compaction testing of limestone is not required; and

- Where fill is required to build up levels, use approved fill (refer to Section 7.8), placed and compacted in layers of no greater than 300 mm loose thickness.

After compaction, verify that the required level of compaction has been achieved by testing to a minimum depth of 0.9 m:

- On each lift of fill at the rate of 1 test per 500 m^3 (approximately 1 test per 1,670 m^2, assuming a lift thickness of 0.3 m);
- At 15 m centres along retaining wall footings; and
- At 15 m centres on pavement subgrades (on the road centerline).

Note: Our experience suggests that limestone fill is not likely to be amenable to the performance specification outlined above. We suggest that a method specification for the compaction of limestone fill should be developed by field compaction trials.

7.7 Compaction

Granular fill must be compacted using suitable compaction equipment to achieve a dry density ratio of at least 95% of maximum modified dry density (MMDD) as determined in accordance with AS 1289 5.2.1. If sand is used as fill and a Perth sand penetrometer (PSP) is used for compaction control, we recommend a minimum blow count of 8 blows per 0.3 m penetration. If difficulty arises in achieving the specified PSP blow count, then a calibration must be established between PSP blow count and the *in situ* density. This will allow confirmation of the blow count required to achieve a dry density ratio of at least 95%.

Over-excavation and replacement of loose materials may be required where the minimum density cannot be achieved.

Fill must be placed in horizontal layers of not greater than 0.3 m loose thickness. Each layer must be compacted by suitable compaction equipment, and carefully controlled to ensure even compaction over the full area and depth of each layer.

Care will need to be taken when compacting in the vicinity of existing structures (i.e. during the later stages of the development). This is particularly important if vibratory compaction is being carried out. Tynan (1973)[4] provides assistance with the selection of compaction equipment for use adjacent to structures.

We note that compaction within 1 m of the groundwater table is likely to be difficult. However, due to the depth of the water table in this area, it is generally not expected to influence the earthworks. Localised difficulties may be encountered in low-lying areas (e.g. at the north-east corner), particularly during the rainy season.

[4] Tynan (1973) Ground Vibration and Damage Effects on Buildings, Australia Road Research Board, Special Report No. 11.

7.8 Approved Fill

Imported granular fill must comply with the material requirements as stated in AS 3798-2007, "Guidelines on Earthworks for Commercial and Residential Developments". Sand fill must comprise clean sand that is free of organic matter and have a fines content of less than 5%.

Generally, the clean *in situ* sand and sand fill present at the site will be suitable for re-use as inert structural fill. Any organic-rich sand or sand containing significant proportions of fines (material less than 0.075 mm in size) must not be used.

We also understand that limestone excavated at the site is potentially to be re-used as structural fill. We consider this to be generally acceptable, however we note that:

- The maximum particle size permissible in any lift of fill is 200 mm (i.e. 2/3 of the thickness of the loose layer thickness) to ensure that adequate compaction is achieved. Larger particles will either need to be broken down by track rolling, rock breaking or crushing.
- We expect that at least some of the limestone will be relatively easy to break down to suitable sizes and is likely to be graded sufficiently to produce a suitable structural fill. However, where well cemented limestone is encountered, fill may comprise poorly graded limestone cobbles and boulders. A geotechnical engineer must be engaged to inspect trial earthwork areas where such material is being placed and compacted to review and comment on the earthwork methodology so that a suitably graded structural fill can be produced.

  Our experience suggests that limestone fill is not likely to be amenable to the performance specification outlined in Section 7.7. We consider it prudent to develop a suitable method specification in consultation with the earthworks contractor.

Where doubt exists about the excavation or use of any materials on site, a geotechnical engineer must be engaged to inspect and approve the use of potential fill materials.

7.9 Use of Limestone for Basecourse and Sub-base

According to Main Roads WA (MRWA)[5], crushed Tamala Limestone has been used successfully as a subbase on several roads. While it has been used successfully as a basecourse, seal adhesion problems have occurred. MRWA therefore advise that the limestone is modified with bitumen when used as a basecourse under sprayed surface treatments. The following typical specifications are generally used:

5 Main Roads Western Australia: **A Guide to the Selection and Use of Naturally Occurring Materials as Base and Subbase in Roads in Western Australia, published November 2002**

Table 6: Typical Specification for Crushed Tamala Limestone (MRWA)

Pavement Layer	Subbase	Basecourse	Laboratory Test Data
Sieve size 75.0 26.5 19.0 4.75 2.36 1.18	% passing 95-100 55-85 36-65 	% passing 100 90-100 60-90 35-75	Not applicable as samples were not crushed prior to testing
MDCS (kPa)	≥650	≥650	750-1250 (1000)[1]
$CaCO_3$ (%)	60-85	60-85	52.8-81.6 (68.2)
LA Abrasion	20-60	20-60	51.4
Bitumen Content[2]		≥2%	-
Dry Density ratio (%)	94-95	95-96%	-
Dry Back	≤85% OMC	≤85% OMC	

Note: 1. Values given as range and (average)
2. Bitumen emulsion suggested by MRWA to be "slow setting anionic with Vinsol Resin as the emulsifying agent"

The laboratory test data suggests that with appropriate selection, crushing and screening, the limestone would be suitable for use as subbase and basecourse for the construction of lightly trafficked roads within the development.

7.10 Karst Assessment

We have not undertaken a Karst Assessment as part of the investigation. "Karst" refers to solution cavities, etc in limestone that can lead to the presence of voids or collapsing zones which have an influence on engineering works. We are aware that karstic features were identified in the Secret Harbour development.

Inspections must be undertaken during the bulk earthworks, particularly when excavation, ripping and compaction is being undertaken.

During earthworks is the most likely time for karstic features to be identified at the site. Additional work required for delineation of Karst (if any) could only be identified at that time.

7.11 Retaining Structures

Retaining structures may be designed in accordance with AS 4678-2002 "Earth-Retaining Structures". For the design of retaining structures, the following parameters are considered appropriate for retaining wall design using compacted *in situ* sand, *in situ* medium dense sand and compacted sand (and sand / limestone blends) backfill:

- angle of internal friction, $\phi = 36°$;
- coefficient of active earth pressure $K_a = 0.26$;
- coefficient of passive earth pressure $K_p = 3.85$;
- at rest coefficient of earth pressure $K_0 = 0.41$; and
- bulk density: 18 kN/m^3.

Compaction plant can augment the lateral earth pressure acting on retaining walls. Hand operated compaction equipment is recommended within 2 m of any retaining walls to minimise compaction pressures.

It is important to note that some ground movement is to be expected behind any soil retaining system, including gravity retaining walls.

7.12 Shallow Footings

We consider that shallow pad and strip footings will be suitable for supporting the proposed structures provided the site preparation measures outlined in Section 7.6 have been completed. Notwithstanding the requirements of AS2870-2011 with respect to bearing pressures, Table 7 and Table 8 present allowable bearing pressures and estimated settlements for shallow pad and strip footings respectively.

Table 7: Pad Footing Allowable Bearing Pressures and Estimated Settlements

Footing Embedment (m)	Minimum Footing Dimension (m)	Allowable Bearing Pressure (kPa)	Estimated Settlement (mm)
0.5	0.5	140	<5
	1.0	170	<5
	1.5	200	5-10
	2.0	200	5-10
	2.5	200	5-10

Table 8: Strip Footing Allowable Bearing Pressures and Estimated Settlements

Footing Embedment (m)	Footing Width (m)	Allowable Bearing Pressure (kPa)	Estimated Settlement (mm)
0.5	0.5	130	<5
	1.0	150	5-10
	1.5	175	10-15
	2.0	200	15-20
	2.5	200	15-20

Allowable bearing pressures for footings of intermediate plan dimensions to those tabulated can be interpolated. Footings that have a plan dimension either smaller or larger than those covered by the tables above will need to be considered individually along with other embedment depths. Footings carrying significant eccentric loading, such as below retaining walls, must be assessed separately. An allowable working bearing pressure of 200 kPa is considered to be an upper limit for shallow footings at this site to limit total and differential settlement.

Settlement of the proposed structures will depend upon a number of factors including the applied pressures, footing size and base preparation. The estimates of settlement provided in Table 7 and Table 8 assume that the site preparation measures detailed in Section 7.6 have been completed. The estimated settlements are for the working bearing pressure values shown. Differential settlements of up to half of the total estimated settlement values are likely between footings of similar sizes and loads. About 70% of the settlement is expected to occur during construction.

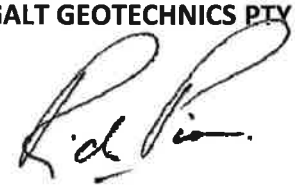
Where footings are underlain by both *in situ* limestone and sand, we advise that the limestone is over-excavated by 300 mm below the footings and replaced with sand fill to limit differential settlements.

8. CONCLUSION

We would like to draw your attention to Appendix F of this report, "Understanding your Geotechnical Engineering Report". The information provided within is intended to inform you as to what your realistic expectations of this report should be. Guidance is also provided on how to minimize risks associated with groundworks for this project. This information is provided not to reduce the level of responsibility accepted by Galt, but to ensure that all parties who rely on this report are aware of the responsibilities each assumes in so doing.

Yours Faithfully,

GALT GEOTECHNICS PTY LTD



Rick Piovesan CPEng

Geotechnical Engineer

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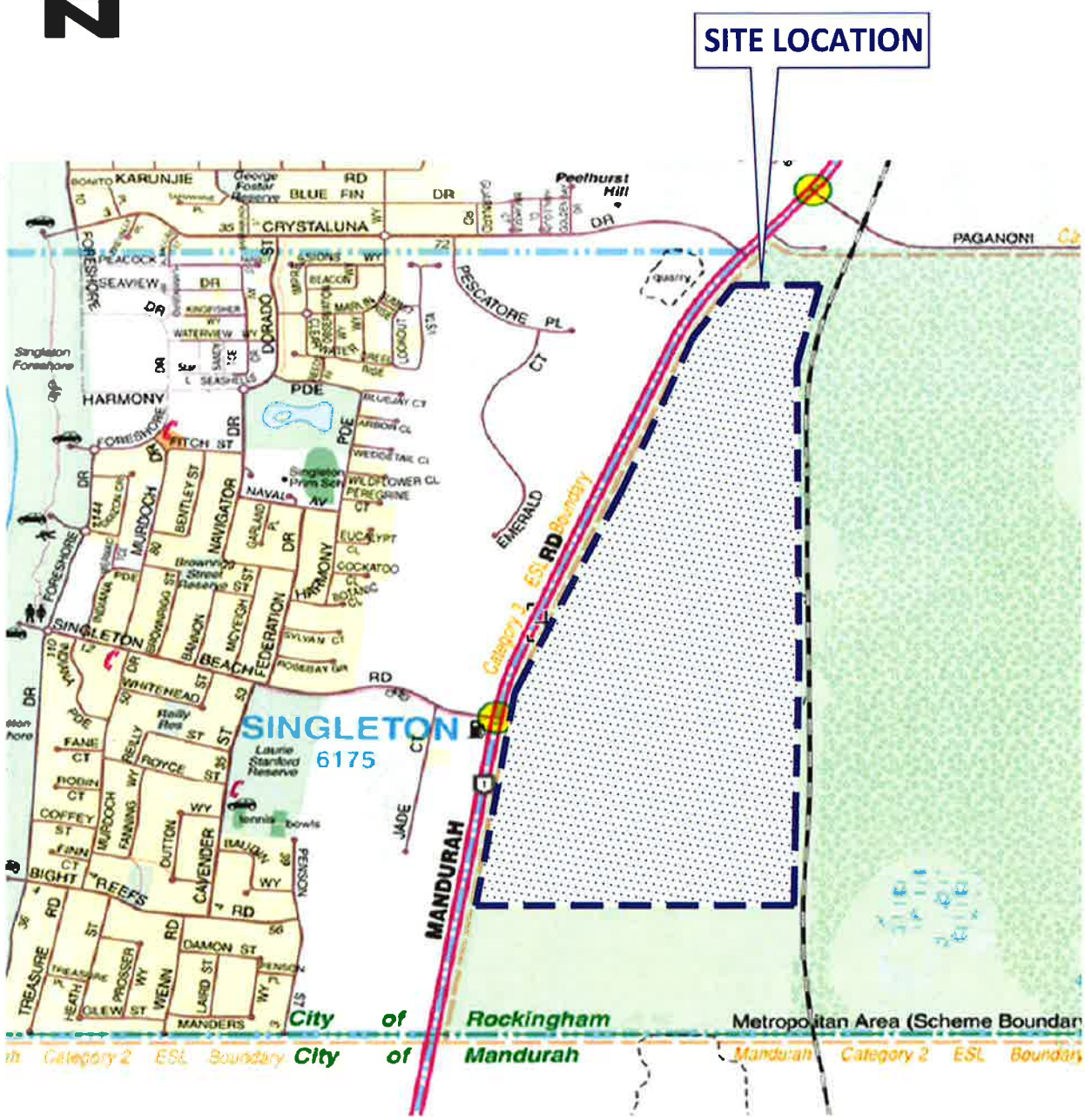

Galt GEOTECHNICS	SCALE NTS	CLIENT JDSi / Gold Right Pty Ltd	
	DRAWN AR / DATE Oct '10	PROJECT GEOTECHNICAL INVESTIGATION LOTS 3, 805 AND 806 MANDURAH RD, KARNUP	
	CHECKED JECR / DATE Oct '10		
		TITLE LOCATION PLAN	
		Job No J1001085 002 R Rev0	FIGURE 1 / A4

LEGEND

- TP1 - TEST PIT LOCATION (2011)
- P1 - INFILTROMETER TEST LOCATION (2011)
- BH1 - BOREHOLE LOCATION (2011)
- TP1 - TEST PIT LOCATION (2010)
- P1 - INFILTROMETER TEST LOCATION (2010)

NOTE - TEST LOCATIONS ARE APPROXIMATE ONLY

REV.	DESCRIPTION	DATE	CHK
0	ISSUED FOR REVIEW	15/07/11	ST

SCALE	NTS
DRAWN	DAR
DATE DRAWN	July '11
CHECKED	ST
DATE CHECKED	July '11

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CLIENT	Gold Right Pty Ltd
PROJECT	LOTS 3, 805 AND 806 MANDURAH ROAD, KARNUP
TITLE	AERIAL PLAN
Job No.	J1001085
	FIGURE 2
	A3
Rev.	0

LEGEND

- TP1 - TEST PIT LOCATION (2011)
- P1 - INFILTROMETER TEST LOCATION (2011)
- BH1 - BOREHOLE LOCATION (2011)
- TP1 - TEST PIT LOCATION (2010)
- P1 - INFILTROMETER TEST LOCATION (2010)

NOTE - TEST LOCATIONS ARE APPROXIMATE ONLY

REV.	DESCRIPTION	DATE	CHK
0	ISSUED FOR REVIEW	1507/11	ST

SCALE	NTS
DRAWN	DAR
DATE DRAWN	July '11
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Galt GEOTECHNICS
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CLIENT	Gold Right Pty Ltd
PROJECT	LOTS 3, 805 AND 806 MANDURAH ROAD, KARNUP
TITLE	SITE PLAN
Job No.	J1001085
	FIGURE 3
	A3
Rev.	0

J1001085 001 L Rev0

01 November 2010

Gold Right Pty Ltd
c/- JDSi
Suite 3, 5 Tully Road
EAST PERTH WA 6004

Attention: Steven Foley

Test Pits and Permeability Testing
Lots 805 and 806 Mandurah Road, KARNUP

Dear Steven,

1. INTRODUCTION

This letter presents Galt Geotechnics Pty Ltd's (Galt's) report on the excavation of test pits and completion of permeability tests conducted on Lots 805 and 806 Mandurah Road, Karnup. The location of the site relative to the surrounding area is shown on Figure 1, Location Plan. The work was requested by Mr Steven Tay of Gold Right Pty Ltd (Gold Right) and authorised in a Client Authorisation Form signed by Steven Tay of Gold Right on 30 September 2010.

3. SITE DESCRIPTION AND BACKGROUND

The site lies to the east of Mandurah Road. The total area is roughly triangular in shape, about 2.1 km long along Mandurah Road and about 840 m along the southern boundary. There are two quarries on the site. Typical photographs showing the various surface features are presented in Attachment A. A site plan is included as Figure 2.

We understand that a geophysical investigation has been undertaken across the site. The excavation of test pits was required to assist in calibrating the geophysical data. In addition, some permeability tests have been carried out at select locations.

4. SCOPE OF WORK

The scope of work comprised:

- excavate test pits at 10 locations, extending to a depth of 2.5 m, shallower refusal or collapse;
- logging the soils encountered;
- preparing test pit reports; and
- carrying out permeability tests using the 'inverse auger hole' technique at 5 locations, at a depth of about 0.5 m to 1.0 m below ground.

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5. FIELDWORK

Fieldwork was conducted on 15 October 2010 and comprised:

- excavation of test pits at 10 locations, extending to a maximum depth of 3.0 m; and
- permeability testing using the 'inverse auger hole' technique at five locations, at a depth of approximately 0.1 m to 0.6 m below ground.

The test locations are shown on Figure 2, Site Plan, and were located using a hand held GPS accurate to about 5 m horizontally. Details of the tests are presented in Table 1.

Table 1: Summary of Tests

Test Name	Test Depth (m)	Reason for Termination	Sand Thickness	Comments
TP01	2.1	Refusal	1.3	Sand over limestone
TP02	1.1	Refusal	0.1	Sand over limestone
TP03	1.4	Refusal	1.1	Sand over limestone
TP04	0.3	Refusal	0	Limestone
TP05	2.5	Target Depth	2.5	Sand
TP06	0.9	Refusal	0.6	Sand over limestone
TP07	1.4	Refusal	1.0	Sand over limestone
TP08	1.5	Refusal	0.1	Sand over limestone
TP09	3.0	Target Depth	3.0	Sand fill over sand
TP10	0.5	Refusal	0	Limestone
P1	0.6	Target Depth	0.6	Sand
P2	0.2	Refusal	0	Limestone
P3	0.2	Refusal	0	Limestone
P4	0.1	Refusal	0	Limestone
P5	0.1	Refusal	0	Limestone

Test pits were excavated using a rubber tyred New Holland NH95 backhoe supplied and operated by J Erskine. The backhoe was equipped with a 600 mm wide, toothed bucket. Test pit reports are presented in Attachment B, along with a list of notes and abbreviations, the method of soil description and the method of cementation classification used on the reports.

Permeability testing was carried out at five locations using the inverse auger hole method described by Cocks[1] The approximate locations of the tests were specified by JDSi and are shown on Figure 2. The results of the permeability testing are presented in Attachment C and are summarised in Table 2.

[1] Cocks, G (2007), "Disposal of Stormwater Runoff by Soakage in Perth Western Australia", Journal and News of the Australian Geomechanics Society, Volume 42 No. 3, pp 101-114

Table 2: Permeability Test Results

Test ID	Description	Depth to Base of Test (m)	Average Permeability[1], k (m/day)		
			Test 1	Test 2	Test 3
P1	In natural sands at existing surface level	0.6	12.8	10.5	9.2
P2	In limestone at existing surface level	0.2	15.1	13.6	14.5
P3	In limestone at existing surface level	0.2	11.6	9.6	8.3
P4	In limestone at existing surface level	0.1	23.8	19.1	20.1
P5	In limestone at existing surface level	0.1	21.6	20.0	19.0

Notes: 1. *Average* permeability over the duration of the test

An engineer from Galt positioned all test locations, logged the materials encountered and carried out the permeability tests.

6. SITE CONDITIONS

6.1. GEOLOGY

The Rockingham sheet of the 1:50,000 scale Environmental Geology series map indicates that the area is largely underlain by Tamala Limestone.

The expected geological conditions are in accordance with the findings of the investigation.

6.2. SUBSURFACE CONDITIONS

The subsurface conditions across the site were generally uniform and comprised:

- SAND (SP): grey and brown, fine to coarse grained, subrounded, dry to moist, loose, with/trace organics (roots), generally present from the surface to depth varying between 0.1 m and 1.3 m; overlying
- LIMESTONE: excavated as sandy GRAVEL, grey, with weakly to well cemented cobbles and boulders, fine to coarse sand and shell fragments, present from depths between surface (locally outcropping) and 1.3 m to the maximum depth of investigation (between 0.3 m and 2.1 m).

Variations did occur at TP05 and TP09, where no limestone was encountered. The subsurface conditions encountered at TP05 are summarised as:

- SAND (SP): brown, fine to coarse grained, subangular, dry, loose, with organics (roots), present from the surface to 0.1 m; overlying
- SAND (SP): brown, fine to coarse grained, subrounded to subangular, dry to moist, loose to medium dense, with grey limestone gravel, cobbles and boulders, present from 0.1 m to the maximum depth of investigation (2.5 m).

The subsurface conditions encountered at TP09 are summarised as:

- SAND and gravelly SAND (FILL): grey brown and dark brown, fine to coarse grained, subangular, dry to moist, loose to medium dense, with organics (roots)and limestone gravels and cobbles, present from the surface to a depth of 1.9 m; overlying
- SAND (SP): dark brown and brown/yellow, fine to coarse grained, subrounded, moist, loose to medium dense, with organics (roots), present from 1.9 m to the maximum depth of investigation (3.0 m).

We note that the term 'limestone' in this report describes the variably cemented coastal carbonate sediments locally referred to as "limestone" (Tamala Limestone).

6.3. GROUNDWATER

The Perth Groundwater Atlas (2003) shows the maximum groundwater level to be around RL 1 m AHD. This is within a minimum of 7 m of the current ground surface.

Groundwater was not encountered at any of the test locations.

7. CLOSURE

We trust that this information meets your present needs. Please contact us if you have any further queries.

Yours Faithfully,

GALT GEOTECHNICS PTY LTD

Joe Rola

Geotechnical Engineer

Owen Woodland CPEng

Geotechnical Engineer

Attachments: Figure 1 – Location Plan

Figure 2 – Site Plan

A – Site Photographs

B – Test Pit Reports

C – Permeability Results

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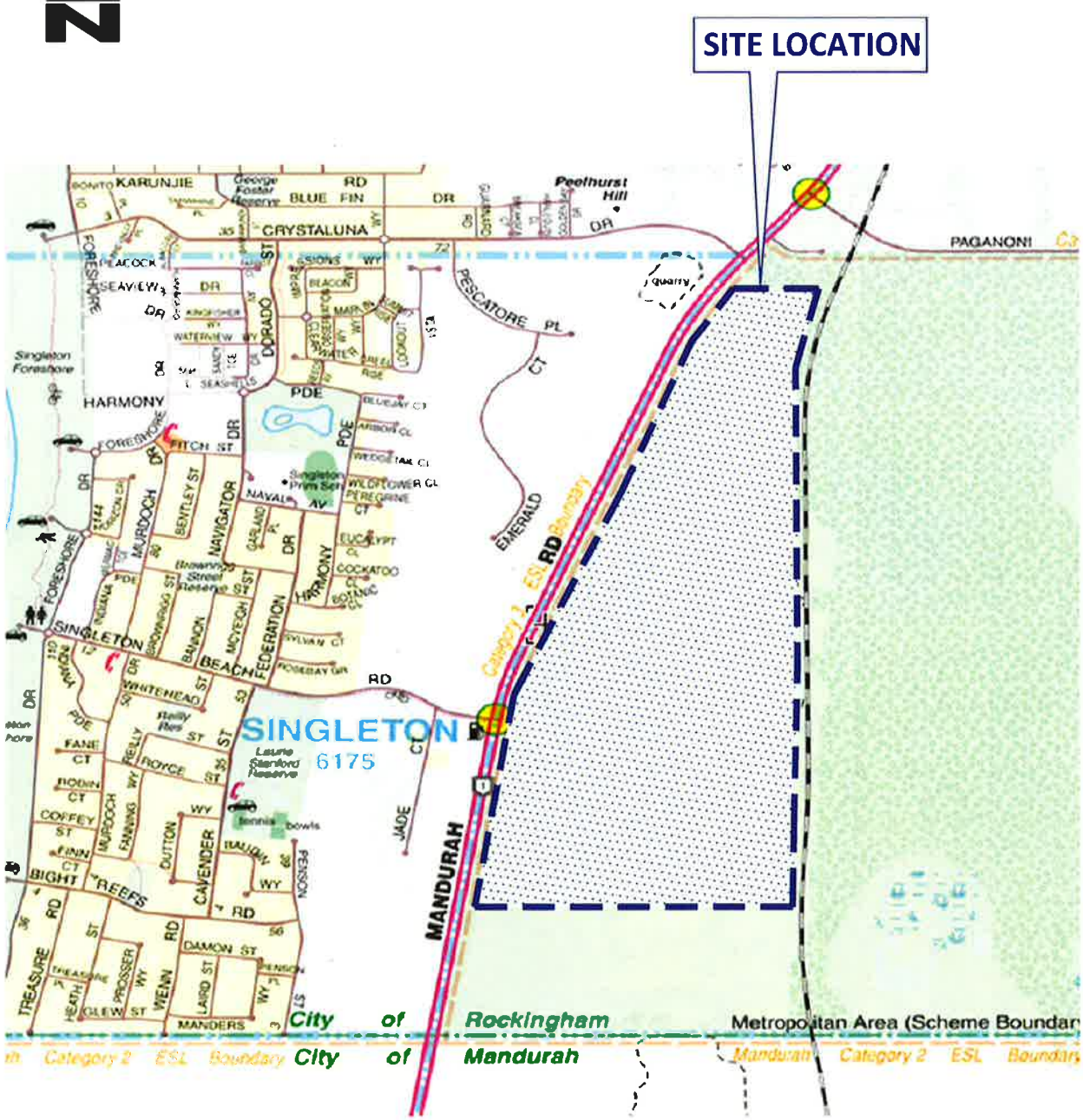

Galt GEOTECHNICS	SCALE NTS	CLIENT JDSi	
	DRAWN AR / DATE Oct '10	PROJECT TEST PITS AND PERMEABILITY TESTING LOTS 805 AND 806 MANDURAH RD, KARNUP	
	CHECKED JECR / DATE Oct '10		
		TITLE LOCATION PLAN	
		Job No J1001085	FIGURE 1 A4

LEGEND

TP01 - TEST PIT LOCATION

P01 - PERMEABILITY TEST LOCATION

TP10/P03 - COMBINED TEST PIT AND PERMEABILITY TEST LOCATION

SITE BOUNDARY

NOTE - TEST LOCATIONS ARE APPROXIMATE ONLY

REV.	DESCRIPTION	DATE	CHK
0	ISSUED FOR REVIEW	28/10/10	JECR

SCALE	NTS
DRAWN	AR
DATE DRAWN	Oct '10
CHECKED	JECR
DATE CHECKED	Oct '10

Galt GEOTECHNICS

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CLIENT	JDSi
PROJECT	TEST PITS AND PERMEABILITY TESTING LOTS 805 AND 806 MANDURAH RD, KARNUP
TITLE	SITE PLAN
Job No.	J1001085

FIGURE 2 | A3 | Rev. 0

ATTACHMENT A

Site Photographs

Photograph 1: View looking north from TP08

Photograph 2: View looking south from TP08

Photograph 3: Backfilling TP09

Photograph 4: View looking east from TP09

ATTACHMENT B

Test Pit Reports

METHOD OF SOIL DESCRIPTION
BOREHOLE AND TEST PIT REPORTS

GRAPHIC LOG & UNIFIED SOIL CLASSIFICATION SYSTEM (USCS) SYMBOLS

Graphic	USCS	Soil Name
		FILL (various types)
		BOULDERS and/or COBBLES
	GP	GRAVEL (poorly graded)
	GW	GRAVEL (well graded)
	SP	SAND (poorly graded
	SW	SAND (well graded)

Graphic	USCS	Soil Name
	ML	SILT (low liquid limit)
	MH	SILT (high liquid limit)
	CL	CLAY (low plasticity)
	CI	CLAY (medium plasticity)
	CH	CLAY (high plasticity)
	OL	Organic SILT (low liquid limit)
	OH	Organic SILT (high liquid limit)

RESISTANCE TO EXCAVATION

Symbol	Term	Description
VL	Very low	All resistances are relative to the selected method of excavation
L	Low	
M	Medium	
H	High	
VH	Very high	

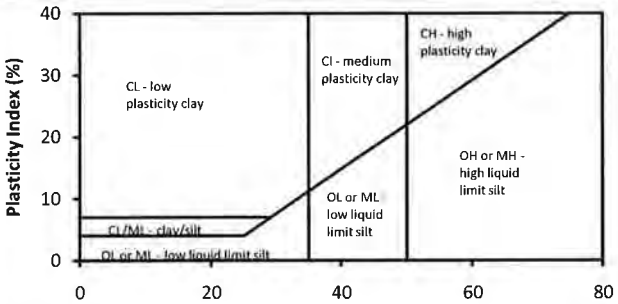
SOIL CLASSIFICATION AND INFERRED STRATIGRAPHY

Soil descriptions are based on AS1726-1993, Appendix A. Material properties are assessed in the field by visual/tactile methods in combination with field testing techniques (where used).

PARTICLE SIZE

Soil Name		Particle Size (mm)
BOULDERS		>200
COBBLES		63 to 200
GRAVEL	Coarse	20 to 63
	Medium	6 to 20
	Fine	2 to 6
SAND	Coarse	0.6 to 2.0
	Medium	0.2 to 0.6
	Fine	0.075 to 0.2
FINES	SILT	0.002 to 0.075
	CLAY	<0.002

PLASTICITY PROPERTIES



MOISTURE CONDITION

AS1726-1993

Symbol	Term	Description
D	Dry	Sands and gravels are free flowing. Clays and silts may be brittle or friable and powdery.
M	Moist	Soils are darker than in the dry condition and may feel cool. Sands and gravels tend to cohere.
W	Wet	Soils exude free water. Sands and gravels tend to cohere.

CONSISTENCY AND DENSITY

AS1726-1993 and HB160-2006

Symbol	Term	Undrained Shear Strength (kPa)	SPT "N"	DCP blows per 100 mm
VS	Very Soft	0 to 12	0 to 2	<1
S	Soft	12 to 25	2 to 4	<1
F	Firm	25 to 50	4 to 8	1 to 2
St	Stiff	50 to 100	8 to 15	3 to 4
VSt	Very Stiff	100 to 200	15 to 30	5 to 10
H	Hard	>200	>30	>10

Symbol	Term	Density Index (%)	SPT "N"	DCP blows per 100 mm	PSP Blows per 300 mm
VL	Very Loose	<15	0 to 4	<1	0 to 2
L	Loose	15 to 35	4 to 10	1 to 2	2 to 6
MD	Medium Dense	35 to 65	10 to 30	2 to 3	6 to 8
D	Dense	65 to 85	30 to 50	4 to 8	8 to 15
VD	Very Dense	>85	>50	>8	>15

Note: PSP correlations only valid to 450 mm depth

Consistency and density may also be inferred from excavation performance and material behaviour.

EXPLANATORY NOTES TO BE READ WITH BOREHOLE AND TEST PIT REPORTS

Galt GEOTECHNICS

METHOD OF DRILLING OR EXCAVATION

AC	Air Core	E	Excavator	PQ3	PQ3 Core Barrel
AD/T	Auger Drilling with TC-Bit	EH	Excavator with Hammer	PT	Push Tube
AD/V	Auger Drilling with V-Bit	HA	Hand Auger	R	Ripper
AT	Air Track	HMLC	HMLC Core Barrel	RR	Rock Roller
B	Bulldozer Blade	HQ3	HQ3 Core Barrel	SON	Sonic Rig
BH	Backhoe Bucket	N	Natural Exposure	SPT	Driven SPT
CT	Cable Tool	NMLC	NMLC Core Barrel	WB	Washbore
DT	Diatube	PP	Push Probe	X	Existing Excavation

SUPPORT

T	Timbering

PENETRATION EFFORT (RELATIVE TO THE EQUIPMENT USED)

VE	Very Easy	E	Easy	F	Firm
H	Hard	VH	Very Hard		

WATER

10 Oct 09	Water Level on Date Shown		Water Inflow
			Water Outflow
			Water Level

SAMPLING AND TESTING

B	Bulk Disturbed Sample	P	Piston Sample
BLK	Block Sample	PBT	Plate Bearing Test
C	Core Sample	U	Undisturbed Push-in Sample
CBR	CBR Mould Sample		U50: 50 mm diameter
D	Small Disturbed Sample	SPT	Standard Penetration Test
ES	Environmental Soil Sample		Example: 3, 4, 5 N=9
EW	Environmental Water Sample		3,4,5: Blows per 150 mm
G	Gas Sample		N=9: Blows per 300 mm after
HP	Hand Penetrometer		150 mm seating interval
LB	Large Bulk Disturbed Sample	VS	Vane Shear; P = Peak
M	Mazier Type Sample		R = Remoulded (kPa)
MC	Moisture Content Sample	W	Water Sample

ROCK CORE RECOVERY

TCR = Total Core Recovery (%) $= \frac{CRL}{TCL} \times 100$

SCR = Solid Core Recovery (%) $= \frac{CCR}{TCL} \times 100$

RQD = Rock Quality Designation (%) $= \frac{ALC>100}{TCL} \times 100$

TCL	Length of Core Run
CRL	Recovered Length of Core
CCR	Total Length of Cylindrical Pieces of Core Recovered
ALC>100	Total Length of Axial Lengths of Core Greater than 100 mm Long

METHOD OF CEMENTATION CLASSIFICATION BOREHOLE AND TEST PIT REPORTS

Cementation Classification System For Cemented Granular Materials

Cementation Classification	Description
Uncemented	No cementation present
Very weakly Cemented	Near uncemented sand
Weakly Cemented	Very soft rock, crushed between fingers
Moderately Cemented	Soft rock, easily scratched, generally friable, rock core can be broken by hand
Well Cemented	Hard rock, can be scratched with thumbnail, requires substantial hand effort to break core
Very well cemented	Typically very hard rock, cannot be scratched easily, core can be broken with blow from hammer

REPORT OF TEST PIT — TP01

PROJECT DETAILS

Job Number: J1001085
Client: JDSi
Project: Test Pits and Permeability Testing
Location: Lots 805 and 806 Mandurah Road

SPATIAL DETAILS

Position: See Plan
Easting (m): 384167
Northing (m): 6409949
Datum: MGA94 Zone 50
Surface RL (m):

DRILLING DETAILS

Logged: JECR — Logged Date: 15/10/2010
Checked: ORW — Checked Date: 01/11/2010
TP Width (m): 0.6 — TP Length (m): 3
Machine: NH95 Backhoe — Bucket: 600 mm
Contractor: Erskine — Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0–0.2	VE					SAND: grey, fine to medium grained, sub-round, with silts, with organics (roots)	D			0.0–0.2
0.2–1.2	E				SP	SAND: brown, fine to coarse grained, sub-round, trace organics (roots)	M	L		0.2–1.2
1.2–2.0	H					LIMESTONE: excavated as Sandy GRAVEL, grey, with weakly to well cemented cobbles and boulders, fine to coarse grained sub-round sand, with shell fragments	D-M	D		1.2–2.0
2.0–3.8										2.0–3.8

End of test pit at 2.1 m
Refusal
No groundwater encountered

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

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REPORT OF TEST PIT **TP02**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 383849	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6409347	TP Width (m): 0.6 — TP Length (m): 3
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0	E				SP	SAND: brown/grey, fine to coarse grained, sub-angular, with organics (roots)	D-M	L		0.0
0.2	F-H					LIMESTONE: excavated as Sandy GRAVEL, grey, with weakly to well cemented cobbles, fine to coarse grained sub-round sand, with shell fragments and pockets of SAND, brown, moist, fine to coarse grained, loose, sub-round		MD-D		0.2
0.4										0.4
0.6										0.6
0.8										0.8
1.0										1.0
1.2										1.2
1.4										1.4
1.6										1.6
1.8										1.8
2.0										2.0
2.2										2.2
2.4										2.4
2.6										2.6
2.8										2.8
3.0										3.0
3.2										3.2
3.4										3.4
3.6										3.6
3.8										3.8

End of test pit at 1.1 m
Refusal
No groundwater encountered

See Explanatory Notes and Method of Soil Description sheets for details of abbreviations and basis of descriptions

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PHOTOGRAPHS OF TEST PIT **TP02**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 383849	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6409347	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

TP02

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

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REPORT OF TEST PIT TP03

PROJECT DETAILS

Job Number: J1001085
Client: JDSi
Project: Test Pits and Permeability Testing
Location: Lots 805 and 806 Mandurah Road

SPATIAL DETAILS

Position: See Plan
Easting (m): 384076
Northing (m): 6409193
Datum: MGA94 Zone 50
Surface RL (m):

DRILLING DETAILS

Logged: JECR Logged Date: 15/10/2010
Checked: ORW Checked Date: 01/11/2010
TP Width (m): 0.6 TP Length (m): 3
Machine: NH95 Backhoe Bucket: 600 mm
Contractor: Erskine Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0	E				SP	SAND: brown/grey, fine to coarse grained, sub-angular, with organics (roots)	D-M	L		0.0
0.2						SAND: brown, fine to coarse grained, sub-round, trace organics (roots)	M			0.2
0.4										0.4
0.6										0.6
0.8										0.8
1.0										1.0
1.2	H					LIMESTONE: excavated as Sandy GRAVEL, grey, with weakly to well cemented cobbles and boulders, fine to coarse grained sub-round sand, with shell fragments	D-M	D		1.2
1.4										1.4
1.6										1.6
1.8										1.8
2.0										2.0
2.2										2.2
2.4										2.4
2.6										2.6
2.8										2.8
3.0										3.0
3.2										3.2
3.4										3.4
3.6										3.6
3.8										3.8

End of test pit at 1.4 m
Refusal
No groundwater encountered

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

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PHOTOGRAPHS OF TEST PIT **TP03**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384076	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6409193	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

TP03

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

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REPORT OF TEST PIT **TP04**

PROJECT DETAILS

Job Number: J1001085
Client: JDSi
Project: Test Pits and Permeability Testing
Location: Lots 805 and 806 Mandurah Road

SPATIAL DETAILS

Position: See Plan
Easting (m): 384459
Northing (m): 6409253
Datum: MGA94 Zone 50
Surface RL (m):

DRILLING DETAILS

Logged: JECR — Logged Date: 15/10/2010
Checked: ORW — Checked Date: 01/11/2010
TP Width (m): 0.6 — TP Length (m): 3
Machine: NH95 Backhoe — Bucket: 600 mm
Contractor: Erskine — Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0	H					LIMESTONE: excavated as Sandy GRAVEL, grey, with weakly to well cemented cobbles and boulders, fine to coarse grained sub-round sand, with shell fragments	D-M	D		0.0
0.2										0.2
0.4										0.4
0.6										0.6
0.8										0.8
1.0										1.0
1.2										1.2
1.4										1.4
1.6										1.6
1.8										1.8
2.0										2.0
2.2										2.2
2.4										2.4
2.6										2.6
2.8										2.8
3.0										3.0
3.2										3.2
3.4										3.4
3.6										3.6
3.8										3.8

End of test pit at 0.3 m
Refusal
No groundwater encountered

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

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PHOTOGRAPHS OF TEST PIT **TP04**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384459	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6409253	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

TP04

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

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REPORT OF TEST PIT — TP05

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384563	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6409682	TP Width (m): 0.6 — TP Length (m): 3
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0	E				SP	SAND: brown, fine to coarse grained, sub-angular, with organics (roots)	D	L		0.0
0.2						SAND: brown, fine to coarse grained, sub-round to sub-angular, with weakly to well cemented gravel, cobble and boulder sized grey limestone fragments	D-M	L-MD		0.2
0.4										0.4
0.6										0.6
0.8										0.8
1.0										1.0
1.2										1.2
1.4										1.4
1.6										1.6
1.8										1.8
2.0										2.0
2.2										2.2
2.4										2.4
2.6										2.6
2.8										2.8
3.0										3.0
3.2										3.2
3.4										3.4
3.6										3.6
3.8										3.8

End of test pit at 2.5 m
Target depth
No groundwater encountered

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

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PHOTOGRAPHS OF TEST PIT **TP05**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384563	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6409682	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

TP05

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

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REPORT OF TEST PIT — TP06

PROJECT DETAILS

Job Number: J1001085
Client: JDSi
Project: Test Pits and Permeability Testing
Location: Lots 805 and 806 Mandurah Road

SPATIAL DETAILS

Position: See Plan
Easting (m): 384455
Northing (m): 6410106
Datum: MGA94 Zone 50
Surface RL (m):

DRILLING DETAILS

Logged: JECR — Logged Date: 15/10/2010
Checked: ORW — Checked Date: 01/11/2010
TP Width (m): 0.6 — TP Length (m): 3
Machine: NH95 Backhoe — Bucket: 600 mm
Contractor: Erskine — Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0	VE				SP	SAND: grey, fine to coarse grained, sub-angular, with organics (roots), trace silt	D	L		0.0
0.2										0.2
0.4	E					SAND: brown, fine to coarse grained, sub-round, trace organics (roots)	M			0.4
0.6	H					LIMESTONE: excavated as Sandy GRAVEL, grey, with weakly to well cemented cobbles and boulders, fine to coarse grained sub-round sand, with shell fragments	D-M	D		0.6
0.8										0.8
1.0										1.0
1.2										1.2
1.4										1.4
1.6										1.6
1.8										1.8
2.0										2.0
2.2										2.2
2.4										2.4
2.6										2.6
2.8										2.8
3.0										3.0
3.2										3.2
3.4										3.4
3.6										3.6
3.8										3.8

End of test pit at 0.9 m
Refusal
No groundwater encountered

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

PHOTOGRAPHS OF TEST PIT **TP06**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384455	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410106	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

TP06

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

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REPORT OF TEST PIT — TP07

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384217	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410380	TP Width (m): 0.6 — TP Length (m): 3
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0	VE					SAND: grey/brown, fine to coarse grained, sub-angular, with organics (roots)	D			0.0
0.2	E				SP	SAND: brown, fine to coarse grained, sub-round, trace organics (roots)	M	L		0.2
0.4										0.4
0.6										0.6
0.8										0.8
1.0	H					LIMESTONE: excavated as Sandy GRAVEL, grey, with weakly to well cemented cobbles and boulders, fine to coarse grained sub-round sand, with shell fragments	D	D		1.0
1.2										1.2
1.4						End of test pit at 1.4 m Refusal No groundwater encountered				1.4
1.6										1.6
1.8										1.8
2.0										2.0
2.2										2.2
2.4										2.4
2.6										2.6
2.8										2.8
3.0										3.0
3.2										3.2
3.4										3.4
3.6										3.6
3.8										3.8

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

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PHOTOGRAPHS OF TEST PIT **TP07**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384217	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410380	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

TP07

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

REPORT OF TEST PIT — TP08

PROJECT DETAILS

Job Number: J1001085
Client: JDSi
Project: Test Pits and Permeability Testing
Location: Lots 805 and 806 Mandurah Road

SPATIAL DETAILS

Position: See Plan
Easting (m): 384387
Northing (m): 6410255
Datum: MGA94 Zone 50
Surface RL (m):

DRILLING DETAILS

Logged: JECR — Logged Date: 15/10/2010
Checked: ORW — Checked Date: 01/11/2010
TP Width (m): 0.6 — TP Length (m): 3
Machine: NH95 Backhoe — Bucket: 600 mm
Contractor: Erskine — Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0	VE				SP	SAND: grey, fine to coarse grained, sub-angular, with organics (roots)	D	L		0.0
0.2						LIMESTONE: excavated as Sandy GRAVEL, grey, with weakly to well cemented cobbles and boulders, fine to coarse grained sub-round sand, with shell fragments				0.2
0.4										0.4
0.6										0.6
0.8	H							D		0.8
1.0										1.0
1.2										1.2
1.4										1.4
1.6										1.6
1.8										1.8
2.0										2.0
2.2										2.2
2.4										2.4
2.6										2.6
2.8										2.8
3.0										3.0
3.2										3.2
3.4										3.4
3.6										3.6
3.8										3.8

End of test pit at 1.5 m
Refusal
No groundwater encountered

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

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PHOTOGRAPHS OF TEST PIT **TP08**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384387	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410255	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

TP08

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

REPORT OF TEST PIT — TP09

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384525	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410711	TP Width (m): 0.6 — TP Length (m): 3
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0	E				SP	SAND (FILL): grey, medium to coarse grained, sub-round, with limestone gravel, fine to coarse grained, with organics (roots)	D	L		0.0
0.2						Gravelly SAND (FILL): grey, brown and dark brown, fine to coarse grained sand, fine to coarse limestone sized gravel, with cobbles, trace orangics (roots), trace plastic and rubble waste	D-M	L-MD		0.2
0.4										0.4
0.6										0.6
0.8										0.8
1.0										1.0
1.2										1.2
1.4										1.4
1.6										1.6
1.8										1.8
2.0						SAND: dark brown, fine to coarse grained, sub-round, with organics (roots)	M			2.0
2.2						SAND: brown/yellow, fine to coarse grained, sub-round				2.2
2.4										2.4
2.6										2.6
2.8										2.8
3.0						End of test pit at 3.0 m Target depth No groundwater encountered				3.0
3.2										3.2
3.4										3.4
3.6										3.6
3.8										3.8

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

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PHOTOGRAPHS OF TEST PIT **TP09**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384525	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410711	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

TP09

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

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REPORT OF TEST PIT — TP10

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 383947	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6409684	TP Width (m): 0.6 — TP Length (m): 3
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0						LIMESTONE: excavated as Sandy GRAVEL, grey, with weakly to well cemented cobbles and boulders, fine to coarse sub-round sand, with shell fragments, with organics 0 to 0.1 m	D	D		0.0
0.2										0.2
0.4										0.4
0.6										0.6
0.8										0.8
1.0										1.0
1.2										1.2
1.4										1.4
1.6										1.6
1.8										1.8
2.0										2.0
2.2										2.2
2.4										2.4
2.6										2.6
2.8										2.8
3.0										3.0
3.2										3.2
3.4										3.4
3.6										3.6
3.8										3.8

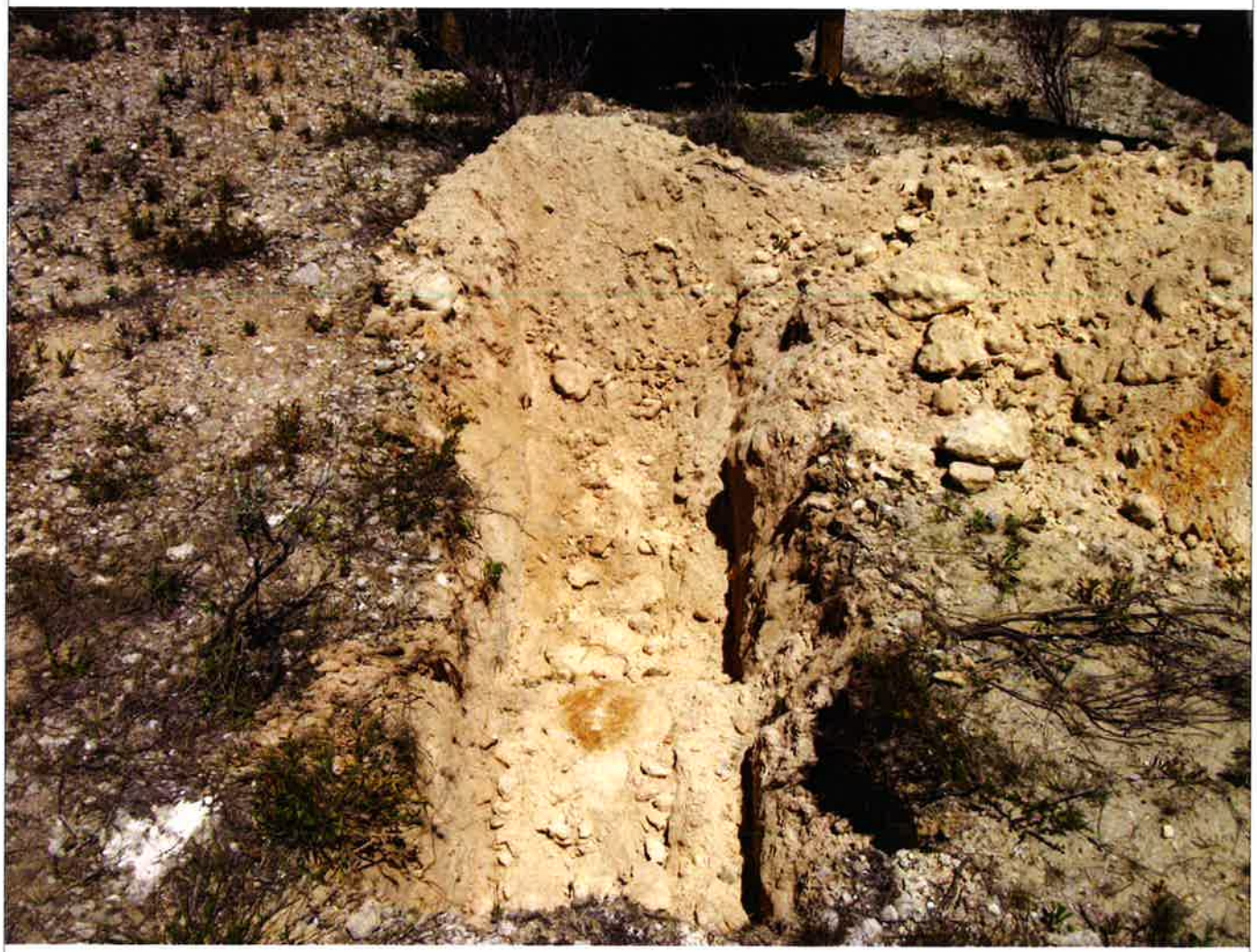
End of test pit at 0.5 m
Refusal
No groundwater encountered

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

PHOTOGRAPHS OF TEST PIT **TP10**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 383947	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6409684	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine



TP10

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

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ATTACHMENT C

Permeability Result

Permeability Calculation - Inverse Auger Hole Method

Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09

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

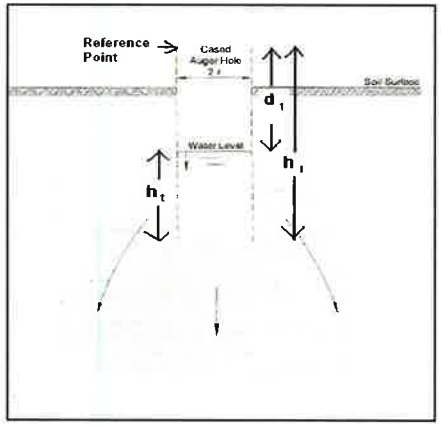
Job No:	J1001085
Client:	JDSi
Site:	Lots 805 and 806
Location:	Mandurah Rd, Kamup
Calc by:	JECR 21-Oct-10
BH Name:	P1

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

Spreadsheet Legend

	Required input
	Calculated field
	Comment field
X	Field not used
	Fixed field

Parameter	Description	Value	Units
K	Permeability		m/s
r	radius of test hole	0.055	m
t	time since start of measurement		s
h_r	reference point height above base	0.96	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m



Test 1

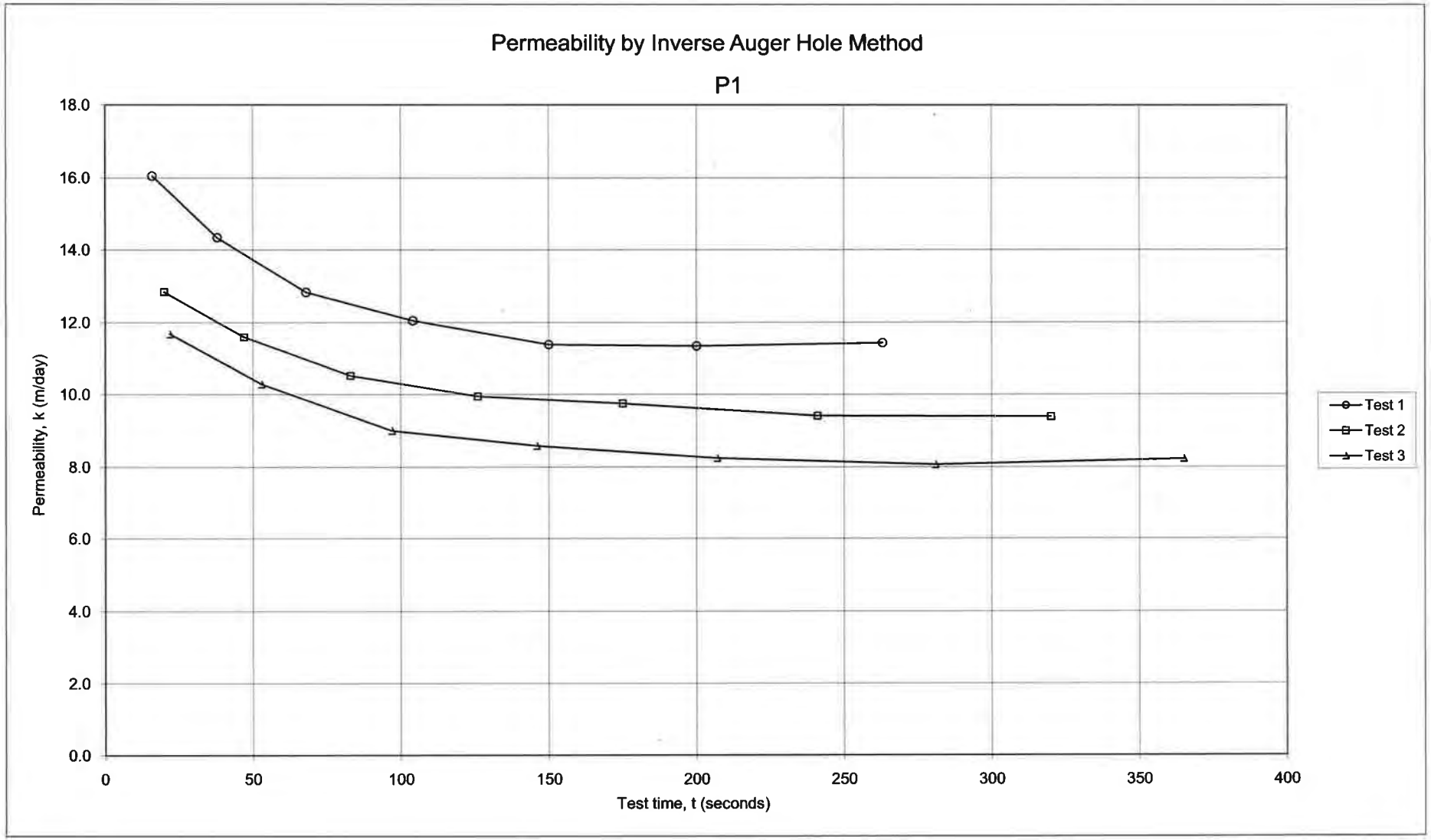
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.5	0.46		
16	0.55	0.41	1.9E-04	16.1
38	0.6	0.36	1.7E-04	14.3
68	0.65	0.31	1.5E-04	12.8
104	0.7	0.26	1.4E-04	12.1
150	0.75	0.21	1.3E-04	11.4
200	0.8	0.16	1.3E-04	11.3
263	0.85	0.11	1.3E-04	11.4
		AVERAGE	1.5E-04	12.8

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.5	0.46		
20	0.55	0.41	1.5E-04	12.8
47	0.6	0.36	1.3E-04	11.6
83	0.65	0.31	1.2E-04	10.5
126	0.7	0.26	1.2E-04	9.9
175	0.75	0.21	1.1E-04	9.8
241	0.8	0.16	1.1E-04	9.4
320	0.85	0.11	1.1E-04	9.4
		AVERAGE	1.2E-04	10.5

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.5	0.46		
22	0.55	0.41	1.4E-04	11.7
53	0.6	0.36	1.2E-04	10.3
97	0.65	0.31	1.0E-04	9.0
146	0.7	0.26	9.9E-05	8.6
207	0.75	0.21	9.5E-05	8.2
281	0.8	0.16	9.3E-05	8.1
365	0.85	0.11	9.5E-05	8.2
		AVERAGE	1.1E-04	9.2



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Permeability Calculation - Inverse Auger Hole Method

Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09

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

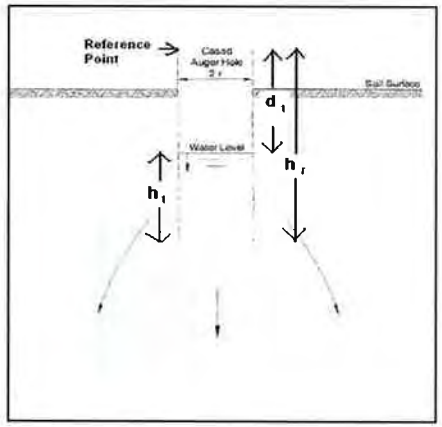
Job No:	J1001085
Client:	JDSi
Site:	Lots 805 and 806
Location:	Mandurah Rd, Karnup
Calc by:	JECR 21-Oct-10
BH Name:	P2

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

Spreadsheet Legend

	Required input
	Calculated field
	Comment field
X	Field not used
	Fixed field

Parameter	Description	Value	Units
K	Permeability	X	m/s
r	radius of test hole	0.055	m
t	time since start of measurement	X	s
h_r	reference point height above base	0.51	m
d_t	depth from reference point to water at time t	X	m
h_t	Water column height at time t	X	m
h_0	h_t at t=0	X	m



Test 1

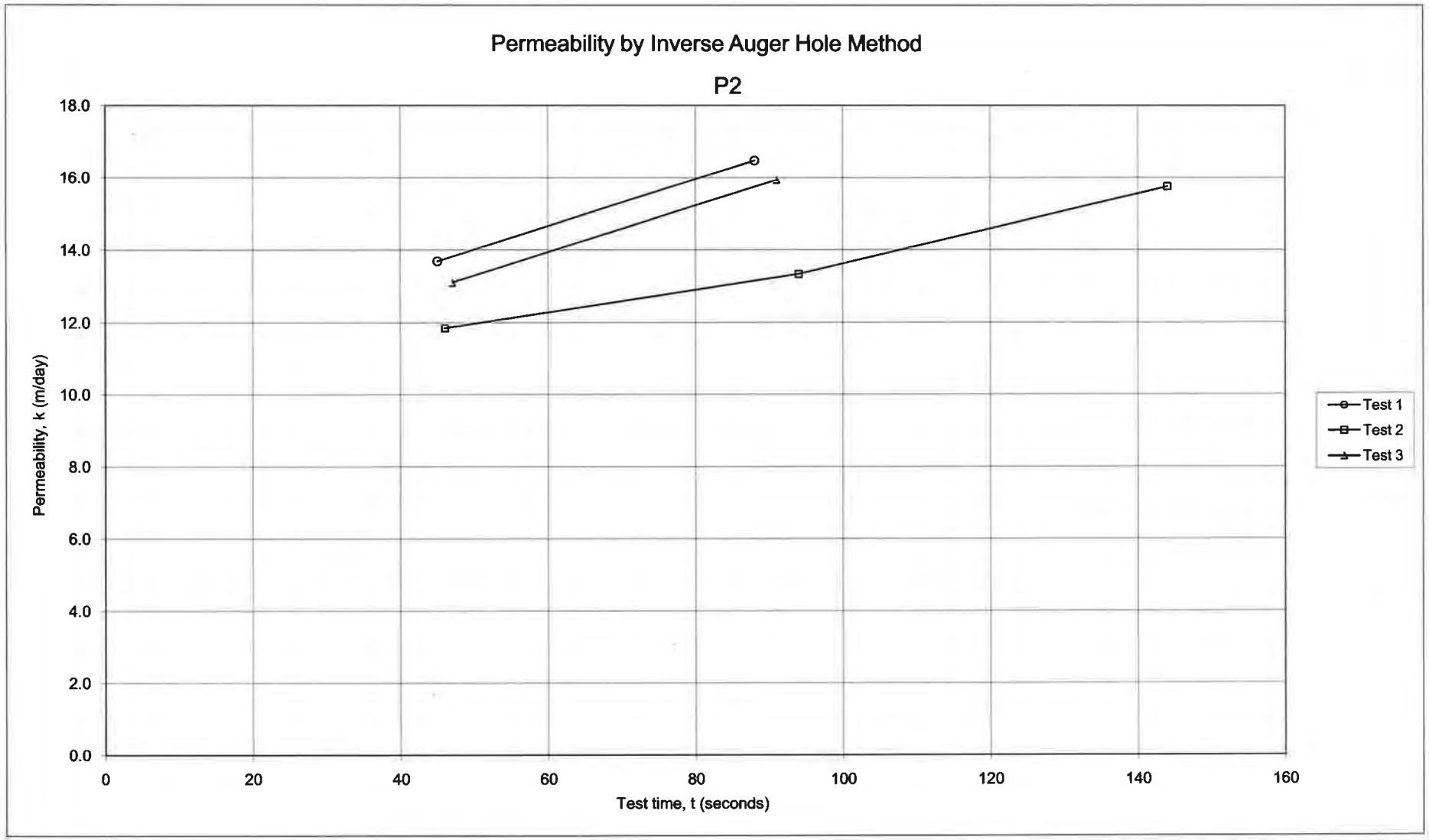
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.45	0.06	X	X
45	0.47	0.04	1.6E-04	13.7
88	0.49	0.02	1.9E-04	16.5
		AVERAGE	1.7E-04	15.1

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.44	0.07	X	X
46	0.46	0.05	1.4E-04	11.8
94	0.48	0.03	1.5E-04	13.3
144	0.5	0.01	1.8E-04	15.7
		AVERAGE	1.6E-04	13.6

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.45	0.06	X	X
47	0.47	0.04	1.5E-04	13.1
91	0.49	0.02	1.8E-04	15.9
		AVERAGE	1.7E-04	14.5



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Permeability Calculation - Inverse Auger Hole Method

Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09

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

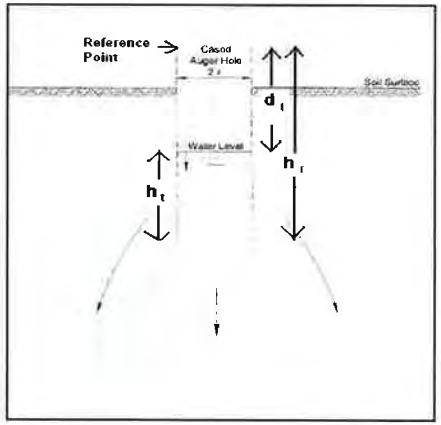
Job No:	J1001085
Client:	JDSi
Site:	Lots 805 and 806
Location:	Mandurah Rd, Kamup
Calc by:	JECR 21-Oct-10
BH Name:	P3

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

Spreadsheet Legend

	Required input
	Calculated field
	Comment field
X	Field not used
	Fixed field

Parameter	Description	Value	Units
K	Permeability	X	m/s
r	radius of test hole	0.055	m
t	time since start of measurement	X	s
h_r	reference point height above base	0.53	m
d_t	depth from reference point to water at time t	X	m
h_t	Water column height at time t	X	m
h_0	h_t at t=0	X	m



Test 1

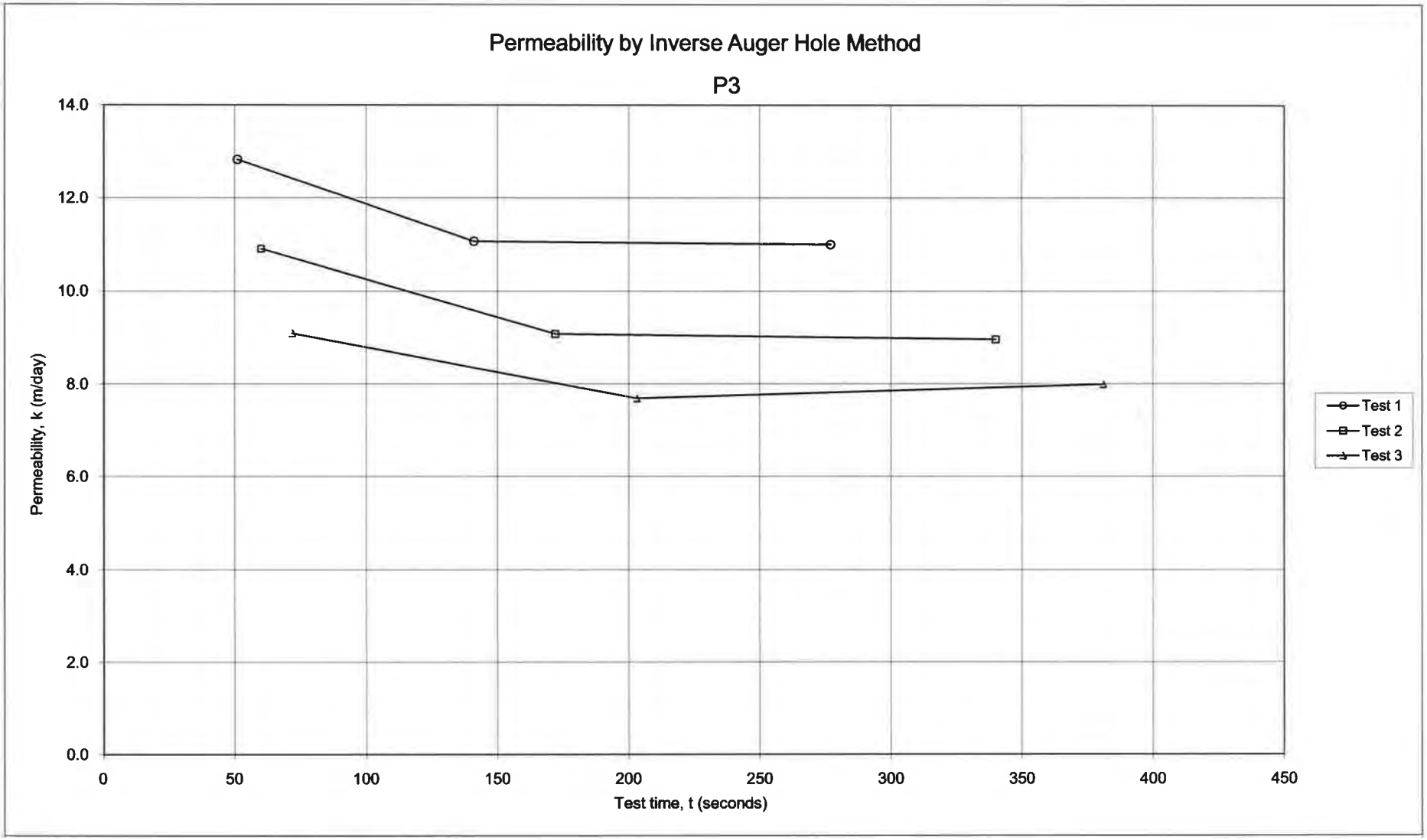
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.35	0.18	X	X
51	0.4	0.13	1.5E-04	12.8
141	0.45	0.08	1.3E-04	11.1
277	0.5	0.03	1.3E-04	11.0
		AVERAGE	1.3E-04	11.6

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.35	0.18	X	X
60	0.4	0.13	1.3E-04	10.9
172	0.45	0.08	1.1E-04	9.1
340	0.5	0.03	1.0E-04	9.0
		AVERAGE	1.1E-04	9.6

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.35	0.18	X	X
72	0.4	0.13	1.1E-04	9.1
203	0.45	0.08	8.9E-05	7.7
381	0.5	0.03	9.3E-05	8.0
		AVERAGE	9.6E-05	8.3



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Permeability Calculation - Inverse Auger Hole Method

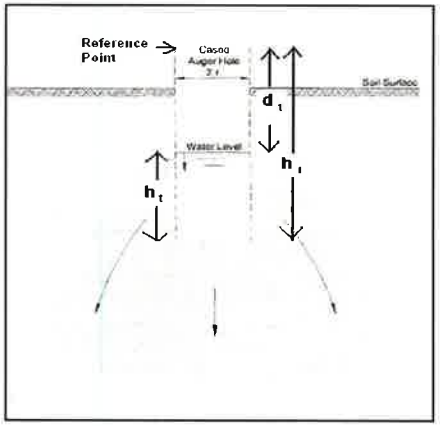
Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09

Job No:	J1001085
Client:	JDSi
Site:	Lots 805 and 806
Location:	Mandurah Rd, Karnup
Calc by:	JECR 21-Oct-10
BH Name:	P4

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

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



Spreadsheet Legend

	Required input
	Calculated field
	Comment field
	Field not used
	Fixed field

Parameter	Description	Value	Units
K	Permeability		m/s
r	radius of test hole	0.055	m
t	time since start of measurement		s
h_r	reference point height above base	0.52	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

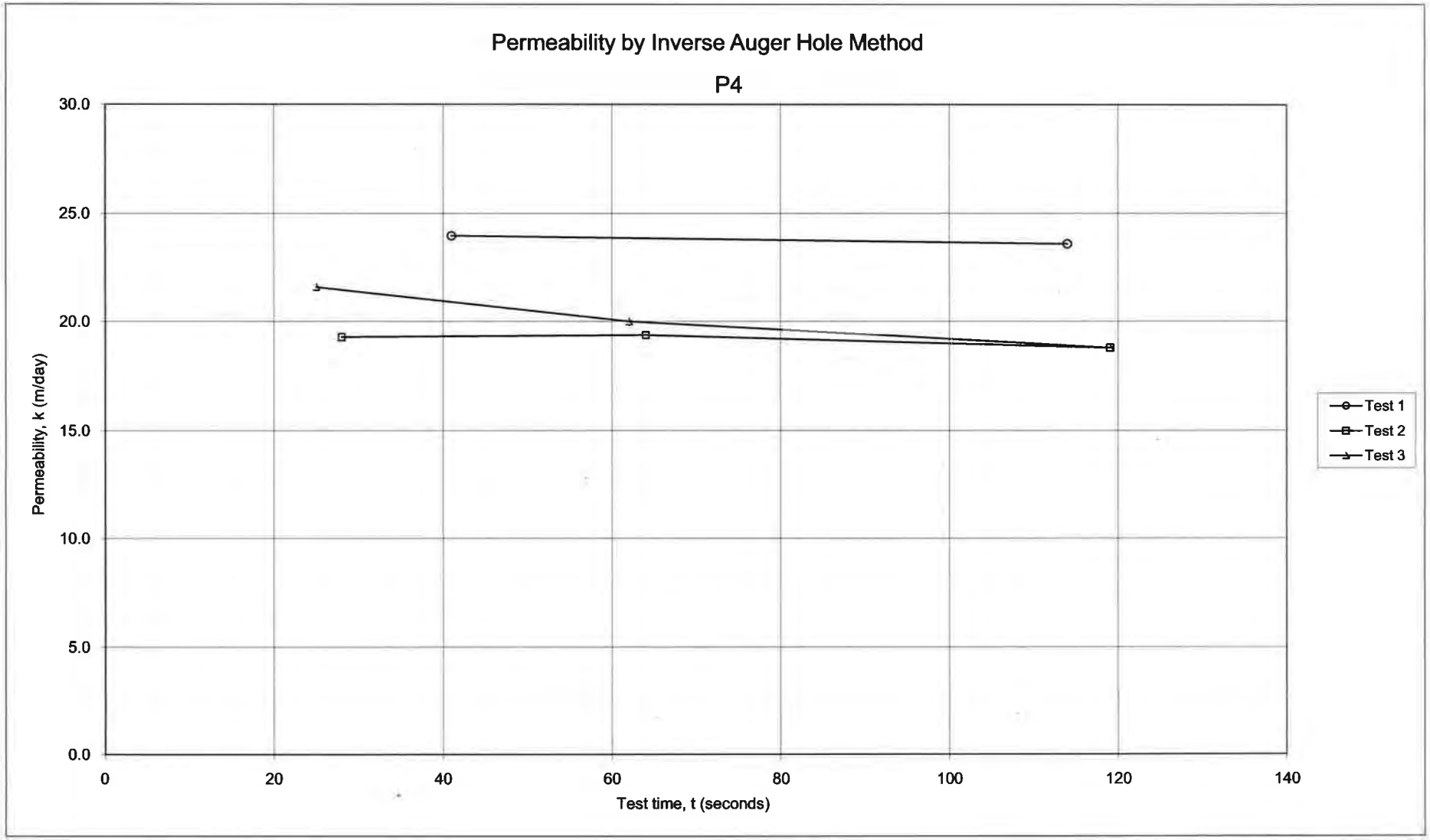
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.4	0.12		
41	0.45	0.07	2.8E-04	24.0
114	0.5	0.02	2.7E-04	23.6
		AVERAGE	2.8E-04	23.8

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.4	0.12		
28	0.43	0.09	2.2E-04	19.3
64	0.46	0.06	2.2E-04	19.4
119	0.49	0.03	2.2E-04	18.8
		AVERAGE	2.2E-04	19.1

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.4	0.12		
25	0.43	0.09	2.5E-04	21.6
62	0.46	0.06	2.3E-04	20.0
119	0.49	0.03	2.2E-04	18.8
		AVERAGE	2.3E-04	20.1



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Permeability Calculation - Inverse Auger Hole Method

Galt Geotechnics

Spreadsheet author:	ORW	17-Oct-09

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

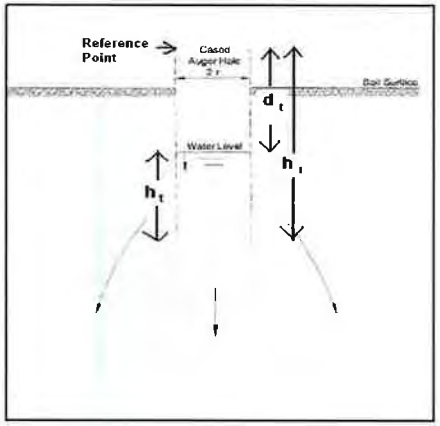
Job No:	J1001085
Client:	JDSi
Site:	Lots 805 and 806
Location:	Mandurah Rd, Karnup
Calc by:	JECR 21-Oct-10
BH Name:	P5

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

Spreadsheet Legend

	Required input
	Calculated field
	Comment field
	Field not used
	Fixed field

Parameter	Description	Value	Units
K	Permeability		m/s
r	radius of test hole	0.055	m
t	time since start of measurement		s
h_r	reference point height above base	0.51	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m



Test 1

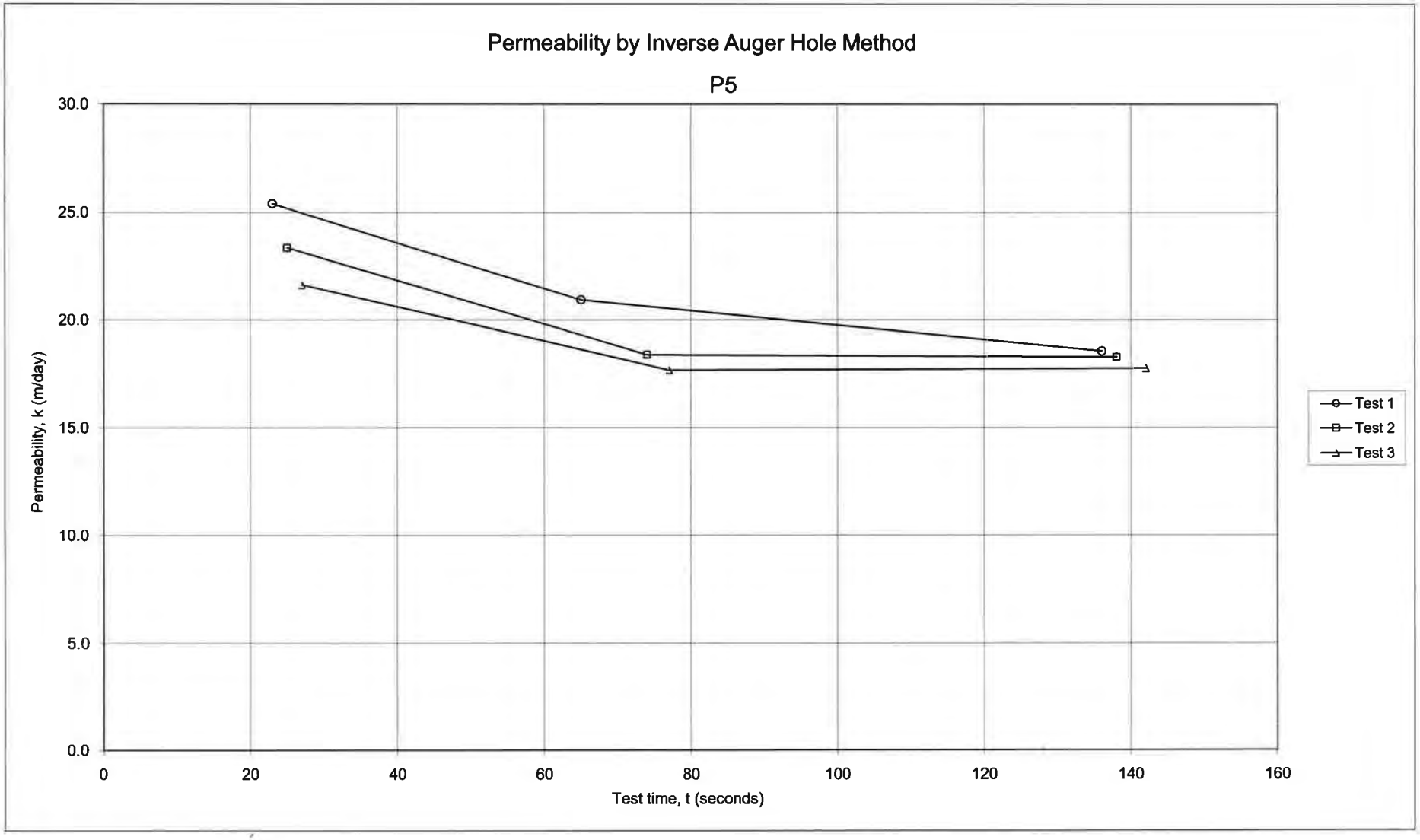
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.4	0.11		
23	0.43	0.08	2.9E-04	25.4
65	0.46	0.05	2.4E-04	20.9
136	0.49	0.02	2.1E-04	18.5
		AVERAGE	2.5E-04	21.6

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.4	0.11		
25	0.43	0.08	2.7E-04	23.4
74	0.46	0.05	2.1E-04	18.4
138	0.49	0.02	2.1E-04	18.3
		AVERAGE	2.3E-04	20.0

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0.4	0.11		
27	0.43	0.08	2.5E-04	21.6
77	0.46	0.05	2.0E-04	17.7
142	0.49	0.02	2.1E-04	17.8
		AVERAGE	2.2E-04	19.0



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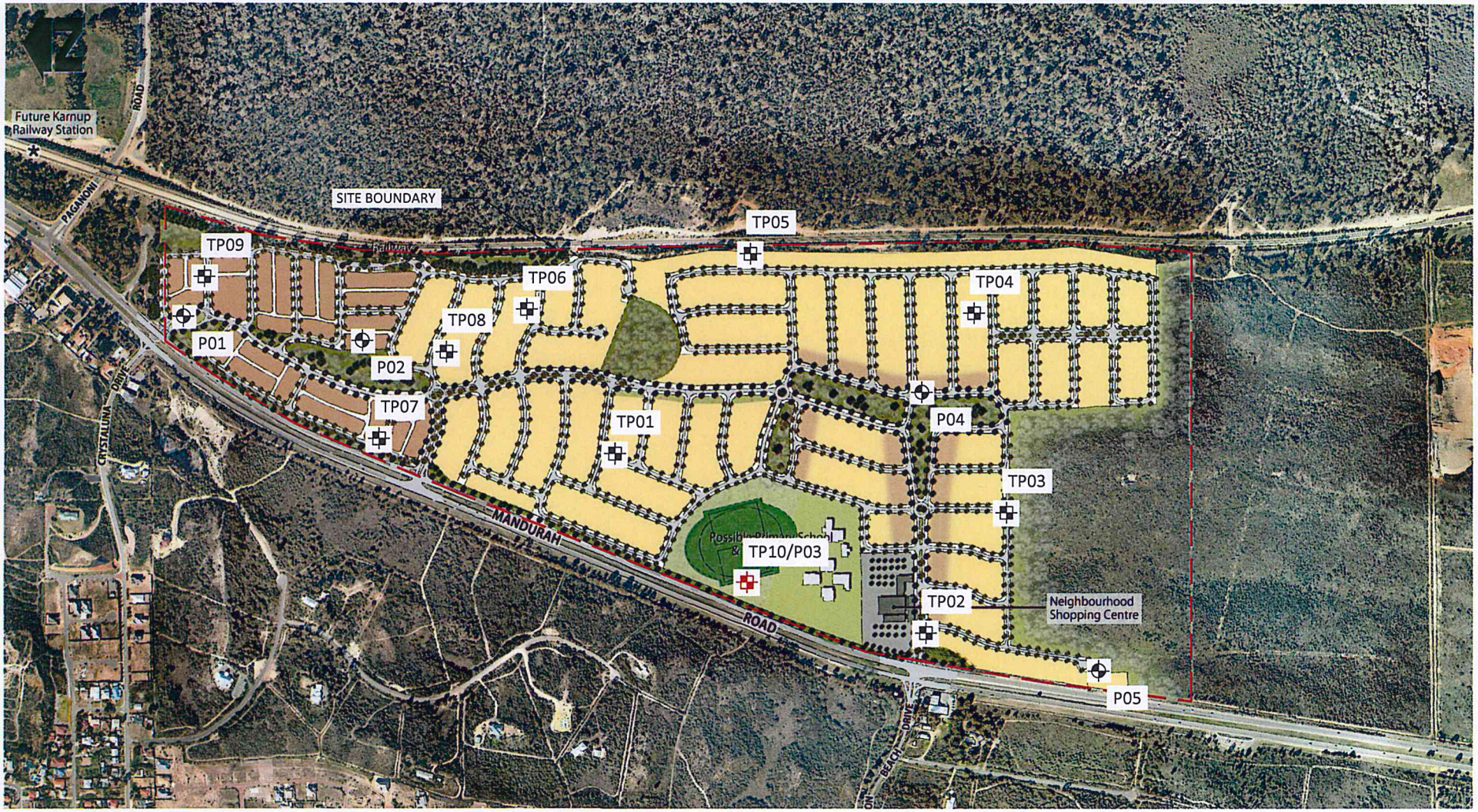

LEGEND

TP01 - TEST PIT LOCATION

P01 - PERMEABILITY TEST LOCATION

TP10/P03 - COMBINED TEST PIT AND PERMEABILITY TEST LOCATION

SITE BOUNDARY

NOTE - TEST LOCATIONS ARE APPROXIMATE ONLY

REV.	DESCRIPTION	DATE	CHK
0	ISSUED FOR REVIEW	28/10/10	JECR

SCALE	NTS
DRAWN	AR
DATE DRAWN	Oct '10
CHECKED	JECR
DATE CHECKED	Oct '10

Galt GEOTECHNICS

Galt Geotechnics Pty Ltd
ACN : 138 490 865
Tel : +61 (0)8 6272-0200
Fax : +61 (0)8 9285 8444
Address : UNIT 2/54 Flynn Street, Wembley, WA, 6014

CLIENT	JDSi
PROJECT	TEST PITS AND PERMEABILITY TESTING LOTS 805 AND 806 MANDURAH RD, KARNUP
TITLE	SITE PLAN
Job No.	J1001085

FIGURE 2 | A3 | Rev. 0

REPORT OF TEST PIT — TP06

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384455	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410106	TP Width (m): 0.6 — TP Length (m): 3
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0 – 0.2	VE				SP	SAND: grey, fine to coarse grained, sub-angular, with organics (roots), trace silt	D	L		0.0 – 0.2
0.2 – 0.4	E					SAND: brown, fine to coarse grained, sub-round, trace organics (roots)	M			0.2 – 0.4
0.4 – 0.6										0.4 – 0.6
0.6 – 0.8	H					LIMESTONE: excavated as Sandy GRAVEL, grey, with weakly to well cemented cobbles and boulders, fine to coarse grained sub-round sand, with shell fragments	D-M	D		0.6 – 0.8
0.8 – 1.0										0.8 – 1.0
1.0 – 1.2										1.0 – 1.2
1.2 – 1.4										1.2 – 1.4
1.4 – 1.6										1.4 – 1.6
1.6 – 1.8										1.6 – 1.8
1.8 – 2.0										1.8 – 2.0
2.0 – 2.2										2.0 – 2.2
2.2 – 2.4										2.2 – 2.4
2.4 – 2.6										2.4 – 2.6
2.6 – 2.8										2.6 – 2.8
2.8 – 3.0										2.8 – 3.0
3.0 – 3.2										3.0 – 3.2
3.2 – 3.4										3.2 – 3.4
3.4 – 3.6										3.4 – 3.6
3.6 – 3.8										3.6 – 3.8
3.8						End of test pit at 0.9 m Refusal No groundwater encountered				3.8

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

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PHOTOGRAPHS OF TEST PIT **TP06**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384455	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410106	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

TP06

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

Galt GEOTECHNICS

REPORT OF TEST PIT TP07

PROJECT DETAILS

Job Number: J1001085
Client: JDSi
Project: Test Pits and Permeability Testing
Location: Lots 805 and 806 Mandurah Road

SPATIAL DETAILS

Position: See Plan
Easting (m): 384217
Northing (m): 6410380
Datum: MGA94 Zone 50
Surface RL (m):

DRILLING DETAILS

Logged: JECR Logged Date: 15/10/2010
Checked: ORW Checked Date: 01/11/2010
TP Width (m): 0.6 TP Length (m): 3
Machine: NH95 Backhoe Bucket: 600 mm
Contractor: Erskine Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0	VE					SAND: grey/brown, fine to coarse grained, sub-angular, with organics (roots)	D			0.0
0.2	E				SP	SAND: brown, fine to coarse grained, sub-round, trace organics (roots)	M	L		0.2
0.4										0.4
0.6										0.6
0.8										0.8
1.0	H					LIMESTONE: excavated as Sandy GRAVEL, grey, with weakly to well cemented cobbles and boulders, fine to coarse grained sub-round sand, with shell fragments	D	D		1.0
1.2										1.2
1.4										1.4
1.6										1.6
1.8										1.8
2.0										2.0
2.2										2.2
2.4										2.4
2.6										2.6
2.8										2.8
3.0										3.0
3.2										3.2
3.4										3.4
3.6										3.6
3.8										3.8

End of test pit at 1.4 m
Refusal
No groundwater encountered

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

Galt GEOTECHNICS

PHOTOGRAPHS OF TEST PIT **TP07**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384217	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410380	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

TP07

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

Galt GEOTECHNICS

REPORT OF TEST PIT TP08

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384387	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410255	TP Width (m): 0.6 — TP Length (m): 3
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0	VE				SP	SAND: grey, fine to coarse grained, sub-angular, with organics (roots)	D	L		0.0
0.2	H					LIMESTONE: excavated as Sandy GRAVEL, grey, with weakly to well cemented cobbles and boulders, fine to coarse grained sub-round sand, with shell fragments		D		0.2
0.4										0.4
0.6										0.6
0.8										0.8
1.0										1.0
1.2										1.2
1.4										1.4
1.6										1.6
1.8										1.8
2.0										2.0
2.2										2.2
2.4										2.4
2.6										2.6
2.8										2.8
3.0										3.0
3.2										3.2
3.4										3.4
3.6										3.6
3.8										3.8

End of test pit at 1.5 m
Refusal
No groundwater encountered

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

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PHOTOGRAPHS OF TEST PIT **TP08**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384387	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410255	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

TP08

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

Galt GEOTECHNICS

REPORT OF TEST PIT — TP09

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384525	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410711	TP Width (m): 0.6 — TP Length (m): 3
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

DEPTH (m)	EXCAVATION RESISTANCE	GROUNDWATER	SAMPLES & FIELD TESTS	GRAPHIC LOG	USCS CLASSIFICATION	MATERIAL DESCRIPTION (Soil type, plasticity or particle characteristics, colour, secondary and minor components)	MOISTURE CONDITION	CONSISTENCY/ DENSITY	ADDITIONAL OBSERVATIONS	DEPTH (m)
0.0	E				SP	SAND (FILL): grey, medium to coarse grained, sub-round, with limestone gravel, fine to coarse grained, with organics (roots)	D	L		0.0
0.2						Gravelly SAND (FILL): grey, brown and dark brown, fine to coarse grained sand, fine to coarse limestone sized gravel, with cobbles, trace orangics (roots), trace plastic and rubble waste	D-M	L-MD		0.2
0.4										0.4
0.6										0.6
0.8										0.8
1.0										1.0
1.2										1.2
1.4										1.4
1.6										1.6
1.8										1.8
2.0						SAND: dark brown, fine to coarse grained, sub-round, with organics (roots)	M			2.0
2.2						SAND: brown/yellow, fine to coarse grained, sub-round				2.2
2.4										2.4
2.6										2.6
2.8										2.8
3.0						End of test pit at 3.0 m Target depth No groundwater encountered				3.0
3.2										3.2
3.4										3.4
3.6										3.6
3.8										3.8

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

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PHOTOGRAPHS OF TEST PIT **TP09**

PROJECT DETAILS	SPATIAL DETAILS	DRILLING DETAILS
Job Number: J1001085	Position: See Plan	Logged: JECR — Logged Date: 15/10/2010
Client: JDSi	Easting (m): 384525	Checked: ORW — Checked Date: 01/11/2010
Project: Test Pits and Permeability Testing	Northing (m): 6410711	TP Width (m): — TP Length (m):
Location: Lots 805 and 806 Mandurah Road	Datum: MGA94 Zone 50	Machine: NH95 Backhoe — Bucket: 600 mm
	Surface RL (m):	Contractor: Erskine — Operator: J. Erskine

TP09

See Explanatory Notes and Method of Soil Description sheets for detials of abbreviations and basis of descriptions

GALT GEOTECHNICS PTY LTD

Galt GEOTECHNICS

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

13 April 2011

Gold Right Pty Ltd
236 Adelaide Terrace
PERTH WA 6000

Attention: Mr Steven Tay

Dear Sir,

RE: LOTS 805 & 806 MANDURAH ROAD- KARNUP

GEOTECHNICAL KARST RISK ASSESSMENT

1 INTRODUCTION

This letter presents the results of a geotechnical karst risk assessment carried out by Coffey Geotechnics Pty Ltd (Coffey) for Gold Right Pty Ltd (Gold Right) at Lots 805 and 806 Mandurah Road, Karnup (Lots 805 & 806). The assessment is based on a desk top review of available information, a site reconnaissance field trip and Coffey experience in the area.

This work was commissioned by Mr Steven Tay of Gold Right on 18 February 2011 via a completed "Authorisation to Proceed" form enclosed with the Coffey proposal (Ref. GEOTPERT09501AA-P-AA) dated 16 February 2011.

This report is prepared and is to be read subject to the terms and conditions contained in our proposal. Our advice is based on the information stated and on the assumptions expressed herein. Should that information or the assumptions be incorrect, then Coffey Geotechnics Pty Ltd shall accept no liability in respect of the advice whether under law of contract, tort or otherwise.

2 PROPOSED DEVELOPMENT AND REVIEWED DOCUMENTATION

It is understood that the project comprises subdivision of the site for urban development with cut to fill earthworks, construction of roads and installation of buried services associated with the creation of residential/commercial lots and areas for public utilities.

GBG Maps has undertaken a shallow geophysical investigation at the site as outlined in their report dated 16 December 2010. Galt Geotechnics Pty Ltd has also undertaken a programme of test pitting and permeability testing at the site as outlined in their report dated 1 November 2010 (Ref: J1001085 001 L Rev0). Both the GBG Maps and Galt reports were reviewed as part of this assessment in conjunction with publicly available geology information published by the Geological Survey of Western Australia and groundwater/topography data published by the Department of Environment.

3 SITE CONDITIONS

Based on our desk top review of available information and site reconnaissance Lots 805 & 806 are considered to be within an area described on the 1:50,000 Environmental Geology Series (Rockingham Sheet) as Limestone – pale yellowish brown, fine to coarse grained, subangular to well rounded quartz, trace of feldspar, shell debris, variably lithified, surface kankar, of eolian origin. The limestone is indicated to be part of the Tamala Limestone and Safety Bay Sand Formations.

The Perth Groundwater Atlas (Second Edition), 2004 indicates a May 2003 groundwater elevation across the site in the order of 1.5mAHD and a current ground surface elevation ranging between about 8mAHD and 24mAHD.

There is extensive disturbance at the site resulting from previous and current quarrying activities which have targeted limestone, and to a lesser extent, sand.

Surface soils at the site comprise predominantly yellow, siliceous sand. The more elevated areas include extensive areas of scattered limestone caprock ("kankar") outcrops. Observations within previous and current quarry areas indicate limestone rock at shallow depth across the majority of the site. The surface caprock layer is typically pinnacled and highly irregular with numerous localised decimetre scale cracks and fissures resulting from the etching and dissolution effects of weathering on carbonate materials. The less elevated areas within the northern part of the site and along the eastern boundary are characterised by a deeper sand profile overlying limestone.

The site is located on the same limestone ridge as the existing Lakelands and Meadow Springs developments to the south. Coffey are not aware of any historical documentation of known karst features or issues associated with voids in limestone within this part of the Swan Coastal Plain. There is no indication of potential karst areas outlined in the 1:50,000 Environmental Geology Series mapping. Reconnaissance of the site and previous experience from adjacent areas does not indicate the presence of natural karst features such as sink holes, dolines or closed depressions.

4 REVIEW OF GEOTECHNICAL REPORTS

The GBG Maps report outlines numerous geophysical anomalies that are interpreted as "*possible features of karstic origin*". The GBG Maps report contains a figure showing the locations of geophysical traverse lines, test pits and includes the interpreted geophysics results and the locations of surface features described as "*Small depression in surface of limestone. Possible sinkhole often associated with possible voiding at depth*". Observations from our field reconnaissance did not identify similar surface features at the locations indicated. Several of the features were interpreted by Coffey as being related to previous quarrying activity as follows:

- A surface depression close to the middle of the northern boundary of the site is considered to be a former borrow pit where sand has been extracted in the past and is now partly revegetated with grasses and low shrubs.
- Close to the northwest corner of the site is an area of disturbed natural ground and spoil heaps from previous quarrying activity, and includes numerous rabbit burrows.
- Within the central part of the site, west of the current quarrying activity is a former borrow pit in limestone that is surrounded by spoil forming an apparent depression in the current land surface

Galt Geotechnics Pty Ltd report does not indicate the presence of karst features within the site.

5 CONCLUSIONS

Based on Coffey experience, the usefulness of GPR and other geophysical techniques for assessing potential karst features within the coastal limestone of Western Australia can be limited by poor antenna connection to the ground and the lack of geophysical/electrical contrast between the various subsurface materials comprising dry to moist sand with varying degrees of cementation. It is also considered that the highly irregular and erratic nature of cementing and highly irregular upper surface of the caprock layer within the coastal limestone limits the clarity of geophysical response in these materials.

The reliance on interpretation of geophysical data alone to indicate the presence of karst within coastal limestone is not recommended. In the absence of any other supporting evidence within this site or adjacent areas and the lack of any historical evidence of karst in this geomorphological environment it is considered that the risk of significant karst features potentially impacting on the proposed development at Lot 805 and 806 Mandurah Road is very low. Despite the lack of evidence of significant karst features potentially impacting on this, or adjacent sites, it is likely that localised, decimetre scale voids occur within the underlying limestone. The conditions indicated within the limestone at this site are considered to be typical of coastal limestone further south along the same ridgeline on which the existing Lakelands and Meadow Springs developments have been constructed. Therefore, additional investigation to address potential karst within the site is not considered to be warranted at this stage. However, an appropriate level of caution and observation is recommended during earthworks during development to ensure that any localised voids encountered are treated to limit their impact on the development.

6 IMPORTANT INFORMATION ABOUT YOUR COFFEY REPORT

The reader's attention is drawn to the important information about this report which follows the main text.

For and on behalf of Coffey Geotechnics Pty Ltd

Philip Mather

Principal Engineering Geologist

ATTACHMENTS:

Important Information About Your Coffey Report

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

Important information about your **Coffey** Report

As a client of Coffey you should know that site subsurface conditions cause more construction problems than any other factor. These notes have been prepared by Coffey to help you interpret and understand the limitations of your report.

Your report is based on project specific criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Coffey and applies only to the site investigated. Project criteria typically include the general nature of the project; its size and configuration; the location of any structures on the site; other site improvements; the presence of underground utilities; and the additional risk imposed by scope-of-service limitations imposed by the client. Your report should not be used if there are any changes to the project without first asking Coffey to assess how factors that changed subsequent to the date of the report affect the report's recommendations. Coffey cannot accept responsibility for problems that may occur due to changed factors if they are not consulted.

Subsurface conditions can change

Subsurface conditions are created by natural processes and the activity of man. For example, water levels can vary with time, fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions which existed at the time of subsurface exploration, decisions should not be based on a report whose adequacy may have been affected by time. Consult Coffey to be advised how time may have impacted on the project.

Interpretation of factual data

Site assessment identifies actual subsurface conditions only at those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by geologists, engineers or scientists to provide an opinion about overall site conditions, their likely impact on the proposed development and recommended actions. Actual conditions may differ from those inferred to exist, because no professional, no matter how qualified, can reveal what is hidden by earth, rock and time. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. Nothing can be done to change the actual site conditions which exist, but steps can be taken to reduce the impact of unexpected conditions. For this reason, owners should retain the services of Coffey through the development stage, to identify variances, conduct additional tests if required, and recommend solutions to problems encountered on site.

Your report will only give preliminary recommendations

Your report is based on the assumption that the site conditions as revealed through selective point sampling are indicative of actual conditions throughout an area. This assumption cannot be substantiated until project implementation has commenced and therefore your report recommendations can only be regarded as preliminary. Only Coffey, who prepared the report, is fully familiar with the background information needed to assess whether or not the report's recommendations are valid and whether or not changes should be considered as the project develops. If another party undertakes the implementation of the recommendations of this report there is a risk that the report will be misinterpreted and Coffey cannot be held responsible for such misinterpretation.

Your report is prepared for specific purposes and persons

To avoid misuse of the information contained in your report it is recommended that you confer with Coffey before passing your report on to another party who may not be familiar with the background and the purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

coffey geotechnics
SPECIALISTS MANAGING THE EARTH

Important information about your **Coffey** Report

Interpretation by other design professionals

Costly problems can occur when other design professionals develop their plans based on misinterpretations of a report. To help avoid misinterpretations, retain Coffey to work with other project design professionals who are affected by the report. Have Coffey explain the report implications to design professionals affected by them and then review plans and specifications produced to see how they incorporate the report findings.

Data should not be separated from the report*

The report as a whole presents the findings of the site assessment and the report should not be copied in part or altered in any way.

Logs, figures, drawings, etc. are customarily included in our reports and are developed by scientists, engineers or geologists based on their interpretation of field logs (assembled by field personnel) and laboratory evaluation of field samples. These logs etc. should not under any circumstances be redrawn for inclusion in other documents or separated from the report in any way.

Geoenvironmental concerns are not at issue

Your report is not likely to relate any findings, conclusions, or recommendations about the potential for hazardous materials existing at the site unless specifically required to do so by the client. Specialist equipment, techniques, and personnel are used to perform a geoenvironmental assessment.
Contamination can create major health, safety and environmental risks. If you have no information about the potential for your site to be contaminated or create an environmental hazard, you are advised to contact Coffey for information relating to geoenvironmental issues.

Rely on Coffey for additional assistance

Coffey is familiar with a variety of techniques and approaches that can be used to help reduce risks for all parties to a project, from design to construction. It is common that not all approaches will be necessarily dealt with in your site assessment report due to concepts proposed at that time. As the project progresses through design towards construction, speak with Coffey to develop alternative approaches to problems that may be of genuine benefit both in time and cost.

Responsibility

Reporting relies on interpretation of factual information based on judgement and opinion and has a level of uncertainty attached to it, which is far less exact than the design disciplines. This has often resulted in claims being lodged against consultants, which are unfounded. To help prevent this problem, a number of clauses have been developed for use in contracts, reports and other documents. Responsibility clauses do not transfer appropriate liabilities from Coffey to other parties but are included to identify where Coffey's responsibilities begin and end. Their use is intended to help all parties involved to recognise their individual responsibilities. Read all documents from Coffey closely and do not hesitate to ask any questions you may have.

* For further information on this aspect reference should be made to "Guidelines for the Provision of Geotechnical information in Construction Contracts" published by the Institution of Engineers Australia, National headquarters, Canberra, 1987.

APPENDIX C

emerge ASSOCIATES
Integrated Science & Design

MODELLING SUMMARY REPORT

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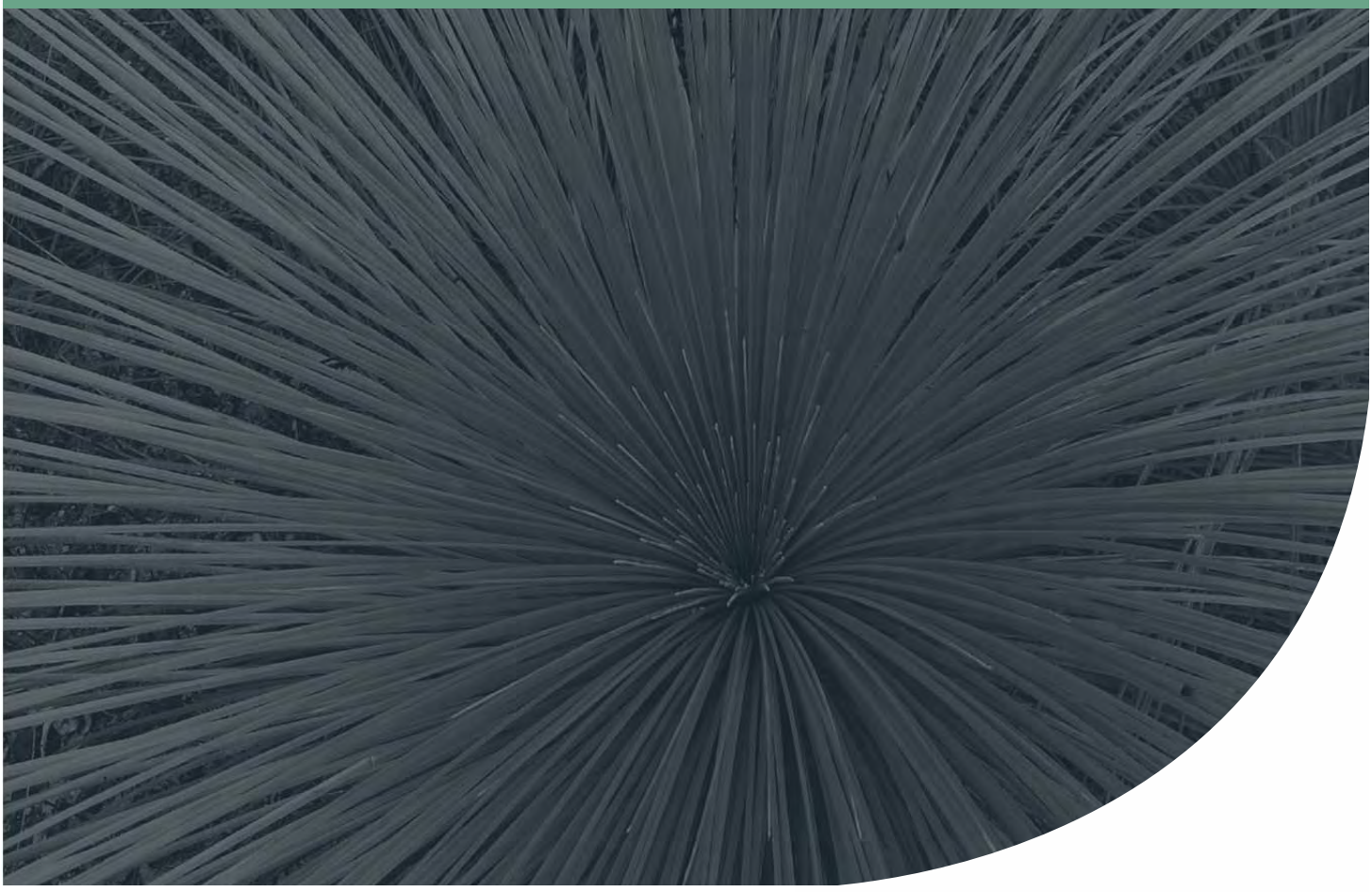
Modelling Assumptions

West Karnup Lot 805 LSP

Project No: EP14-047(06)

Prepared for Golden Right Pty Ltd
June 2017



Document Control

Doc name:	Modelling Assumptions West Karnup Lot 805 LSP				
Doc no.:	EP14-047(06)--019				
Version	Date	Author		Reviewer	
1	June 2017	Amila Prasad	AP	Rachel Evans	RLE
	For inclusion with LWMS addendum				

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List of Tables

1 Modelling Assumptions

Surface water runoff within the West Karnup Lot 805 Local Structure Plan (LSP) has been calculated using the XPStorm hydrologic and hydraulic modelling software.

The hydrologic component of the software uses the Laurenson non-linear runoff-routing method to simulate runoff from design storm events. Key assumptions regarding the hydrologic model include:

- Runoff is proportional to slope, area, infiltration and percentage of imperviousness of a catchment.
- Sub-catchment areas and slopes are determined from surveyed topographical data and earthworks plans.
- Infiltration rates and percentage imperviousness, based on experience with model preparation for similar soil conditions.

Runoff from each sub-catchment is routed through the catchment using the hydraulic component of XPStorm. Assumptions associated with the hydraulic component of the model include:

- Virtual links (i.e. purely for model construction, not equivalent to flow path onsite) between nodes within a sub-catchment are given the length of 10 m and slope of 0.05 to minimise the lag time of conveying the water from a sub-catchment node to a 'storage' node, a 'dummy intermediate' node or a conduit/link.
- Links between sub-catchment storages act as conveyance channels (e.g. sheet flow within roads in 100 year average recurrence interval (ARI) event). These links are given lengths and slopes to represent site conditions and actual pathway lengths between catchments.
- All channels are designed with width of 4 m, roughness of 0.02 (Manning's 'n') and are trapezoidal in shape. This allows for easy conveyance and/or represents concrete pipes/ road surfaces.
- No more than 5% of the volume has been allowed to be ponded within small event (first 15 mm) storage nodes for events greater than the small event.

2 Pre-development Model

An "initial loss - continual loss" infiltration model was adopted for the pre-development environment, with loss values chosen based on project team experience with similar vegetation and soil types to those found within the site. **Table 1** gives the parameters used within the pre-development model.

Table 1 Pre-development parameters

Land Type	Initial Loss (mm)	Continual Loss (mm)	Roughness
Whole site	17.5	3	0.05

Pre-development catchment areas were measured from surveyed topographical contours for the site, and from publicly available contours (obtained from Landgate). The pre-development catchment areas and detailed assumptions are shown in **Table 2** and illustrated in Figure 5 of the *West Karnup - Lot 805 LSP Local Water Management Strategy* (Emerge Associates 2017).

Table 2 Pre-development catchment areas

Catchment	Area (ha)	Slope
7	11.1	0.05
8	6.3	0.05
9	8.4	0.05
10	3.6	0.05
Total	*92.5*	-

A critical event duration analysis was undertaken for the site. The 5, 10 and 100 year ARI events were found to have a critical duration of 6 hours.

3 Post-development Model

The post-development model used an "initial loss - continual loss" infiltration model with parameters that were influenced by the existing loss rates used in the pre-development model. **Table 3** gives the parameters used within the post-development model.

Table 3 Post-development parameters

Land Type	Initial Loss (mm)	Continual Loss (mm)	Roughness
Road verge	12	1.5	0.025
Road pavement	1	0.1	0.02
Lots < 350 m^2 - roof	15	0.1	0.02
Lots < 350 m^2 - impervious	15	0.1	0.02
Lots < 350 m^2 - garden	22.5	3	0.05
Lots >= 350 m^2 - Front paved	1	0.1	0.02
Lots >= 350 m^2 - Front garden	22.5	3	0.05
POS	20	2.5	0.05

The post-development catchment areas were taken from the earthworks strategy provided by the project team engineers (provided in Appendix F of the LWMS (Emerge Associates 2017)). Land types within the catchments were guided by the West Karnup Lot 805 LSP. A summary of post-development catchment information is provided in **Table 4**.

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

- Lots ≥ 350 m^2 have 50% roof area with the remainder of the lots paved (35%) and pervious garden (15%).
- Lots < 350 m^2 have 50% roof area with the remainder of the lots paved (45%) and pervious garden (5%).
- Lots ≥ 350 m^2 will provide onsite storage within the lot to cater for the 100 year ARI event runoff from roof and rear garden areas.
- Lots ≤ 350 m^2 will provide onsite storage within lot to cater for the small rainfall event (first 15 mm) from roof and rear garden areas, with all additional run off (up to the 100 year ARI event) directed to downstream storage infrastructure via overland flow.
- Residential lots will have little slope (i.e. will be flat) and pockets of storage are likely to occur. This will effectively increase the initial loss (storage) and overall infiltration rate (continual loss).
- Garden areas in all lots will have high infiltration rates as it is likely that sand-based landscape mix or mulch will be used, and will infiltrate the small rainfall event.
- POS areas are assumed to be 100% pervious.
- POS areas will contain dense vegetation or turf over a sand-based landscape mix.
- There will be no infiltration on roads, pavement and driveways. There will however be some minor absorption storage loss, this is accounted for in the initial and continuing loss values.
- Road reserve contains 60% verge and 40% impervious bitumen.
- The road verge area is similar in characteristics to POS areas except that it will also have an impervious footpath and some driveway crossovers.

- It is anticipated that the average initial loss in road verges will be lower than POS initial loss rates to account for the impervious portion of road verges.
- The small event runoff from road reserves (and some lots as detailed above) will be retained and infiltrated within verge and medium swales in road reserve and downstream bio-retention areas (BRA) located in POS.
- Surface runoff from events greater than the small event (up to the 100 year ARI event) will be retained and infiltrated in flood storage areas (FSA).
- A hydraulic conductivity of 4.63×10^{-5} m/s is assumed for storage areas with an additional 50% clogging factor applied to treatment areas (i.e. swales and BRAs).
- The effect of infiltration through side slopes of BRAs, swales and FSAs has been included in the overall infiltration rating curve for these areas.
- Volumes leaving the system through evapotranspiration were assumed to be negligible when compared to the total runoff volume and in the timeframe of a storm event since the duration of model run was short, and there would be little/no transpiration when air moisture levels are close to saturation. XPStorm default evapotranspiration assumptions are therefore used.

Table 4 Post-development catchment areas

Catchment	Sub-catchment	Slope	Area (ha)												
			Total Area	Road reserve			Lots>= 350 m^2				Lots < 350 m^2				
				Total Road	Road Pavement	Road Verge	Total area	Front paved	Front garden	Roof and rear	Total area	Roof	Paved	Garden	POS
Ct H	Ct H-1	0.006	1.613	0.802	0.321	0.481		0.000	0.000	0.000	0.279	0.139	0.125	0.014	0.532
	Ct H-2	0.016	1.496	0.487	0.195	0.292	1.009	0.126	0.126	0.757		0.000	0.000	0.000	
Ct I	Ct I-1	0.013	1.847	0.703	0.281	0.422		0.000	0.000	0.000	1.002	0.501	0.451	0.050	0.142
	Ct I -2	0.007	0.853	0.574	0.230	0.344		0.000	0.000	0.000	0.279	0.140	0.126	0.014	
	Ct I -3	0.015	4.666	1.029	0.412	0.617	2.055	0.257	0.257	1.541	0.673	0.337	0.303	0.034	0.909
Ct J	Ct J	0.008	1.718	0.400	0.160	0.240	0.307	0.038	0.038	0.230	0.294	0.147	0.132	0.015	0.717
Ct K	Ct K-1	0.004	6.336	1.845	0.738	1.107	3.843	0.480	0.480	2.882	0.648	0.324	0.292	0.032	
	Ct K-2	0.007	0.694	0.140	0.056	0.084		0.000	0.000	0.000	0.554	0.277	0.249	0.028	
	Ct K-3	0.021	1.247	0.418	0.167	0.251	0.829	0.104	0.104	0.622		0.000	0.000	0.000	
	Ct K-4	0.007	1.687	0.167	0.067	0.100	0.307	0.038	0.038	0.230		0.000	0.000	0.000	1.213
	Total		22.157	6.565	2.626	3.939	8.350	1.044	1.044	6.263	3.729	1.864	1.678	0.186	3.513

4 References

Emerge Associates 2017, *West Karnup - Lot 805 Local Structure Plan Local Water Management Strategy Addendum*, Perth.

APPENDIX D

GROUNDWATER QUALITY DATA

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Table D2: Measured groundwater quality

Parameter	Units	NWQMS	Average *(Std Dev)*[b]					
			MW1	MW2	MW3	MW4	MW5	MW6
Physical Parameters								
Temperature	°C		20.66 *(0.75)*	19.91 *(0.45)*	19.94 *(0.89)*	20.00 *(0.81)*	20.02 *(0.95)*	20.35 *(1.38)*
pH	pH units	6.8 - 8.0	7.91 *(0.16)*	7.52 *(0.10)*	7.49 *(0.21)*	7.94 *(0.14)*	7.60 *(0.19)*	7.09 *(0.17)*
EC	mS/cm	0.3	0.327 *(0.06)*	0.674 *(0.04)*	0.782 *(0.09)*	0.398 *(0.08)*	0.445 *(0.03)*	1.482 *(0.16)*
Salinity	PSS		0.21 *(0.00)*	0.34 *(0.00)*	0.36 *(0.04)*	0.24 *(0.06)*	0.22 *(0.00)*	0.68 *(0.01)*
DO	mg/L		7.82 *(0.57)*	8.37 *(1.00)*	7.63 *(0.65)*	8.01 *(0.51)*	6.63 *(0.30)*	1.50 *(0.80)*
Redox	mV		103 *(55.03)*	117 *(53.47)*	125 *(69.94)*	118 *(65.29)*	97 *(61.50)*	-64 *(159.52)*
Nutrients and Nutrient Species								
Ammonia as N	mg/L	0.08	0.023 *(0.01)*	0.050 *(0.07)*	0.097 *(0.16)*	0.030 *(0.01)*	0.038 *(0.03)*	0.063 *(0.02)*
Oxides of Nitrogen (NO_X) as N	mg/L	0.15	0.768 *(0.27)*	1.368 *(0.07)*	6.413 *(1.76)*	0.893 *(0.23)*	7.507 *(0.81)*	0.065 *(0.08)*
Total Kjeldahl Nitrogen as N	mg/L		0.200 *(-)*	0.325 *(-)*	4.783 *(-)*	0.200 *(-)*	1.100 *(-)*	0.250 *(-)*
Total Nitrogen as N	mg/L	1.2	0.900 *(0.28)*	1.583 *(0.17)*	11.200 *(6.68)*	1.000 *(0.35)*	8.617 *(1.12)*	0.300 *(0.06)*
Total Phosphorous as P	mg/L	0.065	0.030 *(-)*	0.090 *(-)*	2.682 *(-)*	0.045 *(-)*	0.170 *(-)*	0.050 *(-)*
Reactive Phosphorous as P	mg/L		<0.01 *(-)*	0.010 *(-)*	<0.01 *(-)*	<0.01 *(-)*	<0.01 *(-)*	<0.01 *(-)*

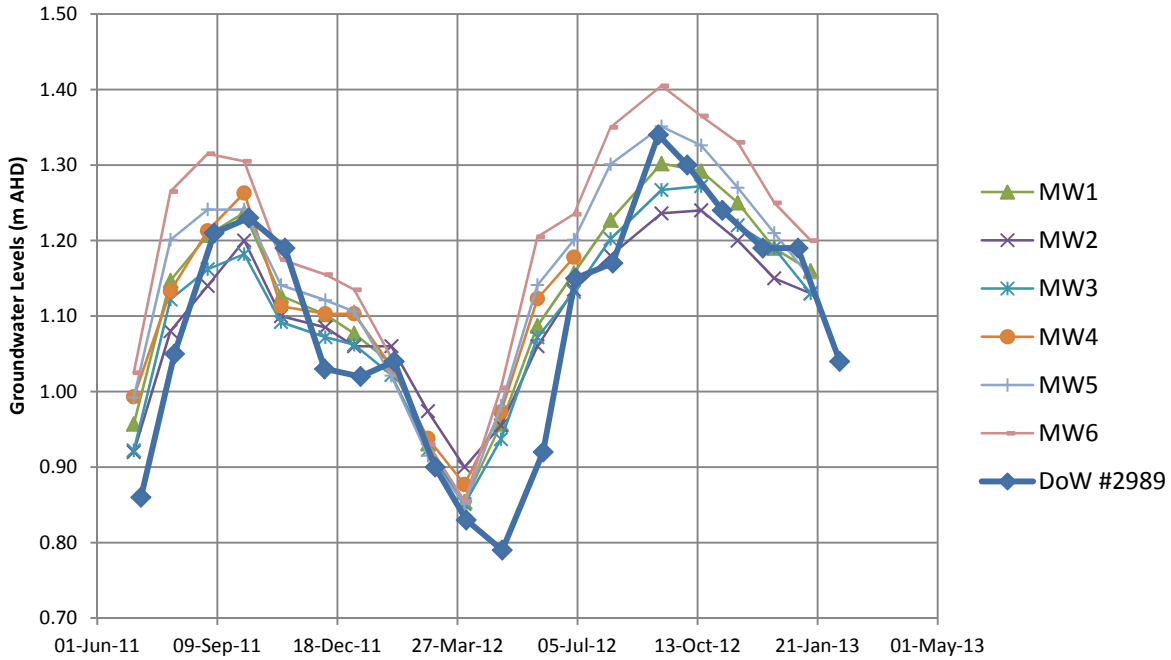

Figure D1 Groundwater levels Lots 3, 805 & 806 Mandurah Road, West Karnup

Table D1: Measured groundwater levels

BORE ID	Groundwater Levels, m AHD (m BGL)																		
	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12	Jan-13
MW1	0.96 (4.69)	1.15 (4.50)	1.21 (4.44)	1.24 (4.41)	1.13 (4.52)	1.10 (4.55)	1.08 (4.57)	1.04 (4.61)	0.93 (4.72)	0.85 (4.79)	0.96 (4.69)	1.09 (4.56)	1.16 (4.49)	1.23 (4.42)	1.30 (4.35)	1.29 (4.36)	1.25 (4.40)	1.19 (4.46)	1.16 (4.49)
MW2	0.92 (8.36)	1.08 (8.20)	1.14 (8.14)	1.20 (8.08)	1.10 (8.18)	1.09 (8.20)	1.06 (8.22)	1.06 (8.22)	0.97 (8.31)	0.90 (8.38)	0.96 (8.33)	1.06 (8.22)	1.14 (8.15)	1.18 (8.10)	1.24 (8.04)	1.24 (8.04)	1.20 (8.08)	1.15 (8.13)	1.13 (8.15)
MW3	0.92 (11.4)	1.12 (11.20)	1.16 (11.16)	1.18 (11.14)	1.09 (11.23)	1.07 (11.25)	1.06 (11.26)	1.02 (11.30)	0.92 (11.40)	0.85 (11.47)	0.94 (11.39)	1.07 (11.25)	1.13 (11.19)	1.20 (11.12)	1.27 (11.06)	1.27 (11.05)	1.22 (11.10)	1.19 (11.13)	1.13 (11.19)
MW4	0.99 (6.67)	1.13 (6.53)	1.21 (6.45)	1.26 (6.40)	1.11 (6.55)	1.10 (6.56)	1.10 (6.56)	1.03 (6.63)	0.94 (6.73)	0.88 (6.79)	0.97 (6.69)	1.12 (6.54)	1.18 (6.49)	*Bore Destroyed*					
MW5	0.99 (12.59)	1.20 (12.38)	1.24 (12.34)	1.24 (12.34)	1.14 (12.44)	1.12 (12.46)	1.11 (12.48)	1.02 (12.56)	0.91 (12.67)	0.85 (12.73)	0.98 (12.6)	1.14 (12.44)	1.20 (12.38)	1.30 (12.28)	1.35 (12.23)	1.33 (12.26)	1.27 (12.31)	1.21 (12.37)	1.15 (12.43)
MW6	1.03 (4.61)	1.27 (4.37)	1.32 (4.32)	1.31 (4.33)	1.18 (4.46)	1.16 (4.48)	1.14 (4.5)	1.05 (4.59)	0.93 (4.71)	0.86 (4.78)	1.01 (4.63)	1.21 (4.43)	1.24 (4.40)	1.35 (4.29)	1.41 (4.23)	1.37 (4.27)	1.33 (4.31)	1.25 (4.39)	1.20 (4.44)

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APPENDIX E

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LANDSCAPE PLANS

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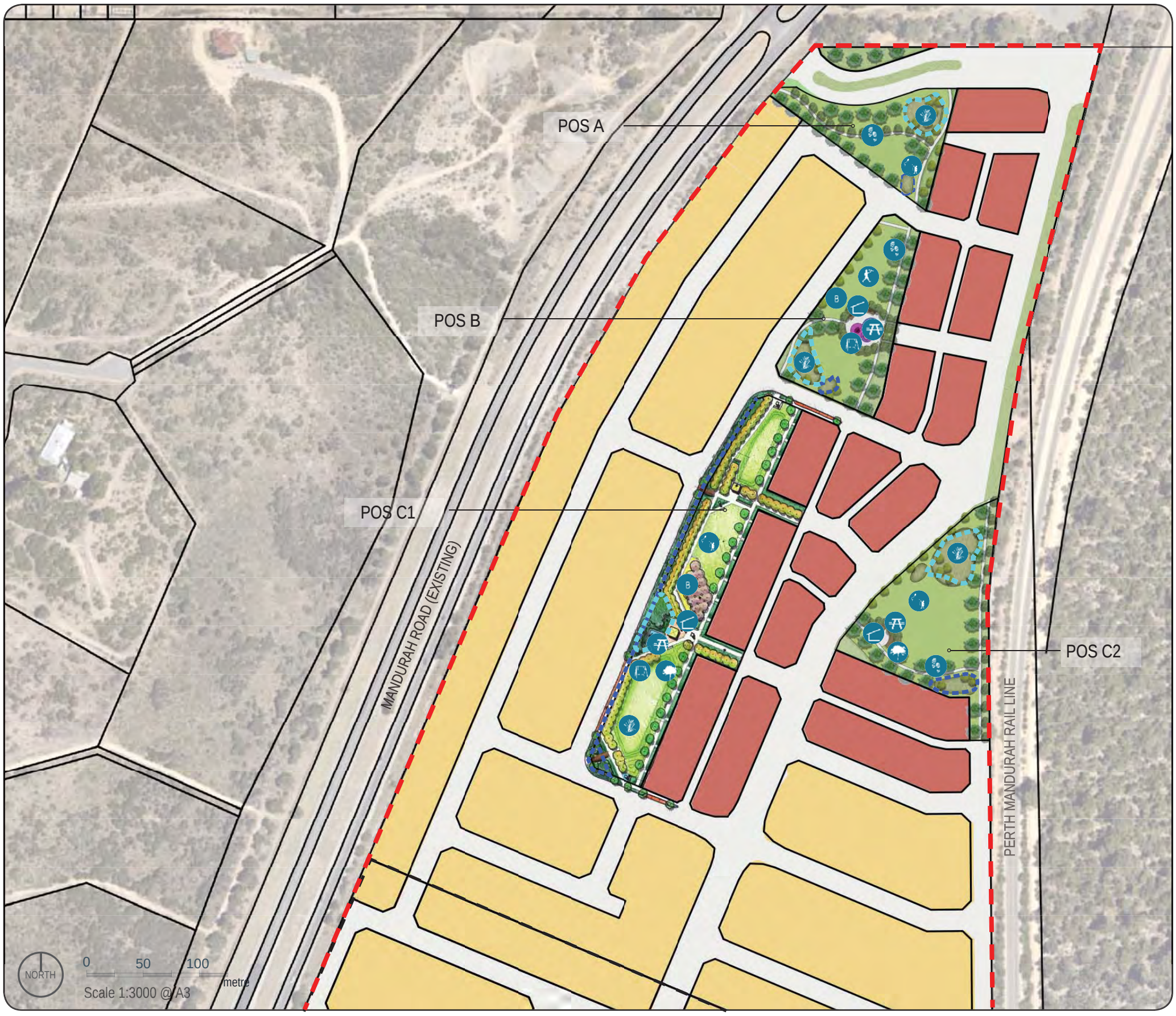
LANDSCAPE MASTERPLAN



LEGEND

- EXTENT OF WORKS
- PLAYGROUND
- SHELTER
- PICNIC FACILITIES
- BBQ
- DRAINAGE
- WALK TRAIL
- NEW SHADE TREES
- NATURE PLAY
- OPEN TURF AREA
- BIO-RETENTION AREA
- FLOOD STORAGE AREA

DRAINAGE

POS A		POS B		POS C1		POS C2	
1 YEAR 1 HOUR ARI:		**1 YEAR 1 HOUR ARI:**		**1 YEAR 1 HOUR ARI:**		**1 YEAR 1 HOUR ARI:**	
AREA:	389m²	AREA:	100m²	AREA:	1167m²	AREA:	970m²
DEPTH:	0.3m	DEPTH:	0.30m	DEPTH:	0.30m	DEPTH:	0.30m
VOLUME:	75m³	VOLUME:	25m³	VOLUME:	177m³	VOLUME:	121m³
5 YEAR ARI:		**5 YEAR ARI:**		**5 YEAR ARI:**		**5 YEAR ARI:**	
AREA:	479m²	AREA:	320m²	AREA:	1156m²	AREA:	1895m²
DEPTH:	0.6m	DEPTH:	0.70m	DEPTH:	0.40m	DEPTH:	0.6m
VOLUME:	206m³	VOLUME:	133m³	VOLUME:	441m³	VOLUME:	617m³
10 YEAR ARI:		**10 YEAR ARI:**		**10 YEAR ARI:**		**10 YEAR ARI:**	
AREA:	555m²	AREA:	375m²	AREA:	1292m²	AREA:	2065m²
DEPTH:	0.7m	DEPTH:	0.80m	DEPTH:	0.60m	DEPTH:	0.7m
VOLUME:	277m³	VOLUME:	176m³	VOLUME:	639m³	VOLUME:	786m³
100 YEAR ARI:		**100 YEAR ARI:**		**100 YEAR ARI:**		**100 YEAR ARI:**	
AREA:	840m²	AREA:	583m²	AREA:	1850m²	AREA:	2760m²
DEPTH:	1.2m	DEPTH:	1.20m	DEPTH:	1.20m	DEPTH:	1.20m
VOLUME:	590m³	VOLUME:	365m³	VOLUME:	1560m³	VOLUME:	1564m³

KARNUP, WA
JUNE 2017

Local Structure Plan
REVISION F

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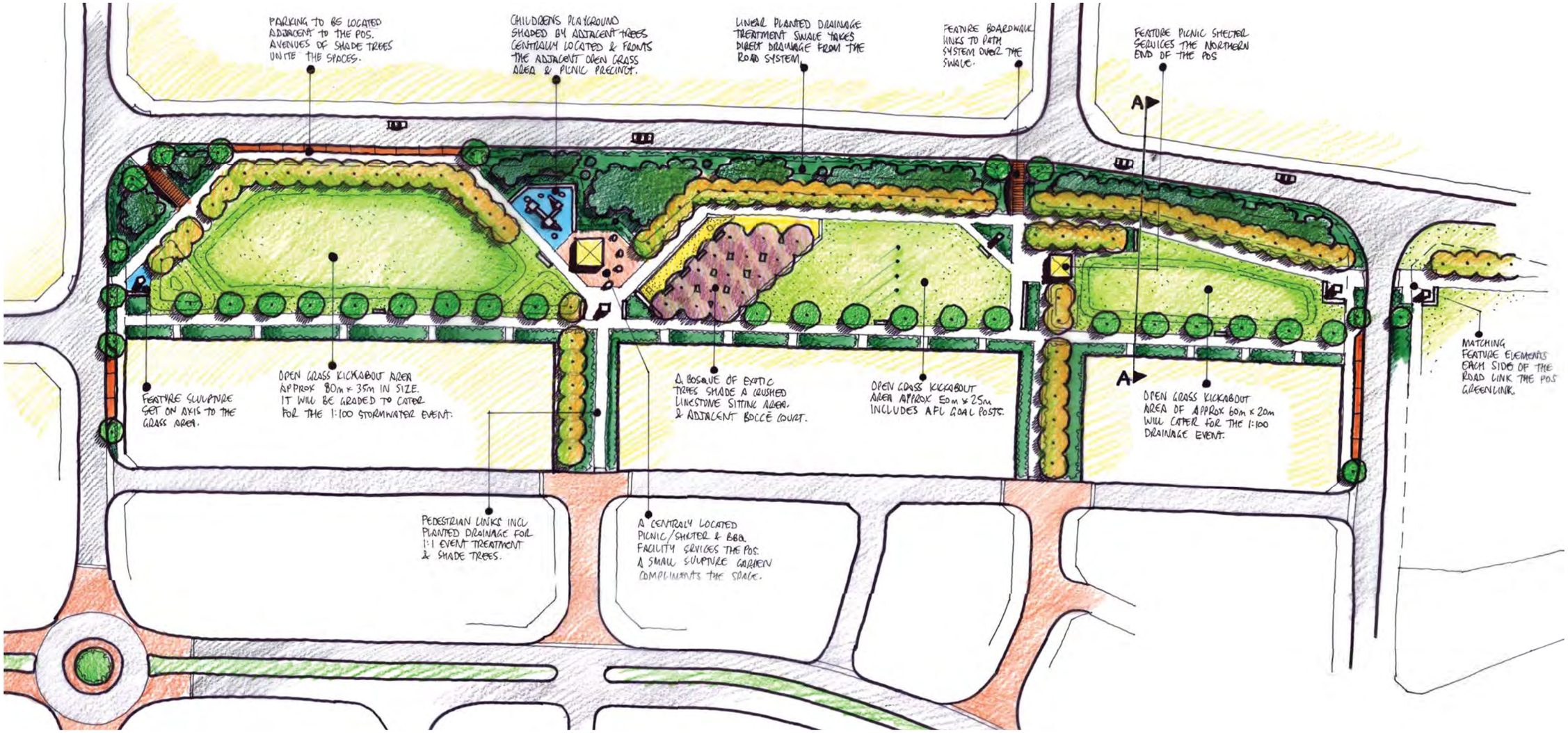
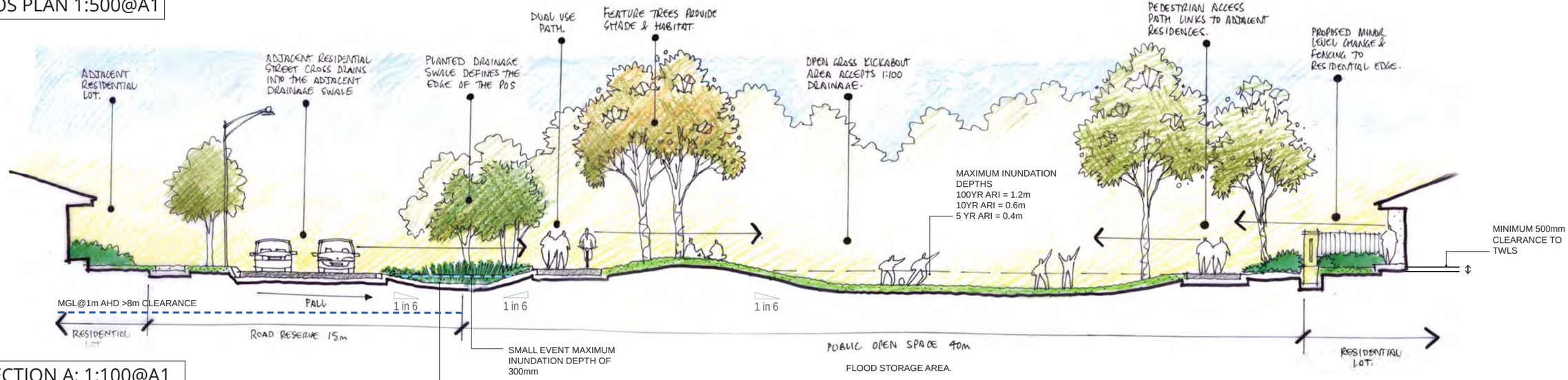


POS PLAN 1:500@A1



SECTION A: 1:100@A1

VISTA ESTATE: LOT 805

NORTHERN POS DESIGN OPPORTUNITY

DWG KQ--805-SK-01
REV B
DATE 02-02-17
0 5 10 15 20 25 m
PLAN SCALE 1 : 500 @ A1

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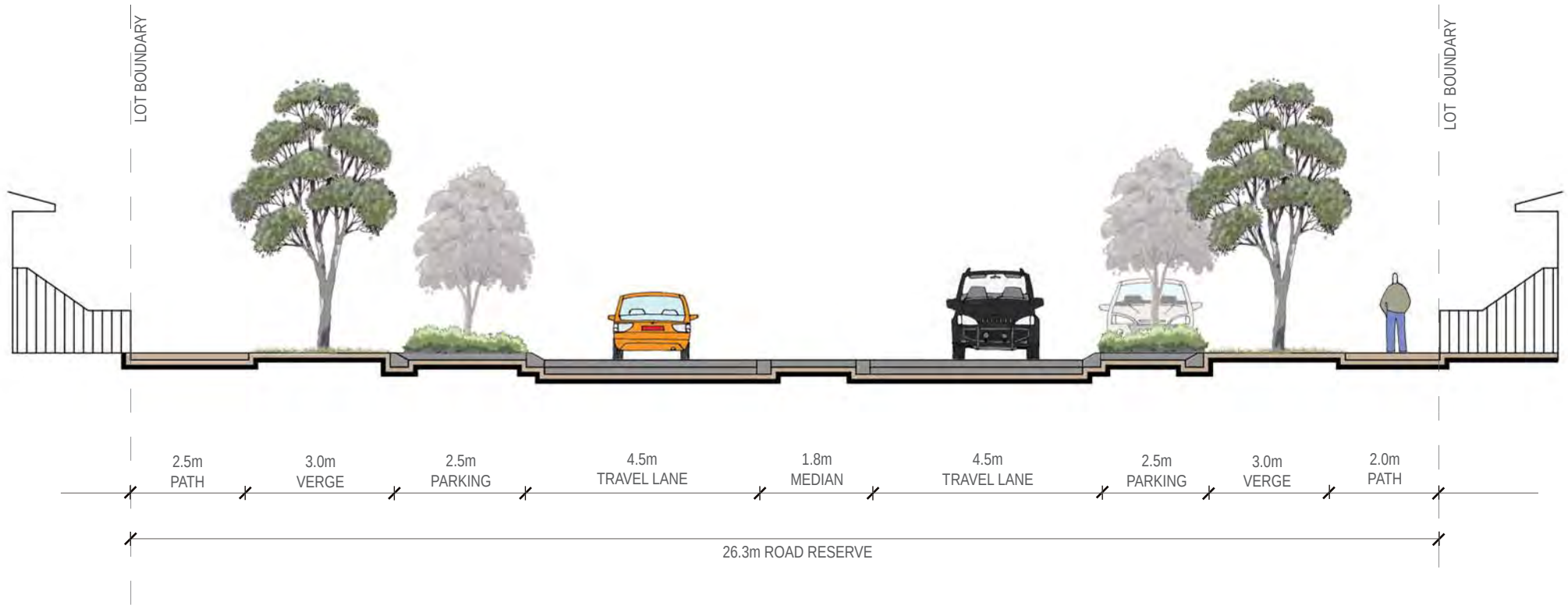
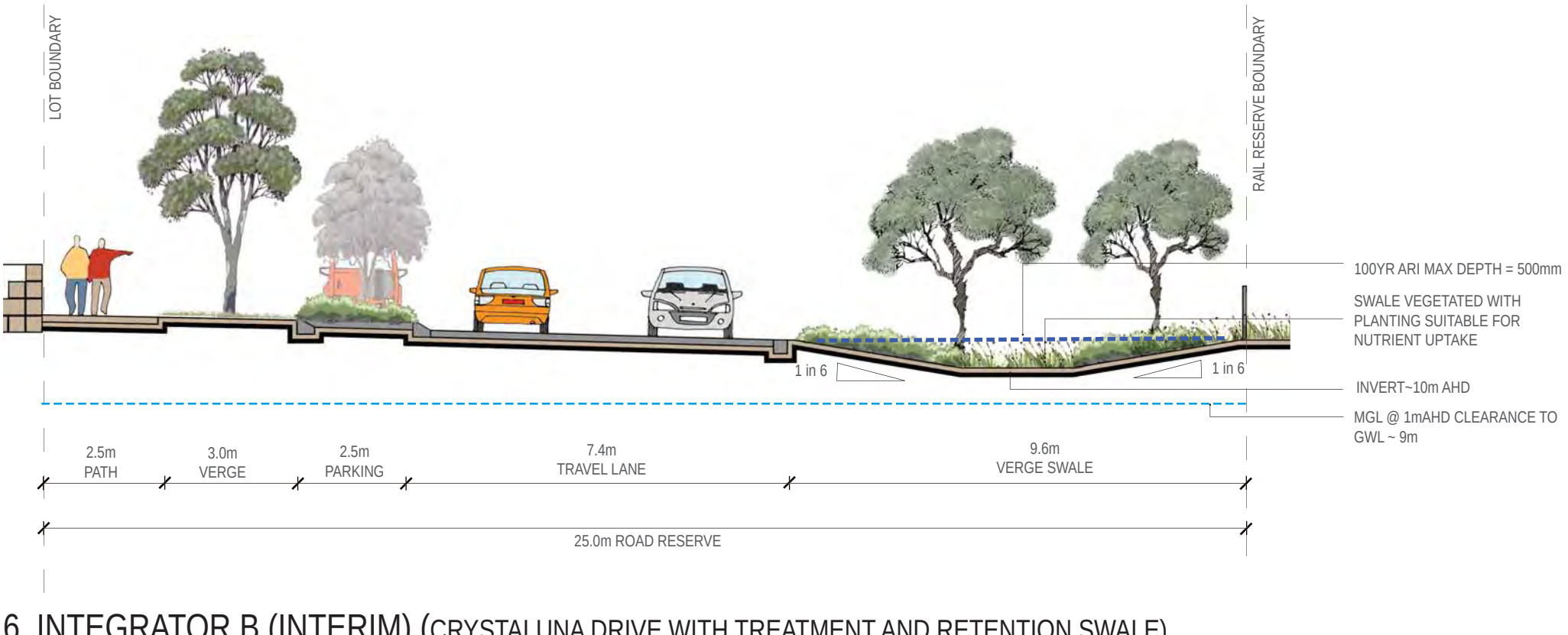
INTEGRATOR TYPICAL SECTIONS

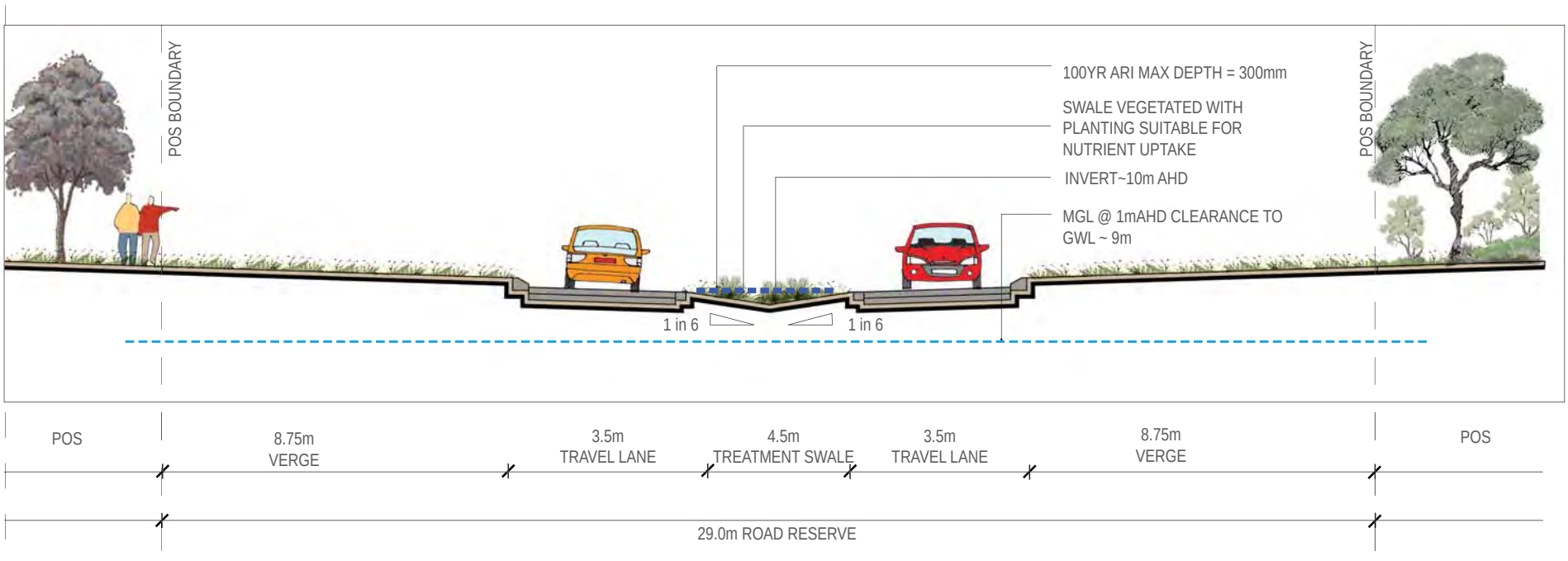
4: NEIGHBOURHOOD CONNECTOR A (AQUAMARINE PARADE SOUTH)



5: NEIGHBOURHOOD CONNECTOR A (AQUAMARINE PARADE NORTH WITH TREATMENT AND RETENTION SWALE)



6. INTEGRATOR B (INTERIM) (CRYSTALUNA DRIVE WITH TREATMENT AND RETENTION SWALE)



Project: VISTA ESTATE - ON-GOING IRRIGATION REQUIREMENTS

emerge ASSOCIATES
Integrated Science & Design

Client :	Golden Group	Landscape Architect:	Chris Newton
Site Details:	Lot 3, 805 + 806 Mandurah Road Karnup		Anna Killick
Planner :	DPS	Reference:	
Plan Reference	*GOGKA-2-001O(Nov 2016)*	Date:	06.06.17
		Revision:	H

WATER REQUIREMENTS FOR LOT 806

POS Reference, Anticipated Staging and POS Area		Landscape Design Input											
	Area of Public Open Space/Greenlinks(sq.m)	NOT - IRRIGATED			IRRIGATED			Total %	Total % Irrigated	Sq.m Irrigated	Hectare Irrigated HIGH Oval Only	Hectare Irrigated STANDARD	STANDARD Water per year (kL)
Stage	POS & POS Verge	% Hard/Sand	% Retain	%1:1 Drainage	% Turf	% Shrubs	% Buffer	Total %					*(Hect x 7500)*
POS D(CoR half)	*6,026*												
POS D (Lot 806 half)	2,990	~~7%~~	~~0%~~	~~8%~~	~~30%~~	~~55%~~	~~0%~~	100%	65%	1,943	NA	0.19	1,458
POS F (Excluding Oval)	24,266	~~18%~~	~~0%~~	~~8%~~	~~30%~~	~~44%~~	~~0%~~	100%	65%	15,773	NA	1.58	11,830
POS G	11,550	~~11%~~	~~0%~~	~~16%~~	~~25%~~	~~48%~~	~~0%~~	100%	73%	8,432	NA	0.84	6,324
PAW	520	~~30%~~	~~0%~~	~~0%~~	~~0%~~	~~70%~~	~~0%~~	100%	55%	286	NA	0.03	215
ROUNDABOUTS	375	~~15%~~	~~0%~~	~~0%~~	~~0%~~	~~85%~~	~~0%~~	100%	85%	319	NA	0.03	215
WIDENED VERGES - Stage 4 Swale	3,025	~~10%~~	~~0%~~	~~0%~~	~~0%~~	~~90%~~	~~0%~~	100%	70%	2,118	NA	0.21	1,429
WIDENED VERGES - Stage 1 Streetscap	2,280	~~10%~~	~~0%~~	~~0%~~	~~0%~~	~~90%~~	~~0%~~	100%	70%	1,596	NA	0.16	1,077
POS F (Oval)	21,434	~~10%~~	~~0%~~	~~10%~~	~~70%~~	~~10%~~	~~0%~~	100%	90%	19,291	2.74		20,550
Total (Excluding Oval)	45,006									30,466			22,547

WATER REQUIREMENTS FOR BUFFER TO MANDURAH ROAD ADJACENT LOT 806

POS Reference, Anticipated Staging and POS Area		Landscape Design Input											
	Area of Public Open Space/Greenlinks(sq.m)	NOT - IRRIGATED			IRRIGATED			Total %	Total % Irrigated	Sq.m Irrigated	Hectare Irrigated HIGH Oval Only	Hectare Irrigated STANDARD	STANDARD Water per year (kL)
Stage	POS + POS Verge	% Hard/Sand	% Retain	%1:1 Drainage	% Turf	% Shrubs	% Buffer	Total %					*(Hect x 7500)*
BUFFER (MANDURAH RD) Allows for 4 metres vegetation along Mandurah Rd	*16,800*												
BUFFER (50%) MANDURAH RD 1	8,400	~~20%~~	~~0%~~	~~0%~~	~~0%~~	~~30%~~	~~50%~~	100%	0%	0	NA	0.00	0
BUFFER (15%) MANDURAH RD 2	2,520	~~20%~~	~~0%~~	~~0%~~	~~0%~~	~~30%~~	~~50%~~	100%	0%	0	NA	0.00	0
	10,920									0			0

WATER REQUIREMENTS FOR LOT 805

POS Reference, Anticipated Staging and POS Area		Landscape Design Input											
	Area of Public Open Space/Greenlinks(sq.m)	NOT - IRRIGATED			IRRIGATED			Total %	Total % Irrigated	Sq.m Irrigated	Hectare Irrigated HIGH Oval Only	Hectare Irrigated STANDARD	STANDARD Water per year (kL)
Stage	POS & POS Verge	% Hard/Sand	% Retain	%1:1 Drainage	% Turf	% Shrubs	% Buffer	Total %					*(Hect x 7500)*
POS A	5,848	~~25%~~	~~0%~~	~~11%~~	~~25%~~	~~40%~~	~~0%~~	101%	60%	3,509	NA	0.35	2,631
POS B	7,883	~~20%~~	~~0%~~	~~7%~~	~~25%~~	~~40%~~	~~0%~~	92%	60%	4,730	NA	0.47	3,547
POS C1	13,343	~~15%~~	~~0%~~	~~23%~~	~~25%~~	~~37%~~	~~0%~~	100%	60%	8,006	NA	0.80	6,004
POS C2	10,005	~~12%~~	~~0%~~	~~13%~~	~~50%~~	~~15%~~	~~0%~~	90%	60%	6,003	NA	0.60	4,502
	37,078									22,247			16,685

Total Water Allocation

GWL 164062	Open Space irrigation up to 1.44ha		39,500
GWL 175845	Oval irrigation up to 2.74ha		20,550
Estimated Civil Construction use			
		Total Allocation	60,050

TOTAL WATER ESTIMATE LOT 806 + 805	39,232

APPENDIX F

INDICATIVE EARTHWORK LEVELS

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N

SWALE AREA 1423m²

ROAD RES AREA 8018m²
LOT AREA 2788m²

ROAD RES AREA 7032m²
LOT AREA 10019m²

POS AREA 5316m²

POS AREA
837m²

POS AREA 7166m²

POS AREA 9094m²

ROAD RES AREA 10293m²
LOT AREA 27284m²

ROAD RES AREA 5741m²
LOT AREA 2791m²

ROAD RES AREA 4003m²
LOT AREA 6014m²

ROAD RES AREA 4866m²
LOT AREA 10086m²

ROAD RES AREA 1401m²
LOT AREA 5539m²

POS AREA 12130m²

ROAD RES AREA 4180²
LOT AREA 8293m²

ROAD RES AREA 1669m²
LOT AREA 3070m²

ROAD RES AREA 18452m²
LOT AREA 44908m²

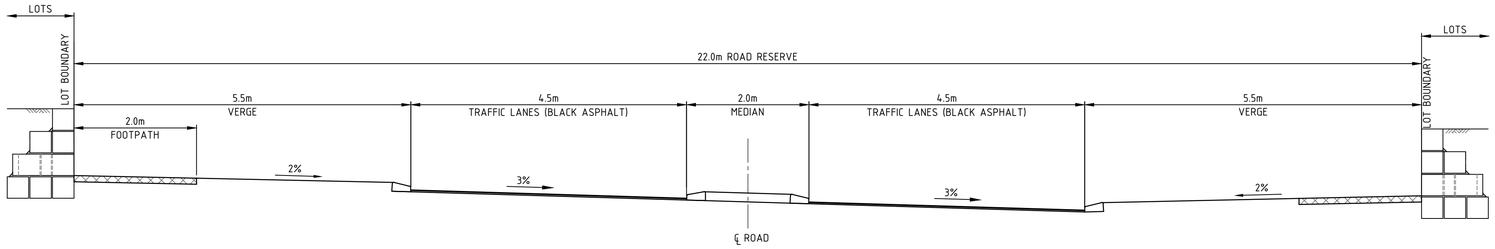
A

B

C

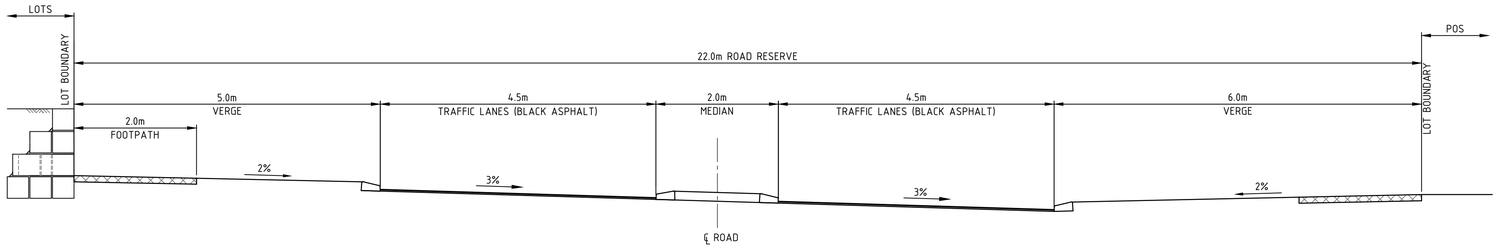
0 10 20 40 60m
SCALE 1:1000 @ ORIGINAL SHEET SIZE A1

Plotted By: MSmithers Plot Date: 11/11/16 - 10:27 Cad File: I:\JDS10425\JDS10425.805\Drawings\DWG\working\20161109 Revised LSP.dwg



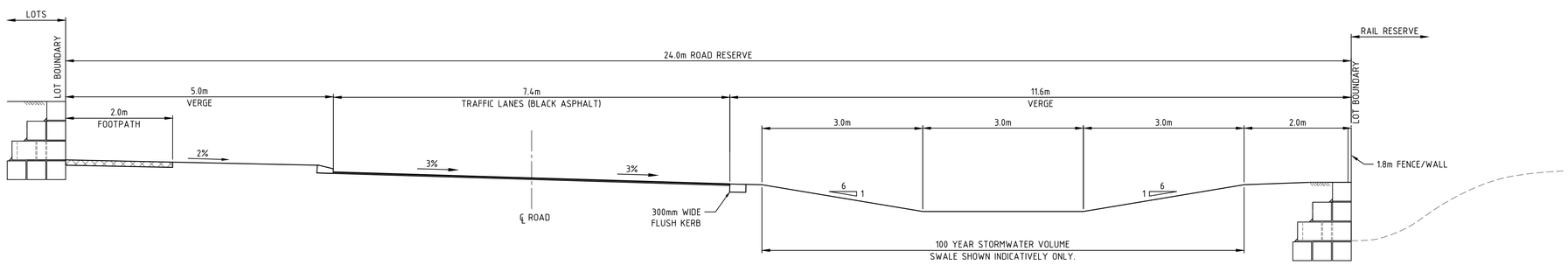
22.0m ROAD RESERVE
2 X 4.5m PAVEMENT
SCALE 1:50

SECTION C
SCALE 1:50



22.0m ROAD RESERVE
2 X 4.5m PAVEMENT
SCALE 1:50

SECTION B
SCALE 1:50



24.0m ROAD RESERVE
7.4m PAVEMENT
SCALE 1:50

SECTION A
SCALE 1:50

0 0.5 1 2 3m
SCALE 1:50 @ ORIGINAL SHEET SIZE A1

Plotted By: MSmithers Plot Date: 11/11/16 - 10:28 Cad File: I:\JDS10425\JDS10425.805\Drawings\DWG\working\20161109 Revised LSP.dwg