PART THREE B APPENDICES

NORTH STONEVILLE STRUCTURE PLAN

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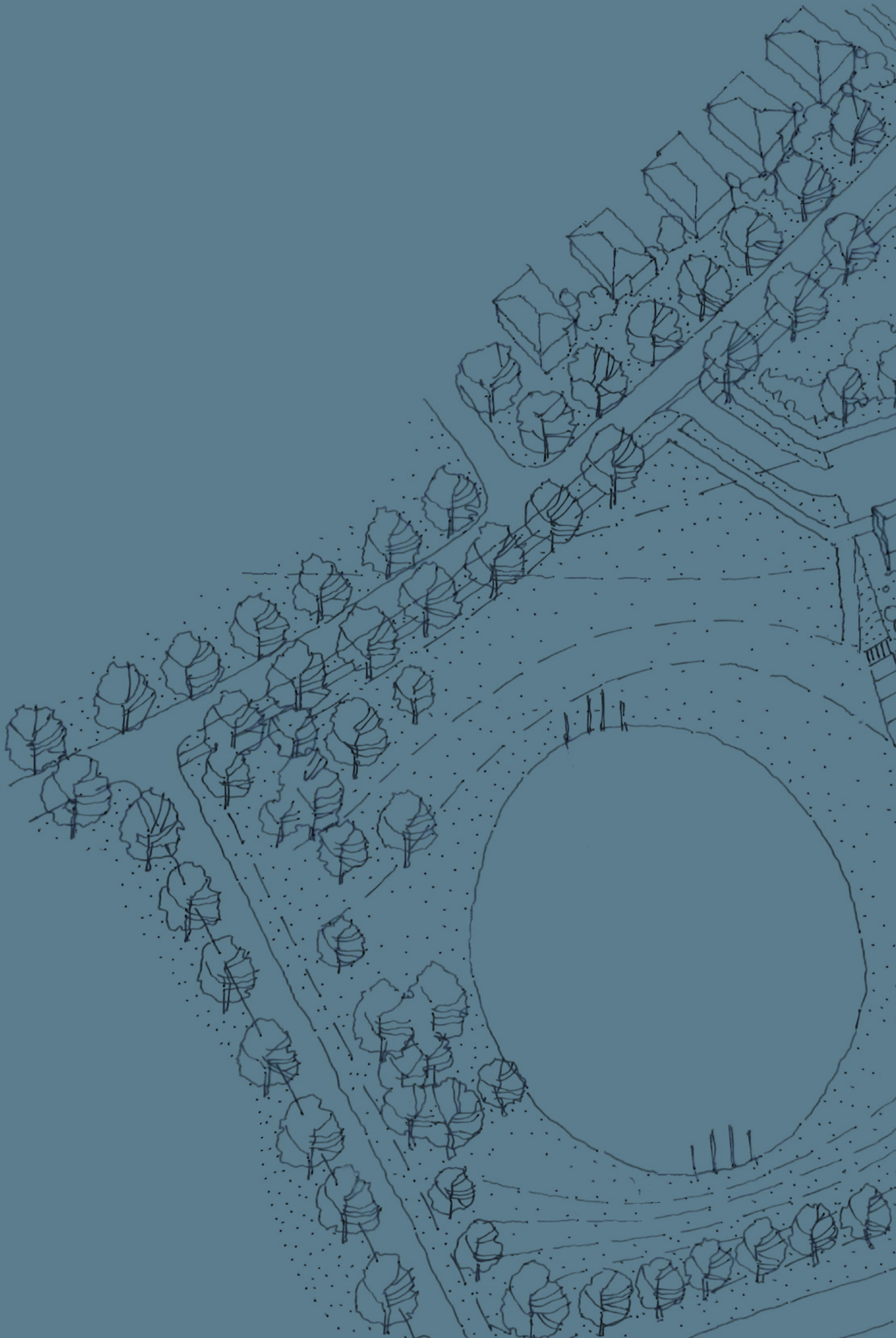
SATTERLEY

APPENDIX 6

LOCAL WATER MANAGEMENT STRATEGY

SATTERLEY



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Document Reference: EP17-013(03)--028 DPC

Emerge contact: Dave Coremans

23 January 2023

Attention: Duane Cole
Hatch Roberts Day

Delivered by email to: duanec@hatch.com

Dear Duane

NORTH STONEVILLE (SP34) PROPOSED STRUCTURE PLAN PROPOSED REVISION AND WATER PLANNING SUPPORT

The Local Water Management Strategy (LWMS) which supported the North Stoneville Structure Plan (SP34) was prepared by Emerge Associates and approved by the Department of Water and Environmental Regulation (DWER) and Department of Biodiversity Conservation and Attractions (DBCA) in 2019.

We understand that SP34 is proposed to be modified and that this will result in a reduced lot yield and some development area and road realignments.

The purpose of this letter is to summarise the likely changes that will be required to the LWMS to accurately reflect the amended SP34 and support future planning and design stages.

Local Water Management Strategy Design Principles and Criteria

The water management approach was based on design principles developed based on the sites natural attributes and the vision of the client and project team that was documented in SP34. The design principles included:

1. Take a sustainable approach to water use within the site.
2. Mimic the existing environmental discharge to the environment, for both peak flow rates and water quality.
3. As much as practicable, attenuate stormwater at source, high in each catchment.
4. Minimise the amount of imported fill and engineered lot design approaches to retain existing landform.
5. Adopt lot drainage practices which align with the size of lots and attributes of the existing environment – these will aim to assist at-source detention.
6. Integrate the drainage network into the road reserve in a manner which aligns with the intent of the design transects.
7. Utilise natural hydrological features of the site to achieve flood conveyance and detention where possible.

Enhance natural hydrological features of the site, and ensure that drainage infrastructure is consistent with these.

The design principles then guided the LWMS water management design criteria, which included:

Water conservation

- Lot scale potable water use to be less than 60 kL/person/year.
- No potable water to be used for non-potable uses in any public spaces.

Recycled water

- Maximise the re-use of recycled water within the site.
- All open space long term irrigation requirements to be met by recycled water.
- Open space irrigated areas to use an average of 7,500 kL/ha/year.
- Recycled water will be retained within the site and will not be discharged to the environment.

Stormwater management

- Major rainfall event post-development peak flow rates leaving the site should be equal to or less than pre-development peak flow rates.
- Flood detention to achieve pre-development discharge rates should occur as high in the catchment as practical.
- Frequent rainfall event runoff should be treated at source, or as close to source as practical.
- Water quality treatment structures to be sized to retain the first 15 mm from directly connected impervious areas.
- Sediment control and erosion protection to be incorporated in to road reserves where practicable.
- Road drainage network to be designed to accommodate and convey the minor rainfall event.

Groundwater management

- Where utilised, subsoil drains are to be set at or above the low permeability soil layer.
- Finished lot levels are to be at least 1.2 m above the controlled groundwater level formed by the invert of subsoil drains.
- Subsoil drains to be discharged via a free draining outlet to an appropriate water quality treatment structure.
- Soil profile beneath T4 and T5 lots to be deep ripped/filled to a minimum depth of 1.0 m.

The above criteria will all remain relevant to the amended SP34, and demonstration that these can be met will be required to guide future planning and design stages.

Potential updates required to the Local Water Management Strategy

The demonstration of compliance with criteria regarding non-potable water use, recycled water and those which demonstrate spatial requirements for water management will require update. Given that the amendment to SP34 involves a reduction of lots by approximately 40%, the extent of impervious areas of the catchment are anticipated to decrease, and on this basis the spatial requirements for water management are unlikely to increase. The water balance and amount of available recycled water to meet non-potable needs versus amount of public open space proposed to be irrigated will also require update. These aspects can adequately be assessed in a revision to the relevant aspects of the LWMS to ensure that future planning and design stages are appropriately informed/guided.

Summary and closing

The approved LWMS provides an appropriate framework, objectives and design criteria to support future planning processes and design stages at North Stoneville. The criteria will be relevant and applicable to the amend SP34. The demonstration of compliance of some aspects relevant to recycled/non-potable water and stormwater management will require update. However, these are not anticipated to change the overall design outcome or level of protection provided to the local and downstream environment. This could be documented in an update to the existing LWMS to support the final (amended) SP34.

Should you have any queries or concerns feel free to contact the undersigned.

Yours sincerely
Emerge Associates

Dave Coremans
DIRECTOR, PRINCIPAL ENVIROMENTAL CONSULTANT

cc: none

Encl: none

Local Water Management Strategy

North Stoneville LSP34

Project No: EP17-013(01)

Prepared for Satterley
June 2019

Document Control

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	For submission with SP34				

Executive Summary

Satterley (the 'proponent') is developing Lot 48 (on plan 29855), 4685 Stoneville Road and Lot 1 (on plan 69650), 340 Roland Road (herein referred to as the site) for residential and associated uses. The site is located approximately 30 km north east of Perth Central Business District within the Shire of Mundaring (SoM). The site covers approximately 555 ha and is bound by Roland Road to the west, Cameron Road to the North and existing rural residential development to the east and south.

The site is zoned "Rural" with large sections zoned "Urban" under the Metropolitan Region Scheme (MRS), and "Development Zone" with a parcel zoned "Rural Smallholdings" to the south of the site under the SoM Local Planning Scheme (LPS) No. 4.

It is important that the manner in which stormwater runoff from residential zoned areas is to be managed to avoid flooding and protect the environment and that this approach is clearly documented early in the planning process. This Local Water Management Strategy (LWMS) details the water management approach to support the North Stoneville Structure Plan 34 Amendment (SP34).

The guiding State and Local Government policies have informed the water management objectives for the site, and these have in turn guided the design criteria proposed to ensure that the objectives are met.

An integrated water cycle management approach requires a thorough understanding of the existing attributes of a site. In summary, the environmental investigations conducted to date indicate that:

- The site receives 1,079 mm of average annual rainfall with the majority of rainfall received between June and August.
- Topography of the site ranges from 264 to 316 m AHD and exhibits average slopes up to 15%. Some minor portions of the site may contain slopes exceeding 15%.
- The majority of the site is comprised of laterite overlain by and associated with gravel (LA1), becoming progressively sandy near streamlines.
- Elevated TN was observed in some surface water monitoring sites.
- Surface water flows discharging to the north of the site show elevated salinity.
- There are some relatively minor upstream contributing catchments. With the exception of these, the site is at the top of catchment.
- The site contains four main dams that currently capture runoff from within the site and could potentially be used to achieve flood detention within the site (with some minor modifications). A minor dam exists in the eastern portion of the site
- Runoff from the site discharges to Clutterbuck Creek, a tributary of Jane Brook (to the south) and tributaries to Susannah Brook (to the north).
- Peak flow rates leaving the site (at six locations) have been characterised for frequent (1 EY) minor (20% AEP) and major (1% AEP) events. This has been undertaken using XPSWMM, and has been informed by calibrated runoff modelling from nearby Gidgegannup townsite.
- There is no true groundwater beneath the site. Shallow clayey soils above gravels/laterite may be seasonally saturated and express some water at the low points (valleys) within the site.

The hydrological conditions of the site have driven the design criteria, which have in turn been reflected in the spatial layout of SP34. The principle has been to understand and quantify the site hydrology, and to then prepare an approach which mimics this. The water management response to the guiding documents, site characteristics and water management principles seeks to guide outcomes for:

- Water Conservation
- Wastewater servicing provision
- Non-potable water demand and supply
- Surface water management
- Groundwater management.

The site has low permeability soils with steep slopes and significant areas of vegetation. The water management approach seeks to address water quality concerns at source, and to mimic the outflow conditions (peak flows and volumes) from the site. This has also considered the landform, and retention and use of existing features (dams, streamlines) is proposed to minimise additional disturbance to the site and subsequent vegetation loss.

A significant component of the water management approach is the ability to provide treated water to public open space (POS) to provide appropriate amenity. This is achieved by potable water serviced by the Water Corporation, teamed with a private, licensed service provider that will recycle wastewater within the site. Recycled water will be used to meet POS irrigation demand, and the POS design has been carefully considered to ensure that the right amount of water is available for irrigation without applying excessive amounts of nutrients.

The design criteria, the manner in which they will be achieved, responsibility for implementation and timing of implementation are summarised in **Table E1**.

The SP34 development proposal includes:

- 1, 410 residential lots
- Neighbourhood Centre
- Primary School and high school
- Approximately 145 ha of open space
- Retained streamlines with appropriate foreshore areas
- A recycled water plant
- Conservation bushland
- Community gardens and common spaces.

Within the development, five characteristic urban-rural transects will gradually integrate several village cores within the surrounding rural landscape, avoiding urban sprawl. Each transect incorporates varying planning and design schemes suited to the relevant land use, including transect specific drainage systems and road layout. Transects include:

T5 Village Core - lots will be 400-600 m^2, and will include higher density mixed use buildings that can accommodate retail, offices, cottages and townhouses. It has a tight network of streets, with wide sidewalks, steady street tree planting and buildings set close to the sidewalks. T5 lots typically frame a central focal point with strong civic presence and have a more formal structure.

T4 Village Urban lot areas will be 800-1,000 m^2 and will primarily be residential traditional neighbourhood grid structure, with some mixed use closer to village core. Setbacks and landscaping will be modest, encouraging public-private interaction at street level. Streets will have kerbs and sidewalks define medium-sized blocks.

T3 sub urban transect lots will be 1,000-2,000 m^2 and will be low density residential areas, within walking distance of T4 village urban areas. Home businesses and outbuildings are allowed within T3 areas. Planting is naturalistic and setbacks are relatively deep. Blocks may be large and the roads irregular to accommodate natural conditions.

T2 Natural Living lots will be 1-2 ha and will be sparsely settled lands in open or cultivated states, with dry rolling land. These include existing cleared agricultural land, grassland, and drainage areas. Typical buildings are pseudo-farmhouses, ranches with large porches, and rural style buildings

T1 Conservation and open space portions of the site will be areas approximating or reverting to a wilderness condition, including lands unsuitable for settlement due to topography, hydrology, vegetation or cultural heritage.

The approach to water management across the site reflects the transect approach, where development transitions from rural character in T1 areas through to urban/village core characteristics in T5 areas.

This LWMS demonstrates that SP34 implements a water sensitive urban design (WSUD) approach, which considers all sources of water, manages water at its source and which utilises the natural/existing characteristics of the site to meet future development needs and to protect the existing and downstream environments.

Table E1: *Water management criteria and compliance*

Management element	Criteria number	Criteria description	Manner in which compliance has been achieved	Responsibility for implementation	When implemented
Water Conservation	WC1	Lot scale potable water use to be less than 60 kL/person/year	Rainwater tank uptake to be encouraged for non-potable water uses in T3 lots and mandated in T2 lots.	Proponent	At time of sale
			Water efficient fittings and appliances adopted within all lots, schools and the local centre.	Residents	Post house construction
			Waterwise gardening principles promoted for use within lots and adopted in all POS areas.	Proponent	At time of sale
	WC2	Non-potable water to be used to irrigate open spaces	Recycled water from the RWP will be used to meet irrigation requirements for all open space areas.	Proponent/SoM	Landscape design
Recycled Water	RW1	Maximise the re-use of recycled water within the site	Recycled water will be stored onsite to provide water to meet non-potable irrigation needs.	Proponent/RWP operator	RWP construction and operation
			Recycled water will be used to irrigate POS, open spaces and schools.	Proponent/SoM	Following POS construction
	RW2	All open space long term irrigation requirements to be ultimately met by recycled water	Initial irrigation demand will be met by onsite surface water dams.	Proponent	During construction, establishment and maintenance period
			The wastewater recycling system will ultimately provide treated wastewater to meet the irrigation requirements of all open space within the development.	Proponent/RWP operator/SoM	Following construction, establishment and maintenance period
	RW3	Open space irrigated areas to use an average of 7,500 kL/ha/year	The actual irrigation rate will vary with climate and demand. The water balance confirms that on average open space will achieve the required irrigation capacity.	Landscape maintenance contractor	Following POS construction
	RW4	Recycled water will be retained within the site and will not be discharged to the environment	Water quality from the RWP will be appropriate for long term irrigation of vegetation within the site.	Proponent/RWP operator	After construction, establishment and maintenance period

__Table E1:__ Water Management Criteria and Compliance (continued)

Management element	Criteria number	Criteria description	Manner in which compliance has been achieved	Responsibility for Implementation	When implemented
Recycled Water	RW4	Recycled water will be retained within the site and will not be discharged to the environment	Design and operational contingencies are existing, or can be implemented, within the wastewater management approach and RWP. No discharge is required, even in a 'wet' year scenario.	RWP operator	During and following construction of entire estate
			Additional contingency will be provided by WSUD features (e.g. the living streams), which will provide nutrient removal to any incidental recycled water runoff.	Proponent/SoM	Following construction
Stormwater	SW1	Major event post-development peak flow rates leaving the site should be equal to or less than pre-development peak flow rates	Roadside swales, median swales and bio-retention areas (BRAs) will provide significant retention/detention storage for frequent events and will contribute to peak flow management in major events.	Proponent/SoM	Following construction
			Flood detention will be achieved by using the significant capacity of onsite dams with the addition of controlled outlet structures.	Proponent	Detailed subdivision design
			Flood storage areas (FSAs) will be constructed to detain runoff from catchments which cannot discharge to one of the existing dams. FSAs will be within private property and protected by easements	Proponent	Detailed subdivision design
	SW2	Flood detention to achieve pre-development discharge rates should occur as high in the catchment as practical	Roadside swales will provide flood detention at source, minimising the need for traditional pipe networks.	Proponent	Detailed subdivision design
			Existing dams will be utilised, which will detain runoff from immediately adjacent and upstream catchments.	Proponent	Detailed subdivision design
			Catchment areas are generally relatively small, and FSAs will be located at the nearest practicable downstream location	Proponent	Detailed subdivision design

Table E1: *Water Management Criteria and Compliance (continued)*

Management element	Criteria number	Criteria description	Manner in which compliance has been achieved	Responsibility for Implementation	When implemented
Stormwater	SW3	Frequent event runoff should be treated at source, or as close to source as practical. This may include detention at source and/or additional treatment if appropriate	Roadside swales will provide water quality treatment at source, minimising the need for downstream water quality treatment.	Proponent	Detailed civil design
			Median swales will provide water quality treatment at source.	Proponent	Detailed civil design
			BRAs will be used in catchments where full treatment of the 1EY event cannot be achieved at source.	Proponent	Detailed civil design
			Living Stream approach will be used to convey treated runoff.	Proponent	Detailed civil design
	SW4	Water quality treatment structures to be sized to detain and/or retain the first 15 mm from directly connected impervious areas	Combined capacity of roadside swales, median swales and BRAs are sufficient to detain and/or retain the first 15 mm of runoff.	Proponent	Detailed civil design
			Living Stream approaches used for onsite streamlines, providing additional water quality treatment prior to discharge.	Proponent	Detailed civil design
	SW5	Sediment control and erosion protection to be incorporated in to road reserves and water quality treatment structures	Roadside swales, median swales and BRAs will utilise mortared and/or loose rock spawls at entry and exit points (using local laterite materials).	Proponent	Detailed civil design
			Roadside and median swales on slopes >5% will utilise rock armoured intermediate weirs to slow down flow, control erosion and to drop out any mobilised sediments.	Proponent	Detailed civil design
	SW6	Road drainage network to be designed to accommodate the minor event	The roadside swales will convey minor event runoff.	Proponent	Detailed civil design
			Where required (i.e. adjacent to T4 and T5 lots or where slope >5%) pit and pipe network may be utilised, and will be designed to convey the minor event.	Proponent	Detailed civil design

Table E1: Water Management Criteria and Compliance (continued)

Management element	Criteria number	Criteria description	Manner in which compliance has been achieved	Responsibility for Implementation	When implemented
Groundwater	GW1	Where utilised, subsoil drains are to be set at or above the low permeability soil layer.	Subsoil drains may be utilised in road reserve, beneath T4 and T5 lots or to ensure WSUD features remain dry in between rainfall events.	Proponent	Detailed civil design
			Where utilised, subsoil drains will be set at or above the underlying low permeability (rock or impermeable clays) layer.	Proponent	Detailed civil design
	GW2	Finished lot levels are to be at least 1.2 m above the CGL formed by the invert of subsoil drains.	Where subsoil drains are used, deep ripped soil and/or imported fill will provide finished lot levels with at least 1.2 m clearance from the CGL.	Proponent	Detailed civil design
	GW3	Subsoil drains to be discharged via a free draining outlet to an appropriate water quality treatment structure.	Subsoil drainage will be constructed such that intercepted water will freely drain to a discharge location (e.g. through appropriate grading and via the invert being at least 150 mm above the receiving environment).	Proponent	Detailed civil design
			Groundwater will be treated by discharging intercepted water into treatment structures (i.e. swales or BRAs), or by providing treatment prior the water entering the drain (e.g. by constructing pipes in filter media).	Proponent	Detailed civil design
	GW4	Soil profile beneath T4 and T5 lots to be deep ripped/filled to a minimum depth of 1.0 m.	The soil profile beneath T4/T5 lots will be deep ripped to an approximate depth of 0.4-0.6 m.	Proponent	Detailed civil design
			T4/T5 lots will be filled with permeable material to an approximate depth or 0.4-0.6 m to ensure a minimum profile of 1.0 m of ripped/filled soil.	Proponent	Detailed civil design

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Stoneville Wastewater Servicing Concept Design Assessment

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Interim Position Statement: Constructed Lakes - Audit

Abbreviation Tables

Table A1: Abbreviations – general terms

General terms	
AEP	Annual exceedance probability
AHD	Australian height datum
ASS	Acid sulfate soils
DWMS	District water management strategy
EC	Electrical conductivity
EY	Exceedance year
FRP	Filterable reactive phosphorous
LWMS	Local water management strategy
NH_4	Ammonium
NO_X	Nitrate and nitrite

Table A1: Abbreviations – general terms (continued)

RWP	Recycled water plant
SP	Structure plan
TKN	Total Kjeldahl nitrogen
TN	Total nitrogen
TP	Total phosphorous
UWMP	Urban water management plan
WSUD	Water sensitive urban design
WWG	Waterwise gardens

Table A2: Abbreviations – organisations

Organisations	
ABS	Australian Bureau of Statistics
ANZECC	Australian and New Zealand Environment and Conservation Council
BoM	Bureau of Meteorology
DBCA	Department of Biodiversity, Conservation and Attractions
DER	Department of Environmental Regulation (now DWER)
DoH	Department of Health
DoW	Department of Water (now DWER)
DWER	Department of Water and Environmental Regulation
EPA	Environmental Protection Authority
ERA	Economic Regulation Authority
SoM	Shire of Mundaring
WAPC	Western Australian Planning Commission

Table A3: Abbreviations – units of measurement

Units of measurement	
ha	Hectare
kL	Kilolitres
kL/annum	Kilolitres per annum
kL/ha/annum	Kilolitres per square meter per annum
km	Kilometre
m	Metre
m AHD	Metres in relation to the Australian height datum
m/day	Metres per day
mm	Millimetre
mg/L	Milligrams per litre
µg/L	Micro-grams per litre
°C	Degrees centigrade
%	Percentage
µS/cm	Micro Siemens per centimetre

Terminology Tables

Table A4: Terminology - design rainfall

Equivalent average recurrence interval (ARI) terminology	Average exceedance probability (AEP) terminology utilised
1 in 1 year ARI event	1 exceedance year (EY) event
1 in 1.5 year ARI event	50% AEP event
1 in 5 year ARI event	20% AEP event
1 in 10 year ARI event	10% AEP event
1 in 20 ARI event	5% AEP event
1 in 50 ARI event	2% AEP event
1 in 100 ARI event	1% AEP event
1 in 200 ARI event	1 in 200 AEP event
1 in 500 ARI event	1 in 500 AEP event

1 Introduction

1.1 Background

Satterley (the 'proponent') is developing Lot 48 (on plan 29855), 4685 Stoneville Road and Lot 1 (on plan 69650), 340 Roland Road (herein referred to as the site) for residential and associated purposes. The site is located approximately 30 km north east of Perth Central Business District within the Shire of Mundaring (SoM). The site covers approximately 555 ha and is bound by Roland Road to the west, Cameron Road to the North and existing rural residential development to the east and south. The location and extent of the site is shown on **Figure 1**.

It is important that the manner in which stormwater runoff from residential zoned areas is to be managed to avoid flooding and protect the environment and that this approach is clearly documented early in the planning process. This Local Water Management Strategy (LWMS) details the water management approach to support the North Stoneville Structure Plan 34 Amendment (SP34).

1.2 Town planning context

The site is zoned "Rural" with large sections zoned "Urban" under the Metropolitan Region Scheme (MRS), and "Development Zone" with a parcel zoned "Rural Smallholdings" to the south of the site under SoM Local Planning Scheme (LPS) No. 4.

1.3 Policy framework

There are a number of State 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)
- *Liveable Neighbourhoods (4th Edition)* (WAPC 2007, 2015)
- *Guidance Statement No. 33: Environmental Guidance for Planning and Development* (EPA 2008)
- *State Planning Policy 2.10 Swan Canning River System* (WAPC 2006).

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 2008)
- *Guideline for the approval of non-drinking water systems Western Australia* (DoW 2013)
- *Australian Runoff Quality* (Engineers Australia 2006)
- *Australian Rainfall and Runoff* (Engineers Australia 2016)
- *Decision Process for Stormwater Management in Western Australia* (DWER 2017)
- *Stormwater Management Manual for Western Australia* (DoW 2007)

- *National Water Quality Management Strategy (NWQMS)* (ANZECC 2000)
- *Separation Distances for Groundwater Controlled Urban Development* (IPWEA 2016)
- *Draft Government Sewerage Policy* (DoP 2016)
- *Guidelines for the Non-potable Uses of Recycled Water in Western Australia* (DoH 2011).

The guidance documents listed indicate a need for accurate water quality 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 and Environmental Regulation (DWER) and engineering standards specified by the SoM, but will also ensure that realistic water quality criteria that are practically achievable are adopted.

1.4 Previous studies

A District Water Management Strategy (DWMS) was prepared in 2009 to support rezoning of Lot 69 Roland Road (Cardno 2009). The DWMS proposed measures to managed water within the site, including the possible onsite management and reuse of treated wastewater. The approach to water management and recycling has significantly progressed since preparation of the DWMS, and therefore the approaches proposed are superseded by this LWMS.

1.5 LWMS objectives

This LWMS has been developed in consideration of the objectives and principles detailed in *Better Urban Water Management* (WAPC 2008). It is intended to support SP34, and is further based on the following major objectives:

- Design and implement a water management approach that is consistent with the surrounding hills landscape.
- Take a sustainable approach to water use within the site.
- Mimic the existing environmental discharge to the environment, for both peak flow rates and water quality.
- As much as practicable, attenuate stormwater at source, high in each catchment.
- Minimise the amount of imported fill and engineered lot design approaches to retain existing landform.
- Adopt lot drainage practices which align with the size of lots and attributes of the existing environment – these will aim to assist at-source detention.
- Integrate the drainage network into the road reserve in a manner which aligns with the intent of the design transects.
- Utilise natural hydrological features of the site to achieve flood conveyance and detention where possible.
- Enhance natural hydrological features of the site, and ensure that drainage infrastructure is consistent with these.

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

2 Proposed Development

The SP34 area includes a total land area of approximately 555 ha and the development includes:

- 1, 410 residential lots
- Neighbourhood Centre
- Primary school and high school
- Approximately 145 ha of open space
- Retained streamlines with appropriate foreshore areas
- A recycled water plant (RWP)
- Conservation bushland
- Community gardens and common spaces.

North Stoneville SP34 is provided in **Appendix A**.

Within the development, five characteristic urban-rural transects will gradually integrate several village cores within the surrounding rural landscape, avoiding urban sprawl. Each transect incorporates varying planning and design schemes suited to the relevant land use, including transect specific drainage systems and road layout. The transect approach is illustrated in **Plate 1**.

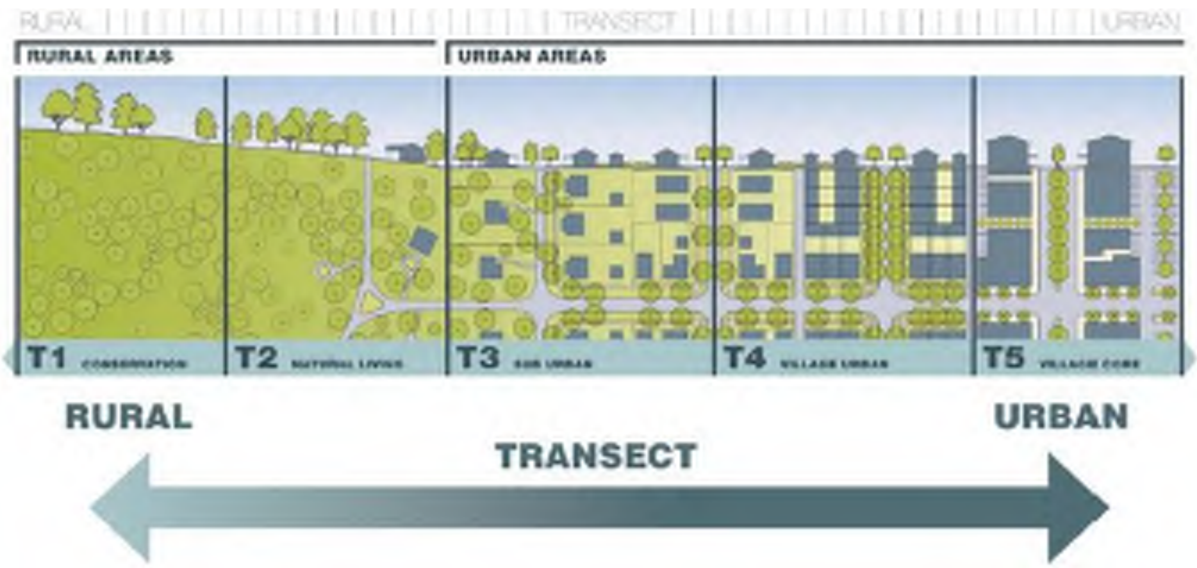

Plate 1: transect development approach

Each transect has different characteristics and approaches to water management. These characteristics and approaches are summarised in the following sections.

2.1 T5 Village Core

T5 transect lots will be 400-600 m^2, and will include higher density mixed use buildings that can accommodate retail, offices, cottages and townhouses. It has a tight network of streets, with wide sidewalks, steady street tree planting and buildings set close to the sidewalks. T5 lots typically frame a central focal point with strong civic presence and have a more formal structure.

The parameters relevant to water management for T5 lots include:

- Lots to be deep ripped to ~600 mm, ~600 mm sand fill.
- Lot connections will be provided as per SoM requirements
- Onsite soakage unlikely to be appropriate given small lots sizes, setback requirements and low permeability of underlying soil profiles.
- Lots to be encouraged to include rainwater tanks, though optional.
- Road carriageway to be kerbed and stormwater drainage to be conveyed via a conventional pit and pipe network.
- At source treatment of the frequent (1% average exceedance probability – AEP) in road reserves to be within:
  - Bio-retention areas (BRAs) (where practicable). These may be smaller 1:3 side sloped vegetated treatment areas within adjacent open space or locally widened verges.
  - Tree pits. Adjacent to or incorporated into side entry pits (SEPs).
- No minor (20% AEP) event or major (1% AEP) event flood detention proposed in open spaces (as the urban core public open space (POS) spaces are intended to provide maximum amenity).

2.2 T4 Village Urban

T4 transect lot areas will be 800-1,000 m^2 and will primarily be residential traditional neighbourhood grid structure, with some mixed use closer to the village core. Setbacks and landscaping will be modest, encouraging public-private interaction at street level. Streets will have kerbs and sidewalks define medium-sized blocks.

The parameters relevant to water management for T4 lots include:

- Building pad area and immediate surrounds as necessary to be deep ripped to ~600 mm, ~600 mm sand fill.
- Onsite soakage will not be enforced due to minimal infiltration profile, however may be possible where geotechnical conditions indicate this is appropriate.
- The exception to ripping/fill is lots >4% slope, where lots may take alternative approaches to building (e.g. split level/pole homes)
- Lots to be encouraged to include rainwater tanks, though optional.
- Road carriageway to be kerbed and stormwater drainage to be conveyed via a conventional pit and pipe network.
- To reduce pit and pipe network infrastructure, stormwater conveyance within road pavement formation is likely to be applied, subject to gutter flow depth and width.
- At source treatment of the frequent event in road reserves to be within verge/median conveyance swales: 1:3 side slopes and maximum depth of 0.5 m. Average depth likely to be less due to slope. May be vegetated or rock pitched, depending on slope.
- No minor or major event flood detention proposed in open spaces, however green corridors are used for conveyance and will provide some in-line detention (via weir like structures).
- Where green corridors used for conveyance, erosion and downstream sedimentation must be considered in design (particularly where road reserve grade > 4 %)

2.3 T3 Sub Urban

T3 transect lots will be 1,000-2,000 m^2 and will be low density residential areas, within walking distance of T4 village urban areas. Home businesses and outbuildings are allowed within T3 areas. Planting is naturalistic and setbacks are relatively deep. Blocks may be large and the roads irregular to accommodate natural conditions.

The parameters relevant to water management for T3 lots include:

- Rainwater tanks mandatory as per SoM specifications.
- Road reserve to preferentially utilise roadside swales for <5 % slope. Roads >5 % slope to utilise pit and pipe network. To reduce pit and pipe network infrastructure, stormwater conveyance within the road pavement formation is likely to be applied, subject to gutter flow depth and width.
- Where lot slope >5 % controls (e.g. contour bunds) at downstream boundary are to be installed, with flow pathway (via easement or similar) directed along downstream property boundary to the nearest road reserve. Nominally this may be needed every 2nd lot boundary.
- At source treatment of frequent event rainfall from road reserves to be via in-line detention, achieved in roadside swales or conveyance in green corridors where possible. Swales may be vegetated and/or rock pitched, depending on localised slope.
- Downstream treatment structures (for sediments) provided at catchment low points for all runoff from frequent events that is not achieved either in lot or road reserves higher in the catchment.
- Minor and major event flood detention to occur either within road reserve swales, at critical low points or in flood storage areas (FSAs) at minor catchment low points or within retained dam structures.
- All discharge locations from road reserves and drainage reserves to be scour protected.

2.4 T2 Natural Living

T2 transect lots will be 1-2 ha and will be sparsely settled land in open or cultivated states, with dry rolling land. These include existing cleared agricultural land, grassland, and drainage areas. Typical buildings are pseudo-farmhouses, ranches with large porches, and rural style buildings.

The parameters relevant to water management for T2 lots include:

- Rainwater tanks mandatory as per SoM specifications – consistent with rural feel of the area.
- Soakwells not required, though may be used for convenience if desired and based on localised constraints/conditions.
- Roads to be unkerbed, table drains only to be utilised where slope and road geometry dictate, or where longitudinal grade >5 %.
- No formal water quality treatment (sediment) structures, except at discharge locations from table drains.
- Where a significant upstream catchment terminates in a T2 area:
  - Catchment runoff may need to be conveyed through T2 lots to the site discharge location to be protected by easements.

- Minor and major event flood detention may need to occur within T2 lots to achieve required flood detention to be protected in easements.
- All discharge locations from road reserves and drainage reserves to be scour protected.

2.5 T1 Conservation & Open Space

T1 transect portions of the site will be areas approximating or reverting to a wilderness condition, including lands unsuitable for settlement due to topography, hydrology, vegetation or cultural heritage.

- No lot development (this land will be vested to SoM and/or Department of Biodiversity Conservation and Attractions (DBCA) for public amenity).
- Roads to be unkerbed with no formal drainage. Table drains only to be utilised where slope and road geometry dictate, or where longitudinal grade >5 %.

3 Pre-development Environment

3.1 Sources of information

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

- *Regional 1:50 000 Geology Map Sheet* (Smurthwaite 1986)
- *Climate Data Online* (BOM 2018)
- *National Water Quality Management Strategy* (ANZECC 2000).

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:

- Surface water quality monitoring conducted by Cardno (2009).
- Surface water quality monitoring conducted by Emerge Associates (2017 to 2018)
- Geotechnical Investigations conducted by Galt Geotechnics (2017a, 2017b).

3.2 Climate

The site experiences a 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 1,079 mm on average annually with approximately half of the regions rainfall received between June and August (BoM 2018). The region experiences rainfall (>1 mm) on 87 days annually (on average) (BoM 2018).

3.3 Geotechnical conditions

3.3.1 Topography

Topographical survey indicates that the site is characterised by undulating topography with a prominent valley running laterally through the site. Available contours indicate that topography within the site ranges from 247 metres Australian height datum (m AHD) to 316 m AHD. The highest point within the site is located on a crest within a section of remnant vegetation toward the centre of the site. The lowest point is located at the discharge of the central streamline on the southern boundary. Slope varies within the site to a maximum gradient of 15 %. The flattest areas within the site are generally located at higher elevations on saddles, ridgelines and crests.

Topographic contours across the site are shown on **Figure 2**.

3.3.2 Soils and geology

The site lies within the “surface of planation and lateric uplands” (Dp), and “narrow, shallow valley floors” (Fv), geological classifications (Smurthwaite 1986).

Regional geological mapping indicates that ground conditions throughout the site are largely comprised of laterite (LA1), which is known to exhibit poor drainage, low permeability and can be difficult to excavate. Laterites are hard and cemented up to 4 m thick, with an overlying layer of Gravel.

Streamline banks, lower lying areas and valleys throughout the site are generally underlain by sand and silt (G2) and fine to coarse grained granites (GR). Gravelly silty sand (Smg), white to grey in colour with fine gravel and common clay underlay streamlines.

Recent geotechnical investigations at the site (Galt Geotechnics 2017a, b) confirm that the site is underlain by materials consistent with the regional mapping, including:

- Gravelly sand/sandy gravel/gravel: fine to coarse grained sand, fine to medium pisolitic gravel, dark grey brown typically becoming pale brown, yellow brown or orange brown, typically dry and loose, trace very well cemented cobbles and boulders, present from ground surface and extending to depths ranging from 0.15 m to 1.2 m;
- Hardpan laterite: very well iron cemented, massive, typically dark red brown variably mottled yellow brown and off-white, becoming yellow brown and weakly to well cemented at depths ranging from 1.8 m to 2.8 m, present from ground surface and extending to investigated depths ranging from 1.0 m to 3.3 m;
- Clayey sand/sandy clay (SC-CI): fine to coarse grained sand, between 15% to 50% low to medium plasticity fines, either mottled red-brown and yellow brown or off-white and yellow brown, varying between laterised clayey soils and extremely weathered granitic rock, present from depths as shallow as 1.5 m and extending to a depth of up to 2.8 m.

The geotechnical investigations (Galt Geotechnics 2017a, b) are provided in **Appendix B**. Geological mapping is shown on **Figure 3**.

3.3.3 Acid sulfate soils

Acid sulfate soils (ASS) were not encountered during the two recent Geotechnical Site Investigations undertaken by Galt Geotechnics (2017a, 2017b). There is no known risk of ASS occurring within 3 m of the natural soil in the surrounding area, including the John Forrest National Park, and it is therefore inferred that the site will contain a similarly low level of ASS risk. The risk associated with ASS is further reduced by the proposed earthworks strategy which favours importing or generating clean sand for filling over excavation into in situ material due to the presence of hardpan laterite.

3.4 Wetlands

There are no mapped geomorphic wetlands located within the site. There is however one portion of the site which exhibits wetland-like characteristics, located immediately downstream of the north-eastern dam and south of Cameron Road. The location of the ‘wetland’ area within the site is shown on **Figure 4**.

3.5 Surface water

3.5.1 Streamlines

The majority of the site is underlain by low permeability soils and an undulating topography grading towards shallow valleys, as described in **Sections 3.3.2** and **3.3.1**. During rainfall events, runoff from the surrounding catchments are concentrated within streamlines within the site. Clutterbuck Creek flows through the eastern portion of the site, and the main central catchment discharges to this Creek south of the site. Clutterbuck Creek is a tributary of Jane Brook and those catchments which discharge northwards eventually discharge to Susannah Brook. There are four main streamlines present within the site, all of which have had surface water capture dams constructed in the past. The locations of streamlines and site discharges is shown in **Figure 4**.

A foreshore area report (FAR) has been prepared by Emerge to establish the extent of hydrological features across the site, identify existing wetland and riparian vegetation, and identify associated foreshore areas. Preparation of the FAR has been based on biophysical assessment including desktop studies, surface water modelling, site inspections and flora and wetland surveys carried out by Emerge Associates.

The FAR proposes that the foreshore should be considered to be the sum of:

- The extent of frequent event flooding within and adjacent to streamlines
- The presence of trees and vegetation immediately adjacent to the dams/storage areas
- The extent of wetland/riparian vegetation adjacent to the streamlines
- Existing trees/vegetation adjacent to Clutterbuck Creek and its tributaries, to the extent that these are intersected by frequent event flooding

If a foreshore reserve were to be spatially determined, an additional 10 m from the outermost of the above features to allow for side slope integration and management access could be adopted. It is noted that where maintenance access and topographical integration can be addressed in an alternative manner this requirement would not be relevant.

The FAR is provided in **Appendix C**.

3.5.2 Roadside swales

Roadside swales are present along the majority of the western and northern boundaries (Roland Road and Cameron Road respectively).

The roadside swale adjacent to Roland Road is located on the eastern side of the road and is conveyed under Roland Road via culverts. Topography grades from east to west in the vicinity of the Roland Road swale and runoff from the western facing portion of the site contributes runoff to the swale. Roland Road swale flows are concentrated and discharged southwards, towards Clutterbuck Creek (a tributary of Jane Brook) (at discharge location Out 7) or locally to a dam west of the site (discharge location Out 3).

The roadside swale within the site and adjacent to Cameron Road is located to the south of the road. The eastern section of the swale conveys runoff from the site towards a localised streamline which discharges under Cameron Road via a 900 mm culvert (discharge location Out 1). The western section of the swale directs flow from the site and an upstream catchment towards the low lying wetland area and culvert (Out 2), which also discharges to the north towards Susannah Brook. The locations of roadside swales and discharge locations are shown in **Figure 4**.

3.5.3 Dams

Surface runoff storage dams have historically been constructed within natural streamlines and would have historically served as a water source for agricultural uses. The four main dams are described in the following sections and are shown in **Figure 4**.

3.5.3.1 Central Dam

The Central Dam is the largest within the site and is within the largest catchment of 186 ha. The seasonal peak water elevation is approximately 262 mAHD (based on surface contours and observations) at which point it is an estimated 2-3 m deep. Above the seasonal peak water level it has a potential storage area of approximately 6,500 m^2 between 266.5 and 267.5 mAHD, providing approximately 16,500 m^3 of detention capacity. The valley immediately upstream provides an additional 13,000 m^2 of potential storage area, providing up to 9,300 m^3 of detention capacity. The main wall of the Dam has been breached and heavily eroded and the wall would need to be repaired to be able to utilise the storage potential of this dam.

3.5.3.2 North-eastern Dam

The North-eastern Dam is located adjacent to a valley floor which is heavily vegetated and has wetland characteristics. The area surrounding the Dam is likely fed by shallow soil saturation which expresses at the base of the valley. The Dam sits within a 168 ha catchment. The seasonal peak water level is assumed to be 272 mAHD (based on surface contours and observations). The potential storage area of the exiting dam is approximately 5,000 m^2. The capacity of this Dam could be increased by minor extension of the western wall, which would inundate an 8,400 m^2 area and provide an estimated flood storage depth of 1.5 m with capacity of 8,000 m^3 of detention storage.

3.5.3.3 North-western Dam

The North-western Dam is located close to Cameron Road within an 88 ha catchment. The Dam has an assumed seasonal peak level of 272 mAHD (based on surface contours and observations) and a surface area of 4,400 m^2. The dam wall is at approximately 273.5 mAHD, with a top water level surface area of approximately 5,500m^2. In order to realise the full capacity of the dam, the two side slopes or the up-slope side of the dam would require some additional bunding (of approximately 0.5 m) to ensure that a flood storage depth of 1.0 m could be achieved. This would provide detention storage of approximately 5,000 m^3.

3.5.3.4 Eastern Dam

The Eastern Dam intersects runoff from within the site and also from an upstream catchment. The catchment within the site is approximately 14 ha, while the upstream catchment is 160 ha. The maximum top water elevation is controlled by an overflow weir, which sits at approximately 266.5 mAHD. However, based on observations onsite and aerial photography the seasonal peak is assumed to be 265 mAHD, at which point the Dam is 9,000 m^2. The top of wall is at 266.75 mAHD, and if a top water level was assumed at 266 mAHD the Dam surface area would be approximately 18,000m^2, and provide a detention volume of 12,000 m^3.

In addition to the main dams, there is a minor dam which intersects a streamline which enters the site from the north. This dam is minor in size and therefore has not been detailed.

Discharge from dams is conveyed offsite via natural streamlines to be ultimately discharged into Clutterbuck Creek (a tributary of Jane Brook) to the south and Susannah Brook to the north.

All surface water features are shown in **Figure 4**.

3.5.4 Pre-development surface runoff modelling

The catchments within and adjacent to the site have been determined by analysis of topographical contours, aerial photography and ground truthing of assumptions (e.g. road crossings, culvert locations and sizes, etc.). Geotechnical analysis of the site shows varying levels of clays, gravel and laterite at varying depths to the surface. For the purposes of catchment analysis it is assumed that the soil types are generally consistent across the site.

The catchment analysis shows varied amounts and density of vegetation across the site, which influence catchment losses. For the purposes of modelling, the existing land uses (and losses) have been based on three vegetation classifications: Sparse, Medium and Dense. The spatial extent of these have been determined by aerial photography analysis. The pre-development catchments and land type are shown in **Figure 5**.

In order to determine appropriate losses for the catchments and land uses, reference was made to runoff modelling undertaken in nearby Gidgegannup to support a District Water Management Strategy (DWMS) (Cardno 2009). The Gidgegannup modelling was calibrated to onsite measurements of flow and rainfall, and the soil types and land uses are very similar to those in Stoneville. The loss rates adopted in the modelling for this LWMS are based with those from the Gidgegannup DWMS. The methodology adopted to convert the Gidgegannup loss rates is described in the modelling assumptions report (MAR; provided in **Appendix D**), as are the resulting initial and continuing loss rates.

The site has been modelled using XPSWMM to determine inflows to and outflows from the site. Analysis within XPSWMM indicates that the critical duration storm event is 6 hours for the 1 % AEP and varies between 12 hours and 48 hours for the 20 %AEP event. The peak flow results of the critical duration are summarised in **Table 2**.

Table 1: Pre-development peak flow analysis results

Flow location	Contributing catchment	Catchment area (ha)	Major (1% AEP) peak discharge (m^3/s)	Minor (20% AEP) peak discharge (m^3/s)	Frequent (15 mm) event peak discharge (m^3/s)
Out1	Ct1	88.7	2.81	1.03	0.20
Out2	Ct2	168	6.34	2.19	0.40
Out3	Ct3	21.9	0.74	0.27	0.05
Out4	Ct4	186.9	7.30	2.70	0.51
Out5*	Ct5	160	3.24	0.87	0.10
Out6*	Ct6	98.8	2.94	1.06	0.20
Out7	Ct7	75.6	3.60	1.48	0.30
Out8	Ct5, Ct6, Ct8	423	10.58	3.33	0.52
Out9**	Ct9	18.9	0.64	0.14	0.00
Out10**	Ct10	20.7	1.31	0.56	0.14

**site inflow*

***sheet flow, no defined 'channel'*

3.5.5 Surface water quality

Surface water quality monitoring was undertaken by Cardno (2009) at two locations within the site as part of DWMS investigations. The samples were taken within existing surface water storages that intersected streamlines (North-Western Dam and the lake adjacent to SW5, shown on **Figure 4**). The intent of the DWMS monitoring was to provide an initial indication of surface water quality within the site. The monitoring locations (in standing water bodies) are not considered appropriate to develop site specific triggers as the samples were taken from a static water source, and not from water flowing/discharging from the site. It is noted in the DWMS report that analysis of surface runoff within streamlines in response to rainfall would be more useful and should be included in a subsequent LWMS. This updated monitoring has been conducted and is discussed below.

Emerge has undertaken surface water quality monitoring between July 2017 and September 2018 at six locations across the site. The locations of the surface water monitoring sites are shown on **Figure 2**. The results of the monitoring are summarised in **Table 2**, with the full results provided in **Appendix E**.

Table 2: Pre-development surface water quality monitoring (2017 – 2018)

Site ID	Description	pH average	EC average (mS/cm)	TSS (mg/L)	TN average (mg/L)	TP average (mg/L)
SW1	North west discharge	6.24	0.850	5.00	1.0	0.02
SW2	North east discharge	6.56	0.491	<5	1.2	0.02
SW3	South east inflow	6.12	0.387	<5	0.1	<0.01
SW4	South west discharge	6.46	0.300	<5	3.7	0.04
SW5	Eastern Dam discharge	5.75	0.364	<5	3.0	0.02
SW6	Central northern inflow	5.55	0.226	-	8.2	0.02
NWQMS	Lowland river	6.5-8	0.3	-	1.2	0.065

Total phosphorus (TP) was observed to be generally below the NWQMS trigger value for lowland rivers (which is most relevant as the destination is a lowland river). This is unusual given the long term and continued agricultural use of the land, and suggests that the clayey soils beneath the site may be very effective at mitigating TP export from the site. Total nitrogen (TN) was above the trigger level values for three sites (SW4, SW5 and SW6).

Measurements of pH across the site ranges from moderately acidic to neutral. Site discharges in particular reached lower pH values on one round of observations (5/7/18). For this round of testing, SW3 was dry and therefore not tested. Surface water throughout the site shows elevated levels of salinity (EC); up to five times greater than the upper limit of the acceptable range.

Pre-development surface water quality monitoring is ongoing. At the time of preparing this revision of the LWMS (Rev C) monitoring had been attempted in June 2019 however no discharge was evident from site following rainfall. Monitoring will continue thoughout the winter 2019 season to ensure that data can be captured once the catchment is saturated and runoff occurs.

Updated results will be provided in future water management documentation, and will be used to refine the preliminary trigger values proposed in this LWMS (see **Section 10.2.1**).

3.6 Groundwater

The low permeability of underlying laterite soils exhibit poor drainage and act as an aquiclude. There is therefore not expected to be any substantial and/or connected aquifers within the site. It is possible that there may be fractured rock aquifers at some locations, however there is no evidence onsite of this occurring. Groundwater is not expected to significantly recharge within the site, and therefore the quality of any limited groundwater contributions are therefore not relevant to the ongoing management of the site.

Runoff from rainfall events is conveyed as sheetflow over the steeply sloped terrain towards low lying areas and streamlines, resulting in localised inundation and increased streamflow. It is likely that there would be seasonal saturation of the shallow clayey soil profile, and that the moisture in this shallow layer would migrate to the lower parts of the site. This is evidenced by the vegetation that is sustained in the low points (valleys) of the site.

3.7 Current and historical land uses

Historically, sections of the site have been cleared for agricultural/grazing purposes. To date approximately half of the site has been cleared including the majority of streamline areas. Large sections of discontinuous remnant vegetation have been retained throughout the site.

Historical aerials show that the southern section of the site was partially cleared and the two dams/lakes along the southern site boundary were constructed prior to 1965 (earliest available imagery). The northern section of the site was cleared and the three significant dams constructed between 1965 and 1974. There have been no significant clearing activities observed within the site since 1974.

Between February and September of 2016 contour bunds were installed in three areas to the south west of the site to control erosion, and these are visible on **Figure 1**.

3.8 Summary of existing environment

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

- The site receives 1,079 mm of average annual rainfall with the majority of rainfall received between June and August.
- Topography of the site ranges from 264 to 316 m AHD and exhibits average slopes up to 15%. Some minor portions of the site may contain slopes exceeding 15%.
- The majority of the site is comprised of laterite overlain by and associated with gravel (LA1), becoming progressively sandy near streamlines.
- Elevated TN was observed in some surface water monitoring sites.
- Surface water flows discharging to the north of the site show elevated salinity.
- There are some relatively minor upstream contributing catchments. With the exception of these, the site is at the top of catchment.
- The site contains four main dams that currently capture runoff from within the site and could potentially be used to achieve flood detention within the site (with some minor modifications). A minor dam exists in the eastern portion of the site
- Runoff from the site discharges to Clutterbuck Creek, a tributary of Jane Brook (to the south) and tributaries to Susannah Brook (to the north).
- Peak flow rates leaving the site (at six locations) have been characterised for frequent (1 EY) minor (20% AEP) and major (1% AEP) events. This has been undertaken using XPSWMM, and has been informed by calibrated runoff modelling from nearby Gidgegannup townsite.

- There is no true groundwater beneath the site. Shallow clayey soils above gravels/laterite may be seasonally saturated and express some water at the low points (valleys) within the site.

4 Design Criteria and Objectives

This section outlines the objectives and design criteria that this LWMS and future Urban Water Management Plans (UWMPs) must achieve. The water management strategy covers stormwater management, groundwater management and water consumption. Design criteria are based on the guiding documentation and policies discussed in **Sections 1.3** and **1.4**.

4.1 Water conservation

Criteria WC1 Lot scale potable water use to be less than 60 kL/person/year.

Criteria WC2 No potable water to be used for non-potable uses in any public spaces.

4.2 Recycled water

Criteria RW1 Maximise the re-use of recycled water within the site

Criteria RW2 All open space long term irrigation requirements to be met by recycled water

Criteria RW3 Open space irrigated areas to use an average of 7,500 kL/ha/year

Criteria RW4 Recycled water will be retained within the site and will not be discharged to the environment

4.3 Stormwater management

Criteria SW1 Major event post-development peak flow rates leaving the site should be equal to or less than pre-development peak flow rates.

Criteria SW2 Flood detention to achieve pre-development discharge rates should occur as high in the catchment as practical.

Criteria SW3 Frequent event runoff should be treated at source, or as close to source as practical. This may include detention at source and/or additional treatment if appropriate.

Criteria SW4 Water quality treatment structures to be sized to retain the first 15 mm from directly connected impervious areas.

Criteria SW5 Sediment control and erosion protection to be incorporated in to road reserves where practicable.

Criteria SW6 Road drainage network to be designed to accommodate and convey the minor event.

4.4 Groundwater management

Criteria GW1 Where utilised, subsoil drains are to be set at or above the low permeability soil layer.

Criteria GW2 Finished lot levels are to be at least 1.2 m above the CGL formed by the invert of subsoil drains.

Criteria GW3 Subsoil drains to be discharged via a free draining outlet to an appropriate water quality treatment structure.

Criteria GW4 Soil profile beneath T4 and T5 lots to be deep ripped/filled to a minimum depth of 1.0 m.

5 Water Conservation Strategy

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.

5.1.1 Scheme water

All lots will utilise scheme water supplied by the Water Corporation for potable water requirements.

The *Parkerville/Stoneville Water Supply – Initial Submission Report* (Worley Parsons 2009) was prepared in consultation with Water Corporation and took into account both the proposed development of Stoneville and nearby Parkerville (to the west of Roland Road). The proposed strategy involved sourcing potable water from the existing Water Corporation Zamia tank site located on the northern edge of the Zamia State Forrest approximately 10 km south of the proposed Stoneville development and supplying the site via predominantly a new pipeline to a new tank site to be located within the proposed Stoneville development. The tank site would be capable of servicing both the Stoneville and Parkerville developments.

Taking into consideration only the Stoneville Development, recent advice from the Water Corporation indicated that the water reticulation requirements for the site would involve the following elements (Cossill & Webley 2018):

- Extension of the water reticulation from the Zamia Tanks via a DN400 and DN300 water main.
- Cross connections of the water retic extension would be required with the existing water reticulation pipework.
- A staged approach to tank construction involving:
  - A single 2.0 ML on-ground tank to be installed followed by a second 2.0 ML on-ground tank at a later stage.
  - An elevated 100 kL tank on a 17.7 m high stand was also proposed to supply the most elevated parts of the proposed Stoneville development.

5.1.2 Recycled wastewater

Recycled wastewater will be utilised to meet all open space irrigation needs. The recycled wastewater system is discussed in detail in **Section 6.3**.

5.1.3 Rainwater harvesting

Rainwater harvesting systems will be encouraged throughout the development and mandated to varying degrees within respective transects. Rainwater harvesting will not be mandated in transects T1 or T5. Lots within T4 and T3 transect areas will be encouraged to utilise rainwater tanks to supply non-potable water requirements however they will not be mandatory. Lots within T2 areas are required to install 10,000 L rainwater tank storage to supply potable and non-potable water requirements in accordance with SoM requirements. It is assumed that rainwater harvested from roof areas in T2 lots will only be utilised for irrigation purposes.

5.1.4 Groundwater

Groundwater is unlikely to be available in any reliable quantity, and will therefore not be relied upon to meet development non-potable needs. Individual lots will be serviced with harvested rainwater, recycled water and scheme water for non-potable water requirements (**Sections 5.1.3**, **5.1.2** and **6.3**).

5.1.5 Surface water

Surface water from nearby dams may be required during construction and for irrigation during the establishment of open space. The existing dams proposed to be utilised for such purposes (Central Dam, North-eastern Dam and North-western Dam) do not have an upstream catchment, and therefore will only capture and re-use surface runoff from within the site.

5.2 Water conservation measures

5.2.1 Water efficient fixtures and appliances

Significant reduction of internal water consumption can be achieved with the adoption of water efficient fittings and appliances (WEFA). The water conservation strategy for the site proposes that all lots (schools, the local centre and residential dwellings) implement WEFA. Water efficient fittings will be mandated through the building licence, while uptake of water efficient appliances can be encouraged by state and local government rebates.

5.2.2 Waterwise gardens

Employing water use efficiency measures can significantly reduce total water usage. In addition to retaining significant areas of remnant vegetation, irrigation requirements can be reduced across the development by employing waterwise garden (WWG) measures including:

- Improve soil with conditioner certified to Australian Standard AS4454 to a minimum depth of 150 mm where turf is to be planted and a minimum depth of 300 mm for garden beds.
- Design and install the irrigation system according to best water efficient practices.
  - Control systems must be able to irrigate different zones with different irrigation rates.
  - Emitters must disperse coarse droplets or be subterranean.
  - Utilise subsoil irrigation where appropriate.
- Minimise the amount of turf areas.
- Mulch garden beds to 75 mm with a product certified to Australian Standard AS4454.
- Retain remnant native trees and vegetation where possible.
- Minimise use of fertiliser and utilise slow release fertilisers.

5.3 Lot water balance

A water balance analysis has been undertaken to demonstrate the effectiveness of the water conservation strategy proposed. The analysis considers realistic uptakes of non-mandatory water conservation measures including WEFA and WWG. Uptake rate and population assumptions are calculated using data from the Australian Bureau of Statistics (ABS) (ABS 2004, 2010). Rainwater tanks are assumed to be taken up by all T2 lots.

The water balance analysis has been based on the rates and calculation methodology presented in the Water Corporation Spreadsheet *AltWaterSupply_Water_Use_Model.xls* (Water Corporation 2011). This spreadsheet has been adapted to model the effects of using rainwater tanks, WWG and WEFA.

The water balance analysis assumes an average of 2.8 people per lot. Values are calculated from data provided by the ABS for new housing developments in Perth (ABS 2009). 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 54 kL/year/person. This achieves the state water consumption target of no more than 60 kL/year/person and satisfies **Criteria WC1**.

5.4 Irrigation demand

SP34 provides 153 ha of open space, though some of this is conservation area and will not be irrigated. In addition to the school ovals and formal POS areas, there will be some irrigation requirements for BRAs, road verges and other open space areas (e.g. adjacent to and including the living streams). For the purposes of matching irrigation demand with the available non-potable water (from the recycled water plant (RWP)), irrigation rates have been assumed to be either active POS (turf) areas irrigated at 7,500 kL/ha/year or recreational POS (which will include some turf, garden beds and other areas described above) assumed to be irrigated at 6,750 kL/ha/year. In reality, some of these irrigation rates may vary to meet the requirements of different POS types and to match with the available water from the RWP (which may differ in ‘dry’ or ‘wet’ years. **Table 3** provides a summary of the irrigated areas and rates proposed across the development, and **Appendix F** shows the overall irrigated area assumptions.

Table 3: Irrigated areas and rates

Land use type	Total area (ha)	Irrigation rate (kL/ha/yr)	Annual irrigation demand (kL)
POS - active	10	7,500	75,334
POS – recreation	24	6,750	162,309

5.5 Water conservation criteria compliance summary

A summary of the proposed water conservation design criteria and how these are addressed within the site is provided in **Table 4**.

Table 4: Water conservation compliance summary

Criteria number	Criteria description	Manner in which compliance will be achieved
WC1	Lot scale potable water use to be less than 60 kL/person/year	Rainwater tank uptake to be encouraged for non-potable water uses in T3 lots and mandated in T2 lots
		WEFA adopted within all lots, schools and the local centre
		WWG principles promoted for use within lots and adopted in all POS areas.
		Combined water conservation measures result in average use of 54 kL/person/year
WC2	Non-potable water to be used to irrigate open spaces	Recycled water from the RWP will be used to meet irrigation requirements for all open space areas.

6 Wastewater management

6.1 Introduction

A key requirement for the planning approval and subsequent development of the site was the implementation of a technically and economically feasible wastewater servicing solution. The proponent engaged Water West to investigate and propose a solution to the wastewater requirement. Initial investigations identified a suitable approach which was expanded upon in the succeeding *Stoneville Wastewater Servicing Concept Design Assessment* (CDA) (Water West 2019), provided in **Appendix G**. The servicing approach considered most appropriate involves the on-site tertiary treatment of wastewater within a RWP and the re-use of treated wastewater to meet non-potable irrigation requirements. The overall approach of the wastewater recycling system is outlined in the following sections and is discussed in detail within the CDA (**Appendix G**).

6.2 Assumptions

6.2.1 Structure Plan and population

The CDA has been based on the structure plan, and includes assessment of lot yield, type, creation rate and irrigation requirements for open spaces and are summarised within Section 4 of the CDA. Key inputs include a total yield of 1,410 lots, dwelling population density of 2.8 and an open space irrigation area of 34 ha.

An additional allowance for the potential future inclusion of treatment capacity required to service the nearby Parkerville development has been made by Water West in the event that the adjacent development proceeds, providing a flexible and future proofed approach. Note however that this does not influence the approach proposed for the Stoneville development.

It is noted that the assumptions specified in the report were based on SP34, and that the yield estimates and therefore design approach for the site will be subject to detailed design in the future, and this will be finalised within future documentation detailing ultimate RWP design.

6.3 Sewer and recycled water reticulation networks

A pressurised sewer system will supply the RWP with raw sewage from developed areas. Pressurised sewage systems will limit excavation requirements within the underlying rocky soils, enable lot specific contamination and production tracking (through nodal monitoring) and can minimise excessive system demand during rainfall events. Recycled treated water will be distributed via piped flow pumped from the RWP and several booster pumps along the piped network.

Water West will ultimately own and maintain the sewer reticulation system, the RWP and the encompassing lot after handover.

6.4 Recycled water plant

All wastewater produced within the site will be processed through the on-site RWP located in the north west of the site (in the vicinity of a former gravel quarry). Access to the RWP will be provided from Cameron Road and along a 6 m wide service access track located within the site. The RWP will be situated on a levelled pad covering approximately 0.6 ha hardstand. The location and extent of the RWP is detailed in the CDA.

The RWP will be a tertiary-treatment facility that will utilise membrane technology and biological processes, typically referred to as a membrane bio-reactor (MBR). Permeate from the membranes will be treated to ensure recycled wastewater is of a suitable quality for irrigation as per the *Guidelines for the Non-potable Uses of Recycled Water in Western Australia* (DoH 2011). The treated water characteristics typically achieved by the RWP are provided in the CDA and are summarised in **Table 5**.

Table 5: Treated wastewater characteristics (Water West 2018).

Parameter	Units	Design water quality
5 day Biological oxygen demand	mg/L	<10
Total suspended solids	mg/L	<10
TN	mg/L	10-15
TP	mg/L	3-5
pH	-	6.5-8.5
E.coli	cfu/100 mL	<1
Clostridium perfringens	cfu/100 mL	<1
Somatic Coliphage	pfu/100 mL	<1
Free chlorine residual	mg/L	0.2-2.0
Turbidity	NTU	<0.3
Alkalinity	mg/L	<50

The treated wastewater characteristics will mean that it is suitable for use as irrigation water, with the vegetation taking up the nutrient being irrigated within the treated water, this is discussed further in **Section 6.5.1**. Water West are aware that a modification to their existing ERA licence will be required, and that the RWP will require a works approval to construct. It is accepted that water quality criteria will be agreed with DWER through the RWP licencing process under the *Environmental Protection Act 1986.*

The RWP is expected to service approximately 650 kL/day. Storage of treated/recycled wastewater will be required to ensure the supply of open space and lot irrigation demands over the summer period. The final required storage capacity of 84 ML will be provided by high density polyethylene (HDPE) lined dams adjacent to the RWP on the site of the former quarry. The lined dams will be constructed in two stages, with approximately 40 ML provided in each stage. The staged construction will allow the final storage capacity to be revised based on monitoring of wastewater production from earlier stages of development and/or any required adjustments (e.g. to irrigation rates). The final storage volume will have the capacity to fully contain recycled water without the need to discharge directly to the environment under any circumstance (i.e. even in 'wet' years).

6.5 Recycled water management approach

The use of recycled wastewater provides an important fit-for-purpose irrigation source for open spaces within the development. The operational and risk management approach associated with the supply of recycled wastewater has been developed in consideration of receiving environments, site-specific conditions, development requirements and in consultation with government agencies. In light of these considerations, a key requirement of the approach is to ensure the constituents (e.g. nutrients) present in treated wastewater are suitably managed and that appropriate contingencies are available. These are discussed in the following sections.

6.5.1 Irrigation nutrient uptake

A water balance analysis conducted by Water West has determined that that the volume of recycled wastewater produced from the RWP will meet the irrigation demand from the approximately 34 ha of irrigated POS assuming an irrigation rate of 6,750 - 7,500 kL/ha/year (derived from MEDLI modelling using the median of 50 years of climate data). The use of recycled wastewater will also provide the majority of the nutrient requirements for open spaces. It is anticipated that active open spaces/turf may require additional nutrient inputs, and this would be guided by leaf and tissue analysis to ensure that the potential for excess nutrients to leave the site is mitigated.

A nutrient balance has been prepared which accounts for the differing requirements of various surface treatments and the proposed irrigation application rates (see **Table 6**). The target nutrient application rates have been referenced from Geritse et al (1990).

Table 6: Nutrient application and balance

Land use type	Area irrigated (ha)	Annual irrigation rate (kL/ha/yr)	Nutrient	Nutrient application via recycled water (kg/ha/yr)	Additional nutrient required beyond recycled water (kg/ha/yr)
POS - sport	10	7,500	TN	75	75-125
			TP	22.5	7.5-17.5
POS – recreation	24	6,750	TN	67.5	82.5-232.5
			TP	20.25	9.75-19.75

As demonstrated in **Table 6**, the irrigation demand and associated nutrient application to open spaces will result in full uptake of nutrients by vegetation within open space areas. Comparison to the nutrient application rates provided in Geritse et al (1990) suggest that additional nutrients may still be required in some areas to meet typical application rates. As indicated above, the need for this would be determined by leaf and tissue analysis or similar. While there are no excess nutrients expected, if there were to be any nutrients exported from open space areas these would be captured and further treated within WSUD features (discussed in **Section 7.1**) such as the living streams.

Surface water leaving the site will be monitored to ensure that water quality does not exceed trigger level values (see **Section 10.2.1**). There are contingencies proposed (see **Section 10.3**) that can be implemented if any trigger criteria are exceeded. These include utilising the RWP ability to decrease nutrient levels to meet the needs of the receiving environment.

6.5.2 Contingency and risk management

As discussed in **Section 6.5.1**, the proposed approach is that all nutrients and water will be taken up by POS and landscaped areas. However, it is noted that there may be extenuating circumstances where the effectiveness of the proposed approach may require refinement. There are a number of contingency and redundancy measures that are inherently present within the RWP infrastructure and operation, as well as the wider development. Active measures can also be implemented when required. An overview of the contingency measures are provided below.

6.5.2.1 Recycled water plant design and operation

The RWP has been designed based upon a number of assumptions (e.g. lot creation rate, total lot numbers, persons per household, irrigation rate, etc.). Monitoring of recycled water and irrigation of this during earlier stages of development will serve to validate, or form the basis for updating, the assumptions and associated design responses. The linear nature of development stage creation will mean that ample time is available for data analysis and any required changes can be implemented well within an appropriate timeframe (i.e. before there is any risk to consumers or the environment). For example, any projected additional storage requirement can be accommodated by making the second lined dam (i.e. stage 2) larger, or with provision of an above ground storage tank.

The quality of recycled water can also be verified through ongoing monitoring and operations, and this can be adjusted to meet the desired quality. For example, recycled water can be passed back through the treatment facility to achieve further treatment of water quality (e.g. additional removal of phosphorous can be achieved by use of Alum and subsequent settling).

The RWP has itself been designed to include redundancy (e.g. additional capacity in the bioreactor and flow balance tank) and duty/standby of key equipment (e.g. pumps and a diesel-powered generator). These will cater for scheduled maintenance and unscheduled shutdown events. Given the RWP is designed to cater for scheduled maintenance shutdowns/reduced operations, any unscheduled shutdown can also be catered for.

In the unlikely event of a prolonged shutdown, raw sewerage would be pumped out and tankered off-site to a waste receival destination (e.g. via a trade waste agreement to Water Corporation's network) until the unscheduled shutdown event was resolved.

6.5.2.2 Development WSUD

The living streams within the site are proposed primarily as a WSUD approach for the management of stormwater and are discussed in **Section 7.1.6**. The implementation of livings streams will provide a measure of indirect contingency for recycled water irrigation. In line with living stream principles (see **Section 7.1.6**), the landscaping approach to the 60 m corridor (required for heritage purposes) within which the living streams are located will facilitate a vegetated buffer (nominally 5 m - 30 m in width) encompassing the low flow channel. This buffer and selective location of irrigation will prevent any potential spray drift from directly entering receiving the streamlines. The vegetation buffer/green corridors may also provide some uptake of nutrients that may be mobilised in localised runoff if soils are saturated (though irrigation of effluent would not occur if soils are saturated).

The bio-chemical and physical processes occurring within the living streams will provide a polishing effect for stormwater runoff from the site (up to 50% removal of TN and 30% removal of TP) (see **Section 7.1.6**). Any nutrients from recycled water that could potentially be mobilised under extenuating circumstances (e.g. where intense rainfall runoff sheet flows from the site) and enter the waterway will likewise be treated within the living streams.

6.6 Recycled water compliance summary

The manner in which the recycled water system will achieve the recycled water design objectives is summarised in **Table 7**.

Table 7: Recycled water management compliance summary

Criteria number	Criteria description	Manner in which compliance will be achieved
RW1	Maximise the re-use of recycled water within the site	• Recycled water will be stored onsite to provide water to meet non-potable irrigation needs. • Recycled water will be used to irrigate POS, open spaces and schools.
RW2	All open space long term irrigation requirements to be ultimately met by recycled water	• Initial irrigation demand will be met by onsite surface water dams. • The wastewater recycling system will ultimately provide treated wastewater to meet the irrigation requirements of all open space within the development.
RW3	Open space irrigated areas to use an average of 7,500kL/ha/year	• The actual irrigation rate will vary with rainfall. • The water balance confirms that on average open space will achieve the required irrigation capacity.
RW4	Recycled water will be retained within the site and will not be discharged to the environment	• Water quality from the RWP will be appropriate for long term irrigation of vegetation within the site. • Design and operational contingencies are existing, or can be implemented, within the wastewater management approach and RWP. No discharge is required, even in a 'wet' year scenario. • Additional contingency will be provided by WSUD features (e.g. the living streams), which will provide nutrient removal to any incidental recycled water runoff.

7 Stormwater Management Strategy

The principle behind the stormwater management strategy for the site is to maintain the existing hydrology by treating frequent event runoff at source, matching pre-development flow rates leaving the site and maintaining upstream flows through the site.

Each stormwater management component has been designed to achieve the objectives and criteria stated in **Section 4.2**. The size of some management features has been determined using XPSWMM hydrological modelling. The MAR provided in **Appendix D** presents the detailed methods and assumptions used to develop the model.

The water sensitive urban design (WSUD) approaches utilised include:

- Roadside swales used for conveyance in preference to traditional pipe network. This will occur in all roads adjacent to T1, T2 and T3 areas, and where roads abut open spaces.
- At source treatment within roadside BRAs, provided within roadside swales.
- Tree pits, which will typically be collocated with SEPs in appropriate areas.
- Median BRAs within swales at entry roads to provide additional treatment for suitable catchments.
- Catchment scale BRAs to address treatment requirements where they cannot be achieved at source by roadside or median BRAs. Note there are approximately 50 catchments within the site, which ensures these are as close to source as possible.
- Living stream approaches for the streamlines which convey runoff through and out of the site.
- Retention and use of existing dams within the site to achieve major event runoff detention. This will minimise changes to the existing landform.
- Flood conveyance via minor open swales in preference to a traditional pipe network. These will be either in public open space or private lots, where they will be protected by appropriate easements.
- FSAs will be utilised where runoff cannot be accommodated within the existing site features (dams). These will be located within private lots and protected by easements.

The above WSUD measures are further described in the following sections.

7.1 Development drainage strategy

A number of WSUD strategies will be required to treat frequent event runoff and maintain the pre-development hydrological regime within lots. Drainage strategies are adapted to transect specific drainage requirements. The overall approach for water quality treatment at the site is to retain/detain the 1 EY event from impervious surfaces. Runoff from a 1 EY event will be retained in the context of the storm event, however will actually be detained to discharge over a much longer time period via long vegetated/rocky roadside swales and semi-permeable retention structures. This is consistent with the infiltration losses across the site determined by pre-development flood modelling in **Section 3.5.4**.

7.1.1 Lot drainage strategy

7.1.1.1 Lot soakage

The majority of the site will not be suitable to adopt onsite infiltration as a mandated stormwater retention method. This is due to the low permeability of most onsite clay based soils, shallow laterite and gravel within the soil profile and the minimal amount of site works (and imported fill) proposed to develop the site. Some residents may elect to adopt soakwells to achieve localised amenity outcomes, however these are not mandated and any site storage capacity provided by these is not relied upon by the overall runoff treatment and flood management system.

While onsite soakage is not mandated, the frequent event will still be predominantly retained within development lots due to the large average lot sizes, which result in relatively minor changes in lot imperviousness. Stormwater runoff from development lots in excess of the frequent event will be discharged to road surfaces via overland flow, or sheet flow according to the existing hydrological regime. The retention of runoff from the frequent event on lot will help to achieve **Criteria SW3.**

7.1.1.2 Rainwater harvesting and storage

Lots throughout the development will be encouraged to incorporate rainwater harvesting and storage systems. While it is anticipated that many lot owners will elect to install rainwater tanks, their uptake for T3, T4 and T5 lots will not be mandatory.

Rainwater harvesting and storage systems will be mandated for T2 lots, and will be required to provide at least 10,000 L of rainwater storage. This will substitute the water required for both potable and non-potable uses.

The volume of rainwater harvested at a lot scale has not been accounted for when sizing stormwater infrastructure, as per CoM requirements.

7.1.2 Roadside swales and bio-retention

Roadside swales will be used for conveyance in preference to traditional pipe network, subject to gutter flow depth and width. This will occur in all roads adjacent to T1, T2 and T3 areas and where roads abut open spaces. These carriageways will be typically unkerbed and will use either table drains or roadside conveyance swales.

The exception to this will be where the longitudinal grade exceeds 5%, in which case kerbing and kerb breaks may be used to discharge to swales. Alternatively conveyance via a traditional pit and pipe network may be necessary in order to manage erosion.

The general profile of roadside swales will be up to 0.5 m deep, with 1:4 side slopes adjacent to pavement and 1:3 side slopes adjacent to lots.

Roads which abut T4 and T5 lot areas will be kerbed and stormwater drainage conveyed via a conventional pit and pipe network.

The roadside swales will be treated according to the slope environment and density of adjacent development. Where swales are adjacent to T4 and T5 lots (e.g. where frontage also exists to a POS or other open space) and where slopes are less than 5% native vegetation may be used to assist in slowing down runoff, to uptake nutrients and to slow down sediments.

Where swales are adjacent to T1, T2 and T3 areas or where the slope is >5% the primary management consideration will be erosion and retarding velocity of flows. For these areas the swales are likely to be rock spawl armoured to provide appropriate erosion protection. Armouring will be un-mortared when possible.

Runoff with the roadside swales will be slowed using permeable rock armoured check dams. This will force runoff to slow, allowing sediments to drop out of suspension and providing an opportunity for nutrients to be taken up by vegetation where present.

While the swales could retain runoff up to a depth of 0.5 m, it has conservatively been assumed that swales only achieve an average depth of 0.3 m, thereby providing 0.285 m^3 per linear metre of swale. This conservative approach allows for losses that may occur due to cross overs and other features, and inefficiencies that may occur due to longitudinal slope.

7.1.3 Tree pits

Tree pits will be utilised adjacent to T4 and T5 areas where a pit and pipe network is used to capture and convey runoff. These will typically be collocated with or will be adjacent to SEPs and will provide capture and treatment of frequent runoff events. Tree-pits provide a minor storage volume individually, however collectively they can assist in achieving infiltration and treatment higher in the catchment, and can help to reduce peak flows leaving the site.

7.1.4 Median bio-retention

The entry roads to the estate (i.e. those from Roland Road) have the opportunity to provide additional treatment via swales located in the median. These roads are 30 m wide and therefore have sufficient room to accommodate a 6 m wide median swale. The median swales will be treated as per roadside swales in that they will be vegetated with native reeds and rushes if slope permits (i.e. <5%). Where the slope exceeds 5% the swales will be reinforced with rock spawls. Permeable check dams will be utilised within the median swales to ensure that the appropriate amount of treatment/storage is provided. The locations of median bio-retention swales are shown on **Figure 6**.

7.1.5 Catchment scale bio-retention areas

To address water quality treatment requirements where they cannot be achieved at source by roadside or median bio-retention swales, BRAs will be adopted at the bottom of each catchment. Note there are approximately 50 catchments within the site, which ensures that even with the use of a BRA at the bottom of some catchments runoff is still addressed at source. Due to the significant volume provided by roadside and median bio-retention swales, there will only be the requirement for six BRAs. The remaining (44) catchments are able to achieve treatment at source within the roadside and median swales or do not require specific water quality treatment measures.

BRAs have been assumed to accommodate an average depth of 0.3 m and they will be vegetated with plant species suitable for the removal of nutrients from surface runoff, consistent with the

Vegetation guidelines for stormwater biofilters in the south-west of Western Australia (Monash University 2014). It is possible that these could achieve up to 0.5 m depth, however a conservative assumption of 0.3 m has been used to account for varied site slope and site conditions likely to be encountered during construction.

The site soils are generally clay based, and it is therefore not proposed to underly BRAs with an additional layer of high phosphorus retention index (PRI) soil or engineered media as the parent soils will achieve this requirement.

BRAs will nominally have 1:3 side slopes, however both the side slopes and depths will be varied at each location to suit localised site constraints to ensure that these integrate well with the adjacent road network and/or POS/open spaces.

The combined capacity of the roadside and median bio-retention swales and the downstream BRAs will meet the requirement to address runoff from the 1 EY event, being the first 15 mm of runoff. This is consistent with the losses experienced at the site under the existing (pre-development) site conditions (as discussed in **Section 3.5.4**). The locations of BRAs are shown in **Figure 6**.

7.1.6 Living Streams

There are up to five existing streamlines which convey runoff through and out of the site. The form of the existing streamlines is generally that of erosion lines at the base of a valley, with some being more incised than others. Vegetation on all streamlines is generally sparse, with the exception of the north-eastern streamline. The streamlines will be retained as living streams within a 60 m wide corridor that will also meet Heritage considerations according to the existing S18 approval under the *Aboriginal Heritage Act 1972*.

The living streams will be designed in consideration of *Living Stream design principles* (DoW 2007) and *Drainage for Liveability* (Water Corporation, 2017 #2183) and with a profile that varies depending on localised topography. They will nominally have 1:3 to 1:4 side slopes and either a V shape or a flat base, which will be up to 1 m wide and will readily convey the 1 EY event runoff. The living stream approach within the site, where appropriate and in consideration of landscaping and civil requirements, will provide a vegetated buffer (nominally 5 m-30 m wide) encompassing the low flow (1 EY) channel. The flow channel/flood plain for minor events and major events up to the 1% AEP will spill out to a wide floodplain that will require 5-10 m width, depending on localised topographical conditions and location in the catchment. The greatest streamline width will be immediately upstream of the central dam and at the central living stream discharge points, where major event flows will be up to 10 m wide. Given the incised nature of the streamlines the 20% AEP and 1% AEP events will occupy similar footprints. A nominal cross section of the living stream which shows the design intent is contained in **Appendix F**.

Living streams will also provide additional 'polishing' treatment for site runoff. The effectiveness of the living stream at removing nutrients has been estimated based on the Infosheet provided in the UNDO tool (DWER 2019), which indicates that a Living Stream could potentially provide up to 50% removal of TN and 30% removal of TP. The locations of living streams are shown in **Figure 6.**

7.1.7 Retention and use of existing dams

The site contains four major dams (North-western, North-eastern, Eastern and Central), all of which retain water following winter. Due to the topography and geotechnical conditions beneath the site there is limited opportunity to create multiple smaller flood storage areas to achieve the required flood detention to detain runoff from the site to pre-development conditions once fully developed. Taking an approach which creates new detention storage would result in multiple small storages which would be highly likely to result in loss of additional native vegetation and additional infrastructure for SoM to maintain. Therefore, it is proposed that the existing dams will be utilised to achieve flood detention storage for the majority of the site. The approach that has been taken with the four dams is to achieve sufficient detention capacity such that there are no additional FSAs required for the catchments which contribute runoff to the key discharge locations from site (i.e. existing streamlines). The existing major dams are shown on **Figure 4**.

The dams will predominantly retain their existing form, however will require installation of discharge culverts at specified elevations and design of overflow weirs to be able to meet pre-development flow conditions leaving the site under the 1 EY, 20% AEP and 1% AEP events. It will also be necessary for the upstream banks of the Northeast dam to be modified to meet surrounding earth contours to ensure that the required storage is achieved. This modification is relatively minor. The Central dam will require repair to the main dam wall, which has been breached in the past. All dams will require detailed design to be undertaken by a structural engineer to ensure structural integrity. The Eastern dam and Northwest dam will require installation of a low flow culvert to ensure that the required amount of flood storage is achieved. The locations of retained dams (FSAs) are shown in **Figure 6**.

A preliminary concept design for the Central dam which shows how the site will achieve the required flood storage and be integrated into the landscape are contained in the landscape concept drawings in **Appendix F**.

It is recognised that consideration should be given to the Interim Position Statement: Constructed Lakes (DoW 2007). The requirements of the Position Statement have been considered, with the context that the dams are existing/retained, and not newly created features. An audit has been undertaken against the Policy, and this is included in **Appendix H**.

7.1.8 Flood conveyance via minor open swales

Roadside swales will be used for the majority of flood conveyance within road reserve, with some sections of pit and pipe network utilised where slope is >5% and/or adjacent to T4 and T5 lots. There are several points along the western and southern boundaries of the site (predominantly along Roland Road) where flood conveyance will need to occur through either public or private land to be able to discharge to the existing catchment low points. The form of these will be minor V-shaped channels, nominal 0.5 m deep with 1:3 side slopes. Some sections may need protection from erosion (e.g. where slopes are >5%), and in these instances local rock spawls will be used to create permeable barriers within the swale to slow down flows and to minimise erosion.

Where located within private land, these will need to be protected via easements to ensure that they will continue to provide the required flood conveyance into the future. The locations of minor swales/flow paths are shown in **Figure 6**.

7.1.9 Flood storage areas

Some catchments will not be able to be directed to the living streams and/or retained dams to achieve flood detention. This is the case for catchments which discharge westwards towards Roland Road and directly south to Brindle Road. For these catchments FSAs will be constructed within private lots and protected by easements. The FSAs will be designed to detain minor and event major runoff, however are not expected to receive significant runoff from frequent runoff events as this will predominantly be accommodated within the upstream roadside swales, median swales and BRAs.

The FSAs have been designed with a nominal depth of 1.2 m and with 1:6 side slopes, however this may need to be varied to meet localised site constraints. FSAs will be integrated with any contour bunding that may be required across steeper lots. The FSAs will be designed as online flood storage, and will overtop via a combination of low flow pipe (to meet frequent/minor event flow requirements) and a weir structure or similar. The design of FSAs has not assumed any infiltration, and the design and capacity of these could be updated based on localised site conditions and site specific infiltration testing. The locations for FSAs are shown on **Figure 6**.

7.2 Flood modelling assessment

The post-development environment (SP34) was modelled using XPSWMM software. The overarching aim of the flood modelling has to appropriately size the water quality treatment structures (roadside bio-retention, median bio-retention, BRAs) to accommodate the 1 EY event, and to size flood detentions structures (dams, FSAs) so that runoff leaving the site in a 1 EY (frequent), 20% AEP (minor) and 1% AEP (major) flood event do not exceed pre-development flow rates.

7.2.1 Post-development catchments

The post-development catchments were based on the structure plan, site topography and preliminary road geometry advised by the project team civil engineers. Catchments within lots are assumed to follow existing landform with the exception of T4 and T5 lots, which will be earthworked to provide relatively flat building parcels and are therefore directed according to road frontage. Post-development catchments are shown in **Figure 7**.

7.2.2 Loss assumptions

The loss assumptions utilised follow those used in the pre-development environment for all areas except T4 and T5 lots. All lots are assumed to have a 300 m^2 roof/hardstand/paved area. A detailed list of assumptions is provided in the MAR contained in **Appendix D**.

7.2.3 Results

The 1 EY (treatment) volumes required and those provided by the proposed structures are summarised in **Table 8**. Note that water quality treatment requirements are only provided for those catchments which need it i.e. catchments which receive runoff from roads, T3, T4 and T5 lots schools, town centre lots and the RWP area. Formal water quality treatment structures are not required or proposed for school pervious areas, T1 areas and T2 lots.

Table 8: 1 EY treatment volumes

Discharge location	Contributing catchment	Storage volume required (m^3)	Roadside swale volume (m^3)	Median swale volume (m^3)	BRA volume (m^3)	BRA surface area (m^2)	Total volume provided (m^3)
Out 1	Ct 5	184	171		13	56	184
Out 2	Ct 7	444	234		210	748	444
	Ct 9	94	171				171
	Ct 10	254	342				342
Out 3	Ct 13	150	150				150
	Ct 14	95	86	40			126
Out 4	Ct 11	195	256				256
	Ct 16	995	370		625	2166	995
	Ct 19	307	307				307
	Ct 21	49	86				86
	Ct 22	136	171				171
	Ct 23	310	370				370
	Ct 24	243	256				256
	Ct 30	144	228				228
	Ct 31	99	228				228
	Ct 32	517	370		147	530	517
	Ct 36	124	171				171
	Ct 37	56	114				114
Out 7	Ct 15	159	143		16	67	159
	Ct 17	555	370	185			555
	Ct 26	467	399	68			467
Out 8	Ct 40	205	157		49	187	206
	Ct 41	353	570				570
	Ct 44	86	142				142

Table 8: 1 EY treatment volumes (continued)

Discharge location	Contributing catchment	Storage volume required (m³)	Roadside swale volume (m³)	Median swale volume (m³)	BRA volume (m³)	BRA surface area (m²)	Total volume provided (m³)
Out 8	Ct 45	237	340				340
	Ct 50	93	142				142
	Ct 52	76	76				76
	Ct 54	28	35				35
Out 10	Ct 29	117	142				142

The flood detention requirements and volumes provided by the various flood detention measures are summarised in **Table 9**. Note that flood detention structures are not required for all catchments for the site to be able to meet the pre-development flow conditions at the key discharge locations.

Table 9: 1% AEP and 20% AEP flood detention volumes and areas

Downstream outlet location	Storage name	Storage volume required (m³)	20% AEP volume (m³)	20% AEP surface area (m²)	20% AEP Maximum depth (m)	1% AEP volume	1% AEP Surface area (m²)	1% AEP Maximum depth (m)
Out 1	FSA5*	5,100	4,860	5,010	0.44	5,100	5,800	1.0
Out 2	FSA10*	8,000	4,920	6,500	1.05	8,000	8,500	1.5
Out 3	FSA13	1,428	445	1,090	0.49	1428	1,718	1.2
	FSA14	504	145	380	0.55	504	744	1.2
Out 4	FSA30*	25,800	16,700	15,000	3.1	25,800	19,353	4.0
Out 7	FSA15	3,504	1,320	2,820	0.53	3,504	3,730	1.2
	FSA17	6,120	2,720	5,100	0.59	6,120	6,161	1.2
	FSA26	5,280	2,270	4,360	0.58	5,280	5,388	1.2
Out 8	FSA50*	11,500	4,100	11,000	0.40	11,500	15,000	1.0
Out 10	FSA29	840	455	815	0.80	780	1,047	1.2

**flood storage achieved in existing dam*

Note that all dam storage volumes and depths indicated in **Table 9** are based on an assumed existing top water level within the dams that would be maintained by installation of the discharge culverts (see **Appendix D** for further dam design assumptions). All dams could potentially provide further storage if the assumed existing top water level were to be lowered, thereby providing significant flexibility in design for future stages.

Note also that FSA 17 (while modelled as a single storage area) will be split in to seven to eight smaller storage FSAs distributed evenly between the relevant T2 lots. This is to avoid a single large storage that will be difficult to construct on this sloped part of the site. Further, a single large storage would also result in loss of additional vegetation and spreading the required detention volume provides the opportunity to maximise vegetation retention along Roland Road.

The peak flow rates leaving the site will not exceed pre-development peak flow rates. A summary of the critical control points/key discharge locations is provided in **Table 10**.

Table 10: Post-development peak flow rates at critical control points/key discharge locations

Critical control point	20% AEP		1% AEP	
	Pre-development	Post -Development	Pre-development	Post -Development
Out 1	1.03	1.02	2.81	2.80
Out 2	2.19	2.15	6.34	6.21
Out 3	0.27	0.28	0.74	0.72
Out 4	2.70	2.67	7.30	7.27
Out 7	1.48	1.35	3.60	3.62
Out 8	3.33	3.32	10.57	10.64
Out 10	0.56	0.50	1.31	1.30

As shown in **Table 10**, the post-development peak flows are consistent with the pre-development flow regime, and therefore the hydrology of the streamlines and downstream catchments will be maintained.

7.3 Non-structural water quality 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). Non-structural measures that will be implemented within the site include:

- Use of natural site grades and features to create water management features, which are already stabilised and will involve less ongoing maintenance.
- Regular maintenance of WSUD features, in particular to remove sediments and to repair any erosion which may occur after rainfall events.
- Minimising fertiliser use to establish and maintain vegetation within landscaped areas.
- Active and ongoing measurement of leaf and tissue samples to guide the application of any additional nutrients to POS and open spaces.
- Drought tolerant plant species that require minimal water and nutrients will be used.

7.4 Stormwater criteria compliance summary

The proposed stormwater design criteria and how these are addressed are summarised in **Table 11**.

Table 11: Stormwater management compliance summary

Criteria number	Criteria description	Manner in which compliance will be achieved
SW1	Major event post-development peak flow rates leaving the site should be equal to or less than pre-development peak flow rates	• Roadside swales, median swales and BRAs will provide significant retention/detention storage for frequent events and will contribute to peak flow management in major events. • Flood detention will be achieved by using capacity of onsite dams with the addition of controlled outlet structures. • FSAs will be constructed to detain runoff from catchments which cannot discharge to one of the existing dams. FSAs will be within private property and protected by easements.
SW2	Flood detention to achieve pre-development discharge rates should occur as high in the catchment as practical	• Roadside swales will provide flood detention at source, minimising the need for traditional pipe networks. • Existing dams will be utilised, which will detain runoff from immediately adjacent and upstream catchments. • Catchment areas are generally relatively small, and FSAs will be located at the nearest practicable downstream location.
SW3	Frequent event runoff should be treated at source, or as close to source as practical. This may include detention at source and/or additional treatment if appropriate	• Roadside swales provide water quality treatment at source, minimising downstream water quality treatment. • Median swales provide water quality treatment at source. • Bio-retention areas will be used in catchments where full treatment of the 1 EY event cannot be achieved at source. • Living Stream approach will be used to convey initially treated runoff within the site.
SW4	Water quality treatment structures to be sized to detain and/or retain the first 15 mm from directly connected impervious areas	• Combined capacity of roadside swales, median swales and BRAs are sufficient to detain and/or retain the first 15 mm. • Living stream approaches used for onsite streamlines, providing addition water quality treatment prior to discharge.
SW5	Sediment control and erosion protection to be incorporated in to road reserves and water quality treatment structures	• Roadside swales, median swales and BRAs will utilise mortared and/or loose rock spawls at entry and exit points (using local laterite materials) • Roadside and median swales on slopes >5% will utilise rock armoured intermediate weirs to slow down flow, control erosion and to drop out any mobilised sediments
SW6	Road drainage network to be designed to accommodate the minor event	• The roadside swales will convey minor event runoff. • Where required (i.e. adjacent to T4 and T5 lots or where slope >5%) pit and pipe network may be utilised, and will be designed to convey the minor event.

8 Groundwater Management Strategy

8.1 Groundwater level management

The primary objective for groundwater level management is to ensure that finished floor levels have appropriate clearance from any localised rise of perched groundwater (i.e. saturated shallow soil profile, which is not true groundwater/aquifer) (see **Section 3.6**). This will be achieved with a combination of fill and subsoil drains to maintain clearances and control potential rise of groundwater to ensure that flooding of properties and infrastructure does not occur.

8.1.1 Subsoil drains

Subsoil drains may be utilised in some sections of road reserve to ensure pavement integrity and to control the rise of groundwater beneath T4 and T5 lots. Groundwater can be expected to mound approximately 0.7 m -0.8 m at the back of lots where lots are up to 30 m deep, depending on the localised extent and depth of rock in the underlying soil profile and the permeability of fill utilised. Given that T4 and T5 lots will not have soakwells mandated the creation of saturated soil conditions beneath these lots is unlikely, and the estimate provided above is therefore very conservative. Where subsoil drains are required, these would be set no lower than the shallow low permeability (rock) layer, and finished lot levels would be set at least 1.2 m above the subsoil drain invert levels. Subsoil drains are to be discharged via a free draining outlet to an appropriate water quality treatment structure.

Subsoil drains may also be required beneath some portions of roadside swales, tree pits or BRAs to ensure that these can dry out before the next storm event. This is not expected to be required as a wholescale measure, rather it is identified now as a small scale and localised potential measure that could be used to ensure the continued functionality of stormwater management infrastructure.

Subsoil drains are not proposed to control localised soil saturation beneath the remainder of the development.

8.1.2 Imported fill and earthworks

The development of the site will not be taking a broadscale cut to fill approach. There may be some deep ripping of localised soils beneath T4 and T5 lots, and some measure of imported permeable fill will likely be used for these lots. It is anticipated that the average depth of deep ripping will be 0.5 m, and the average fill depth may be 0.5 m, both dependent on localised soil conditions (which vary significantly across the site). The aim of the combined earthworks and fill approach will be to provide T4 and T5 lots with a minimum 1.0 m ripped/permeable soil profile that has been created to facilitate lot-scale construction.

Building footprints within T2 and T3 lots may also require similar treatment to the above, however this will not be undertaken by the developer, and will be the responsibility of each lot owner at time of house construction.

8.2 Groundwater criteria compliance summary

A summary of the proposed groundwater quantity design criteria and how these are addressed within the site is provided in **Table 12**.

Table 12: Groundwater criteria compliance summary

Criteria number	Criteria description	Manner in which compliance will be achieved
GW1	Where utilised, subsoil drains are to be set at or above the low permeability soil layer.	• Subsoil drains may be utilised in road reserve, beneath T4 and T5 lots or to ensure WSUD features remain dry in between rainfall events. • Where utilised, subsoil drains will be set at or above the underlying low permeability (rock or impermeable clays) layer.
GW2	Finished lot levels are to be at least 1.2 m above the CGL formed by the invert of subsoil drains.	• Where subsoil drains are used, deep ripped soil, and/or imported fill will provide finished lot levels with at least 1.2 m clearance from the CGL.
GW3	Subsoil drains to be discharged via a free draining outlet to an appropriate water quality treatment structure.	• Subsoil drainage will be constructed such that intercepted water will freely drain to a discharge location (e.g. through appropriate grading and via the invert being at least 150 mm above the receiving environment). • Groundwater will be treated by discharging intercepted water into treatment structures (i.e. swales or BRAs), or by providing treatment prior the water entering the drain (e.g. by constructing pipes in filter media).
GW4	Soil profile beneath T4 and T5 lots to be deep ripped/filled to a minimum depth of 1.0 m.	• The soil profile beneath T4/T5 lots will be deep ripped to an approximate depth of 0.4-0.6 m. • T4/T5 lots will be filled with permeable material to an approximate depth or 0.4-0.6 m to ensure a minimum profile of 1.0 m of ripped/filled soil.

9 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 2008).

While strategies have been provided within this LWMS 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. The main areas that will require further clarification within future UWMPs include:

- Which WSUD measures will be implemented in the subdivision area
- Design specifications for WSUD measures
- Retention and design of farm dams
- Temporary irrigation measures
- Imported fill and subsoil drainage specifications and requirements
- Recycled water management approach update
- Nutrient and Irrigation Management Plan
- Non-structural water quality improvement measures
- Vegetation retention
- Management and maintenance requirements
- Construction period management strategy
- Monitoring and evaluation program.

These are further detailed in the following sections.

9.1 Selection of WSUD measures specific to subdivision

The incorporation of any of the WSUD measures presented in this LWMS or additional measures are required to display compliance to the criteria specified in this LWMS and applicable SoM requirements. The site is significantly varied in terms of topography and geotechnical conditions. These will dictate which WSUD measures may be able to be utilised in the relevant subdivision area. The selection of WSUD measures will follow the guidance of this LWMS, however it is expected that their adoption across the site may vary as successive stages and subdivision areas seek to improve the WSUD outcomes for the site. The UWMP should include the rationale for these and any detailed design considerations.

9.2 Design specification for WSUD measures

The WSUD measures discussed in **Section 7.1** will require further spatial, design and landscape specification and incorporation of any planning updates within future UWMPs. The initial designs for WSUD features will be provided in the first UWMP, however it is expected that these may evolve based on experience implementing these on the site. The supportive design calculations and rationale for any design changes should be fully explained and contained within the future UWMPs.

The living streams will be central WSUD features that will be the central green spine of the development water management system. They are generally located centrally within the 60 m streamline corridors set aside (though the corridors are wider than 60 m at some points). While conceptual designs have been provided for key POS areas and the living streams (see **Appendix F**) these will be further developed at future stages. The future design will consider requirements of the Shire of Mundaring, DWER and DBCA (e.g. no direct connection of turf to the waterways and setback of irrigation outlets from waterways). Where available these updates will be included within the relevant UWMP.

Any specific monitoring and maintenance requirements for WSUD measures are to be provided within the relevant UWMP.

9.3 Subsoil drain design details

As discussed previously, groundwater rise beneath earthworked portions of lot areas (T4 and T5 only if earthworked) is to be controlled by use of subsoil drains to meet IPWEA guideline clearances. Future UWMPs will provide detailed earthwork and subsoil drainage drawings to demonstrate that the required protection is achieved. These will be specific to each subdivision area due to the variance in topography, soil conditions and proposed lot product, and design details and supportive modelling should be provided in the UWMP where relevant.

9.4 Retention and design of farm dams

The proposed retention of existing farm drains will require a number of design considerations, including safety in design, structural stability, ongoing maintenance requirements, etc. The design of each dam structure should be fully explored in the relevant UWMP that will require development of one of the dams. The most attention will most likely be required for the central dam as this has the largest catchment and the greatest depth.

9.5 Temporary irrigation measures

The water balance described in this LWMS is based on the ultimate development of the site. This may take some years to achieve, and POS establishment for individual stages is likely to occur prior to dwelling construction. Until the RWP has sufficient catchment inflows (or wastewater) there may not be sufficient treated water to irrigate all open space areas.

As a temporary approach it is envisaged that the surface water dams may be utilised to capture runoff from within the site and that this would be utilised to meet irrigation demand. The extent of this is unknown as the staging of subdivision and construction is yet to be determined. If surface water from within the site is proposed to meet temporary irrigation requirements, the UWMP will need to demonstrate via appropriate water balance analysis that the irrigation needs of the development can be met.

9.6 Imported fill specifications and requirements

The requirement for imported fill will vary across the site, depending on the localised site conditions and the lot product being delivered within the subdivision area. This will also be the case for subsoil drains as described in **Section 9.3**. It is expected that the future UWMP will assess the requirement for imported fill and will provide designs and calculations/modelling to justify the depth of imported fill being proposed.

9.7 Recycled water management approach update

The recycled wastewater management approach is discussed **Section 6.5**. Some aspects of the approach are to be confirmed as the design of the system progresses. This is an intentional approach which allows for the adaptation of design and/or processes to account for any required updates following ongoing monitoring. Monitoring is discussed in **Section 10.2.3**.

An update on the recycled wastewater management approach (including the processes, design and contingencies proposed for the RWP) will be provided in a future UWMP. This update will demonstrate compliance with the relevant guidelines and policies (see **Section 1.3**).

9.8 Nutrient and Irrigation Management Plan

Where irrigation of nutrient rich recycled water is proposed, a Nutrient and Irrigation Management Plan (NIMP) may be required. The purpose of a NIMP is to minimise the probability of environmental impact by assessing the factors such as soil properties in irrigation areas, recycled water nutrient concentrations and nutrient management practices. Guidance on preparing a NIMP is provided in the *Guidelines for the non-potable uses of recycled water in Western Australia* (DoH 2011). The NIMP will be provided when and will address the possibility of algal growth within the RWP storage dams.

9.9 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 and drainage reserves. It is expected that the future UWMPs will provide a schedule of management and maintenance actions including timing and responsible parties.

9.10 Vegetation retention

Any existing native trees or vegetation proposed to be retained throughout development (e.g. verge trees or those within private lots) will be identified in the landscape designs that will accompany a future UWMP. The UWMP will also describe how these assets will be protected during development of the site.

9.11 Management and maintenance requirements

The management measures to be implemented to address surface water quality, such as the use of vegetation within median swales, BRAs and FSAs will require ongoing maintenance.

It is expected that the future UWMPs 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).

The future UWMP will set out ongoing management and maintenance responsibilities.

9.12 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, sediment, erosion etc.). The management measures undertaken for construction management will be addressed either in the future UWMPs or a separate Construction Management Plan.

9.13 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 handover to the SoM. 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 10** of this LWMS and will be further detailed at the UWMP stage.

10 Monitoring and Maintenance

10.1 Management and maintenance

The overall condition of developed stages 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. While two years is proposed per subdivision area, in reality, due to the long term staging anticipated, it is likely that post-development monitoring of open space condition will be ongoing, and will conclude nominally two years after the last POS area has been delivered.

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, walkways and other infrastructure.

The management and maintenance objectives will be detailed within future UWMPs along with details of the corresponding monitoring program.

10.2 Water quality monitoring

10.2.1 Surface water monitoring

Annual water quality monitoring will be undertaken and will initially be tied to the relevant UWMP/subdivision area. However, in the longer term the monitoring will need to be undertaken as a part of the operating licence conditions of the RWP.

The indicative proposed locations for surface water monitoring are shown in **Figure 7** and have been selected to provide an indication of the effects of the development on water quality leaving the site.

Post development water quality monitoring will be conducted on a quarterly basis. A summary of the post-development monitoring program is shown in **Table 13**. The post-development monitoring will be conducted for two years post construction of the final stages of development.

Table 13: Surface water monitoring program summary

Monitoring Type	Locations	Frequency	Parameters
Surface Water	Upstream inflows and downstream discharge points at the boundary of the site	• Five times per year. • Weekly when recycled water being discharged.	*In situ* pH, EC, temperature. *Lab analysis* TSS, TN, TKN, NH_4, NO_X, TP, FRP.

An upstream-downstream comparison for surface water across the site is proposed to confirm that the water treatment infrastructure is performing as intended.

10.2.2 Post-development trigger values

Water quality targets have been identified in consideration of the surface water quality monitoring carried out across the site. Short term trigger values have been determined using the pre-development monitoring locations and in consideration of the *NWQMS* (ANZECC and ARMCANZ 2000), whichever is higher. The trigger criteria proposed are shown in **Table 14** with TN and TP values representative of the mean pre-development values discussed in **Section 3** and the default trigger values expected for downstream environments.

Table 14: Short term water quality trigger values

Location	Analyte	
	TN (mg/L)	TP (mg/L)
Northwest Dam outlet (Out 1)	1.0	0.065
Northeast Dam outlet (Out 2)	2.0	0.065
Central Dam outlet	3.7	0.07
Eastern Dam outlet	3.0	0.065
Roland Road north (Out 3)	3.7	0.065
Roland Road south (Out 7)	3.7	0.065
Central southern living stream (Out 4)	3.7	0.07
Eastern living stream (Out 8)	3.0	0.065

While trigger values have been defined in **Table 14**, the water quality data shows some measure of temporal variability. Furthermore, the high levels of measured TN is expected to be attributable to current land use practises, which are proposed to be discontinued. It is therefore proposed that the post-development trigger values provided in **Table 14** are dynamic and short term values. These values should be reviewed and updated with the results of continued pre-development surface water quality monitoring and in consultation with DWER. This will be documented within future UWMPs.

Long term water quality trigger values will be determined in consultation with DWER and SoM, these values are expected to be closer to ANZECC default trigger values (ANZECC and ARMCANZ 2000).

10.2.3 Recycled water plant monitoring

The RWP will have separate and additional monitoring requirements in accordance with its ERA licence and the Prescribed Premises Licence. The monitoring and reporting requirements for the RWP are yet to be developed, however these will be detailed in future works approval applications and ongoing management documentation specific to the operation of the RWP. It is envisaged that the approval process for the ERA and Prescribed Premises Licence will run concurrent with the SP34 assessment process.

The monitoring and reporting commitments for the RWP will be summarised in future UWMPs as relevant. It should be noted that the monitoring proposed in this LWMS is that which relates to urban water management and open space management, and is not intended to address the monitoring requirements for the RWP and processes therein.

10.3 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.

10.3.1 Operational contingency actions

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

The first action that should be undertaken if trigger criteria are exceeded is to repeat the monitoring 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 downstream (outgoing) nutrient concentrations. Incoming nutrient concentrations will be taken either at the inlet to the site or at the top end of the living streams to provide an indication of nutrients that may exported from POS areas.

The secondary trigger to implement a contingency action will be if the downstream concentration of the above parameters is greater than 20% higher than the upstream concentration.

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

- Compare monitoring results with ongoing water quality data from the RWP.
- Review nutrient application practices to identify source if possible.
- Conduct surveillance of subdivision area to determine any other potential and obvious nutrient inputs, including within lot treatment structures.
- Remove source if possible (e.g. fertiliser input, etc.).

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 (temporally) in nutrient concentrations experienced across the site 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 SoM to determine if the trigger values should be revised.

If the upstream (incoming) water quality within the site is >20% higher than the downstream/discharge location nutrient concentrations, the need for additional treatment of relevant parameters (most likely TP) within the RWP will be assessed. If it is determined that additional treatment is warranted this can be achieved by further processing within the RWP.

10.3.2 Recycled water contingency actions

Should it be determined that there is the potential for nutrients from recycled water to contribute to the environment (indirectly), there are a number of contingencies that can be implemented. It is expected that any contingency would be a temporary measure, to be utilised until the cause or source of the water quality breach can be resolved or otherwise remedied. The contingency measures are discussed in **Section 6.5.2**. These include operational measures designed to prevent any occurrence of plant failure or consequential pollution event; such as progressive implementation, continuous monitoring and backup systems. Actionable measures may include provision of additional storage, retreatment within the RWP, further treatment using chemical processes (e.g, Alum dosing) or removing wastewater from the site via tankers. The actual contingency response will be determined in response to the identified fault or cause of nutrient discharge.

10.4 Reporting

A post-development monitoring report will be prepared annually, and will be made available to the SoM, DWER and DBCA on request.

The proponent will be responsible for post-development monitoring activities over a two year period following construction. As indicated, this is anticipated to result in ongoing monitoring which aligns with the staging of the project, and importantly with the delivery of open space areas and water quality treatment structures. The actual monitoring period will be dependent on the progression of the overall development. It is expected that the development (and therefore the overall monitoring period) will occur over a period in excess of 10 years, and that open space areas will be monitored for at least two years post-construction. Monitoring of open spaces may therefore occur over a much longer timeframe (i.e. for the construction life of the project plus two years).

If the overall management objectives are not met during the monitoring period, the proponent will undertake a review of the system to determine why the objectives are not being met. On completion of the review, the SoM and proponent are to agree on the recommended course of action(s) to be undertaken by the proponent to ensure the objectives are met to the satisfaction of the SoM.

11 Implementation

The LWMS is a key supportive document for the Stoneville SP34. The development of the LWMS 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 the future UWMPs.

11.1 Roles and responsibility

The LWMS 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 SoM. The responsibility for working within the framework established within the LWMS rests with the proponent. It is anticipated that future UWMPs will be developed in consultation with the SoM and DWER, will consider the requirements of ERA and will consider other relevant policies and documents. A summary of the key responsibilities for major future stages/actions is provided in **Table 15**.

Table 15: Roles and responsibilities

Management/design element	Location	Timing for commencement	Duration	Responsibility
Subdivision design in compliance with LWMS	Entire Estate	At time of subdivision	During subdivision design and development	Proponent
Construction and maintenance of RWP	RWP location	On commencement of construction	Permanent ongoing	Water West
Construction of estate scale WSUD measures	Entire estate	At time of subdivision	During subdivision design and development	Proponent
Construction and implementation of retained dams	Existing dam locations	When catchments which require flood detention from a dam	During subdivision design and development	Proponent
Maintenance of estate scale WSUD measures	Road reserves	Immediately following road construction	Until practical completion	Proponent, thereafter SoM
	POS and other open spaces	Immediately following POS/open space landscaping	Two years from completion of landscaping	Proponent, thereafter SoM
Maintenance of retained dams	Existing dam locations	Immediately following dam construction	Permanent ongoing, until last contributing catchment has been developed	Proponent while constructing catchments which discharge to dams, SoM thereafter
Construction of estate scale conveyance swales and FSAs	Within T2 lots	When relevant catchments require swales and flood detention	During subdivision design and development	Proponent

Management/design element	Location	Timing for commencement	Duration	Responsibility
Maintenance of swales and FSAs within easements	Within T2 lots	Following construction	Permanent ongoing	Proponent
Implementation and maintenance of in-lot water supply and conservation measures	T2, T3, T4 & T5 areas	At time of house construction	Permanent ongoing	Lot owner

11.2 Funding

Estate scale drainage infrastructure is to be funded by the proponent. This will include construction of swales and FSAs within T2 lots, which will be maintained in the future by SoM. The implementation of the remaining drainage infrastructure is to be funded by the relevant landholder. Funding for lot drainage infrastructure (i.e. soakwells) will be the responsibility of the lot owner. Funding for drainage infrastructure within the school sites will be provided by the future school operator.

11.3 Review

It is not anticipated that this LWMS will be reviewed, unless SP34 undergoes significant change post-lodgement/approval of the LWMS. If the SP34 is substantially modified, surface runoff modelling undertaken for this LWMS 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, and will demonstrate compliance with the Criteria proposed in **Section 4**.

In addition to the issues detailed in **Section 9**, the UWMP will address:

- Compliance with design objectives within the LWMS.
- Detailed stormwater management design.
- Specific structural and non-structural methods to be implemented and their manner of implementation.
- Details of proposed roles and responsibilities for the above measures.

The next stage of development following the UWMP is single lot development. It is recognised that certain elements of the LWMS 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 will be encouraged by the SoM through policy (or modification of these where necessary), building licence or awareness programs.

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Department of Water and Environment Regulation (DWER) 2019, *UNDO tool*, accessed May 2019, <http://www.water.wa.gov.au/planning-for-the-future/water-and-land-use-planning/undo-tool>.

Figures

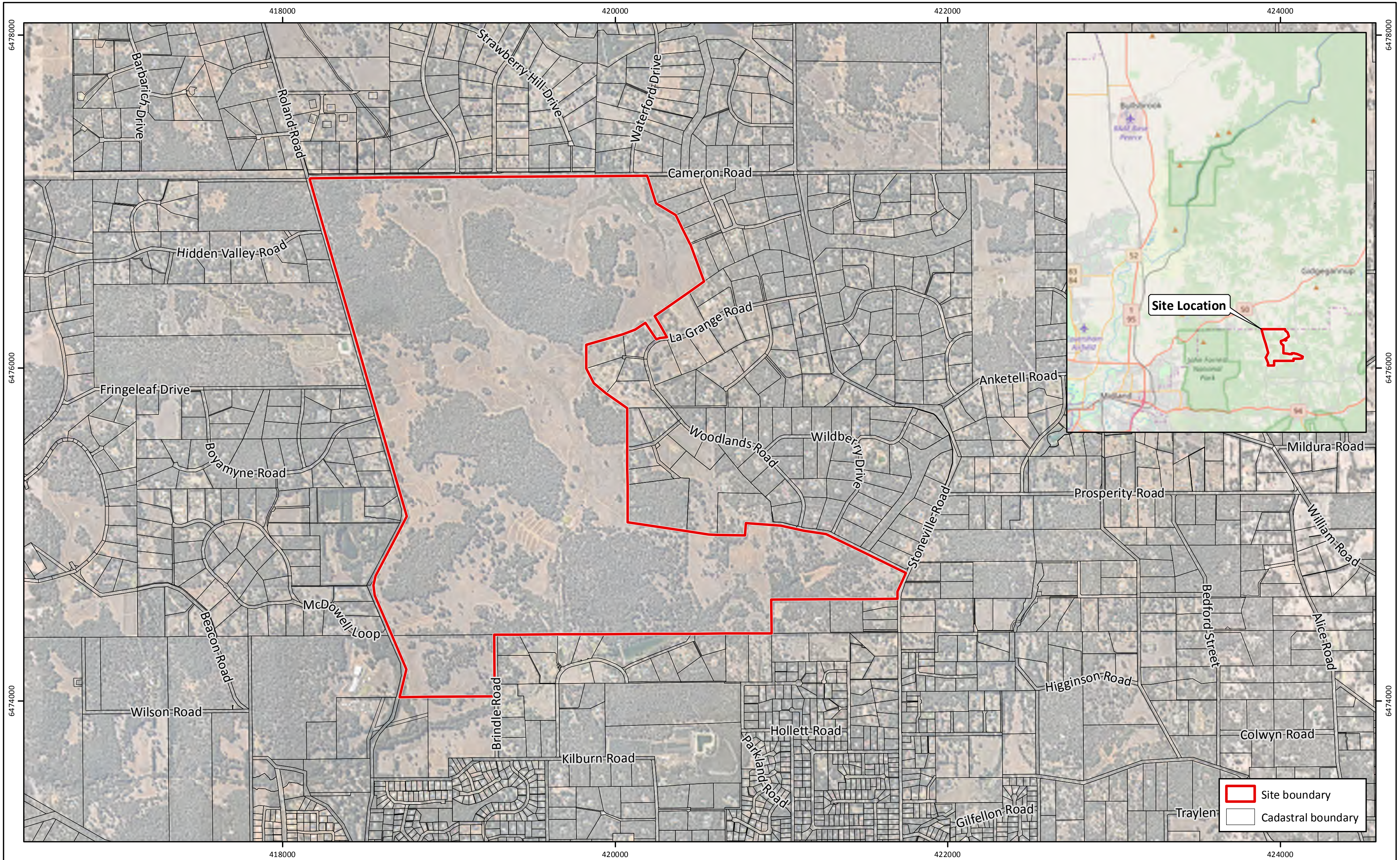

Figure 1: **Site Location**

Project: Local Water Management Strategy
North Stoneville SP34

Client: Satterley

Plan Number:
EP17-013(01)--F03a
Drawn: KNM
Date: 31/05/2019
Checked: MGB
Approved: DPC
Date: 31/05/2019

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GDA 1994 MGA Zone 50

emerge ASSOCIATES

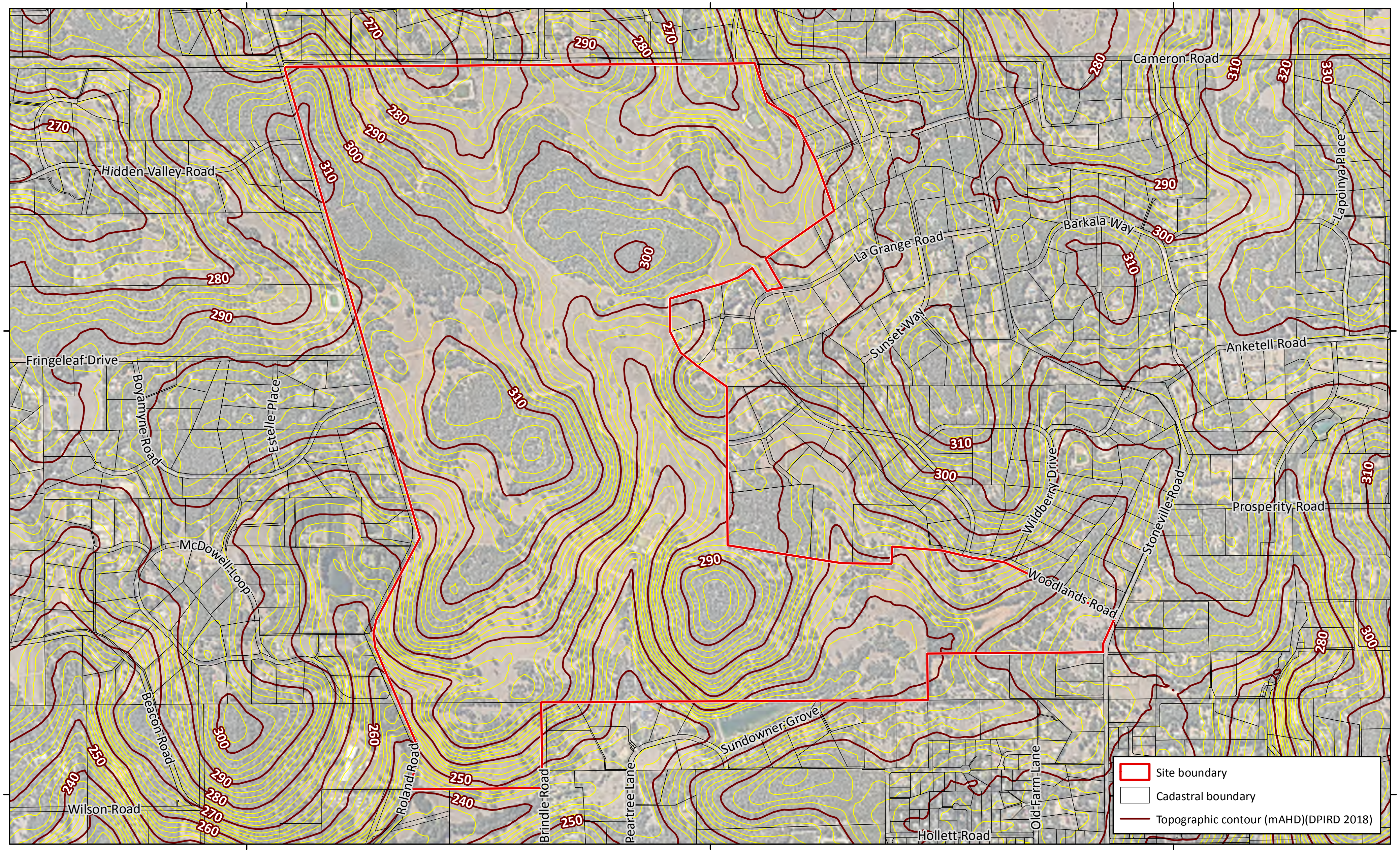

Figure 2: Topography

Project: Local Water Management Strategy
North Stoneville SP34

Client: Satterley

Plan Number:
EP17-013(01)--F04a
Drawn: KNM
Date: 31/05/2019
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Approved: DPC
Date: 31/05/2019

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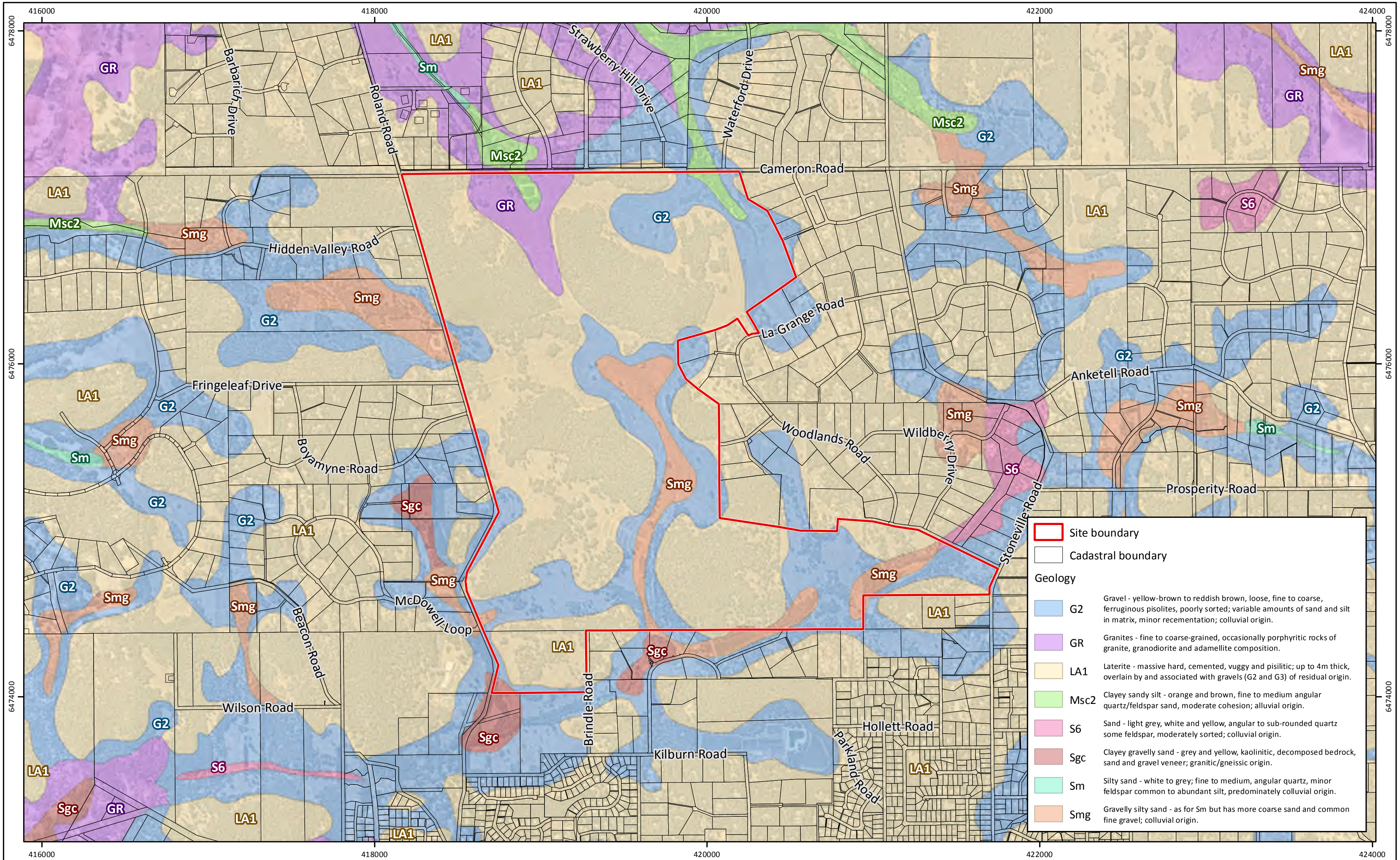

Figure 3: **Geological Mapping**

Project: Local Water Management Strategy
North Stoneville SP34

Client: Satterley

Plan Number:
EP17-013(01)--F05a
Drawn: KNM
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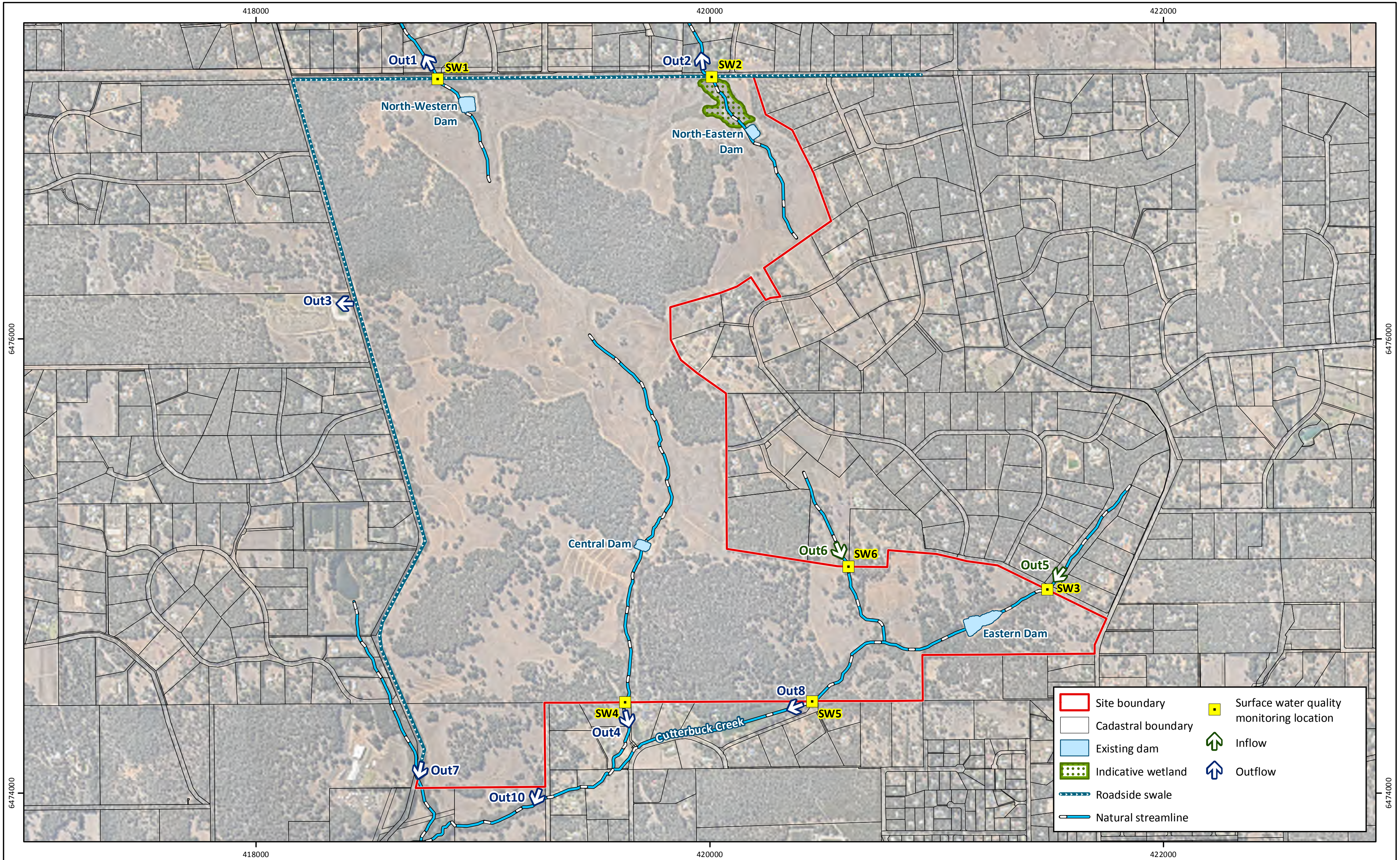

Figure 4: **Hydrological Features**

Project: Local Water Management Strategy
North Stoneville SP34

Client: Satterley

Plan Number:
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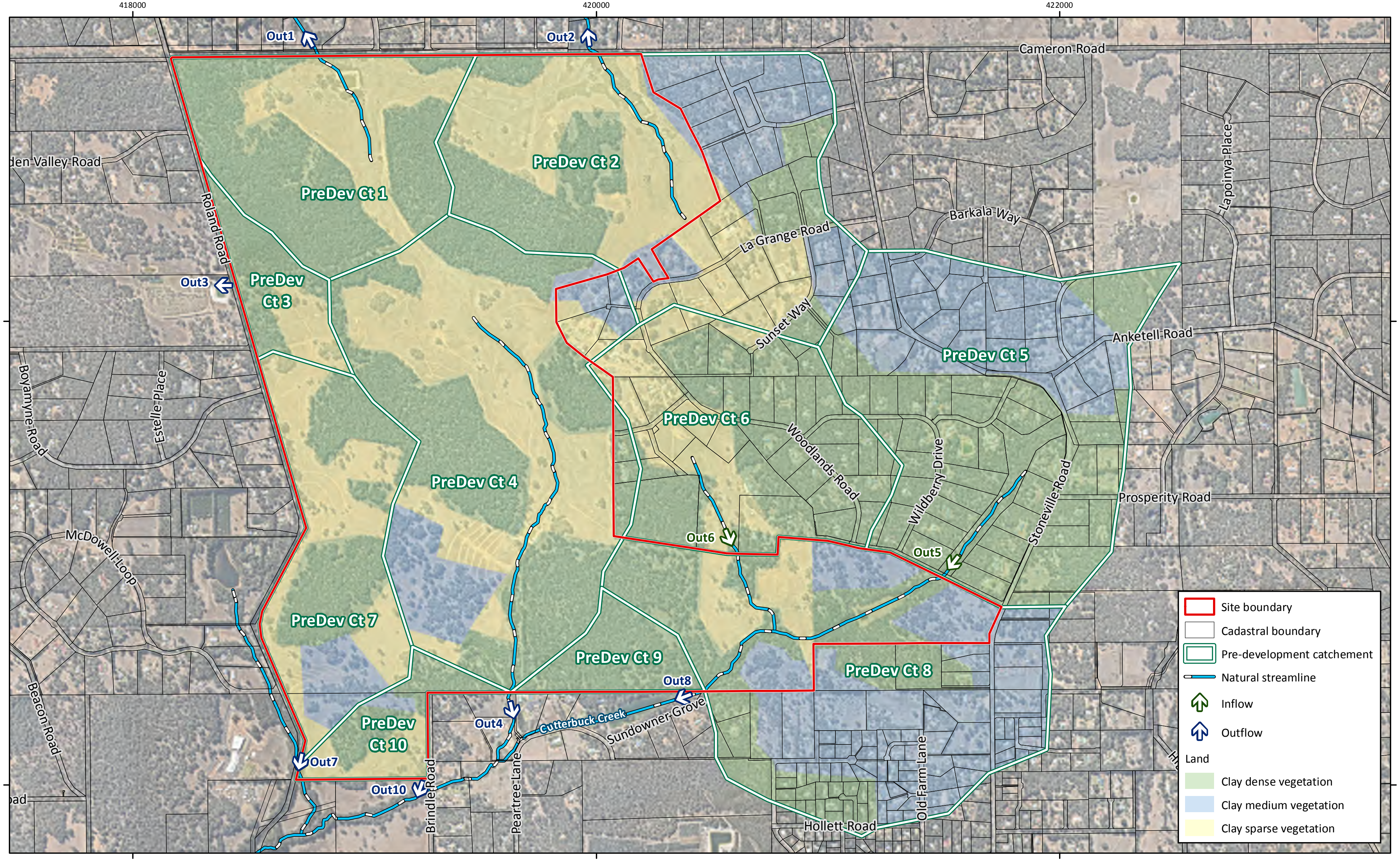

Figure 5: Pre-development Catchments and Land Uses

Project: Local Water Management Strategy
North Stoneville SP34

Client: Satterley

Plan Number: EP17-013(01)--F07a
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Date: 31/05/2019
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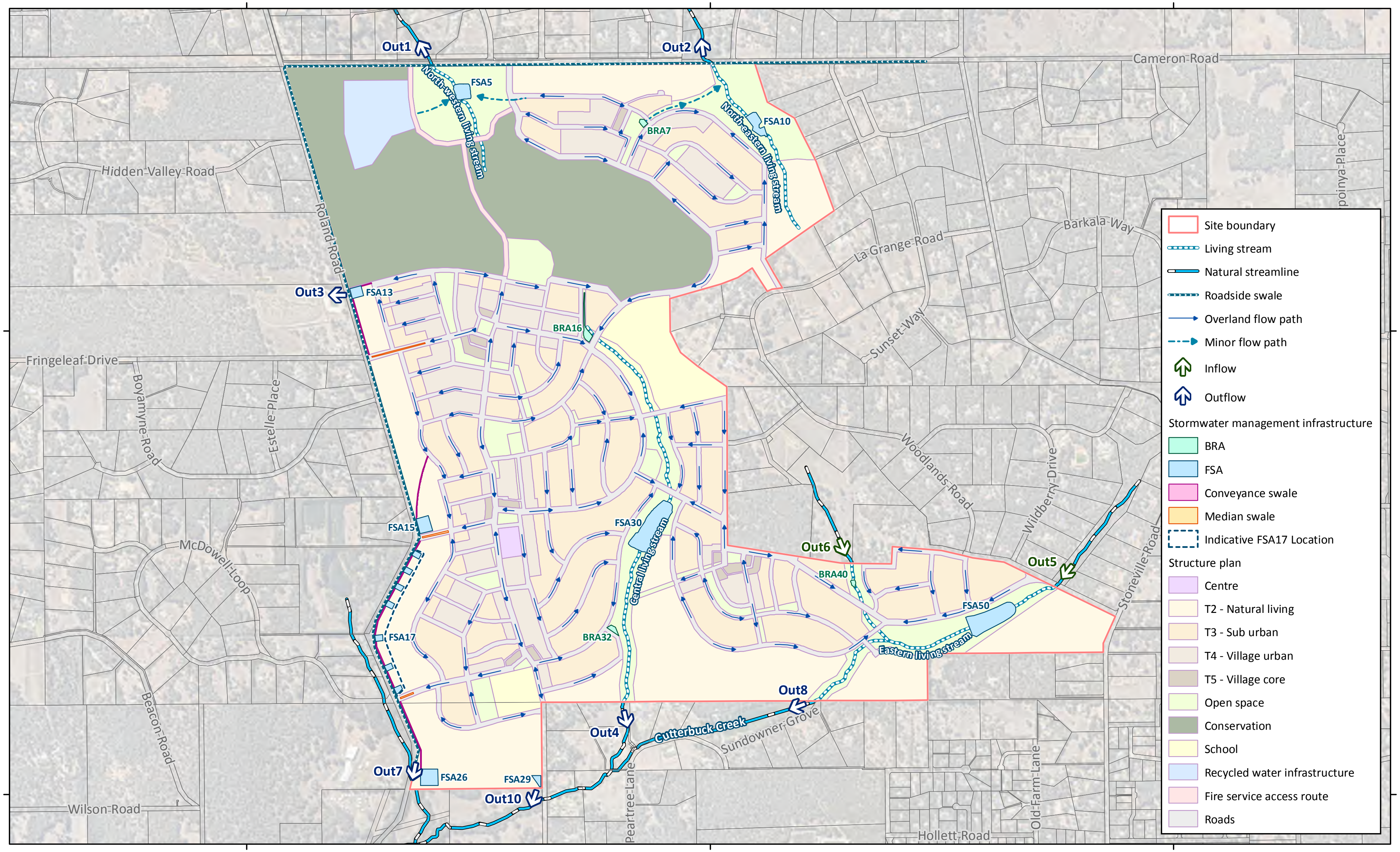

Figure 6: **Stormwater Management Plan**

Project: Local Water Management Strategy
North Stoneville SP34
Client: Satterley

Plan Number:
EP17-013(01)--F08a
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Date: 31/05/2019
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BRA	Side Slope	Treatment (BRA) - 1 year ARI event		
		Maximum depth (m)	TWL surface area (m^2)	Volume (m^3)
BRA7	1/3	0.3	750	210
BRA16			2170	625
BRA32			530	150
BRA40			190	50

FSA	Side Slope	Flood Storage (FSA) 5 year ARI event			Flood Storage (FSA) 100 year ARI event		
		Maximum depth (m)	TWL surface area (m^2)	Volume (m^3)	Maximum depth (m)	TWL surface area (m^2)	Volume (m^3)
FSA 5	varies	0.44	5010	2080	1	5800	5100
FSA 10		1.05	6500	4920	1.5	8500	8000
FSA 13	1/6	0.49	1090	445	1.2	1720	1430
FSA 14		0.55	380	145		745	505
FSA 15		0.53	2820	1320		3730	3510
FSA 17		0.59	5100	2720		6160	6120
FSA 26		0.58	4360	2270		5390	5280
FSA 29		0.8	815	455	1.2	1110	840
FSA 30	varies	3.1	15000	16700	4	19360	25800
FSA 50		0.4	11000	4100	1	15000	11500

Outflows	
Discharge location	Peak flow rate (m^3/s)
Out 1	2.80
Out 2	6.21
Out 3	0.72
Out 4	7.27
Out 7	3.62
Out 8	10.65
Out 10	1.30

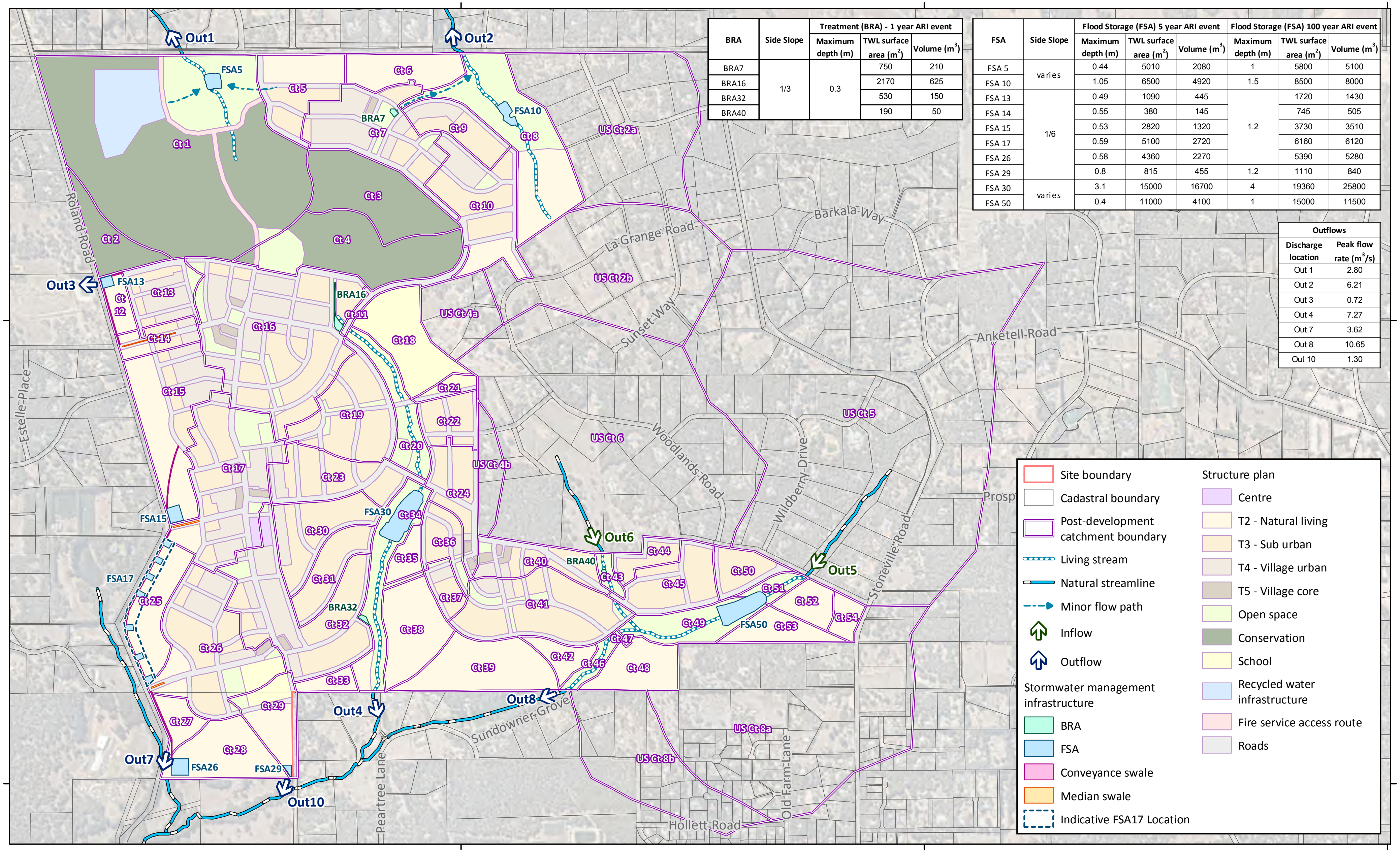

Figure 7: Post-development Catchments, Detention Storage and Discharge Characteristics

Project: Local Water Management Strategy
North Stoneville SP34

Client: Satterley

Plan Number:
EP17-013(01)--F09a
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Approved: DPC
Date: 04/06/2019

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Metres
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GDA 1994 MGA Zone 50

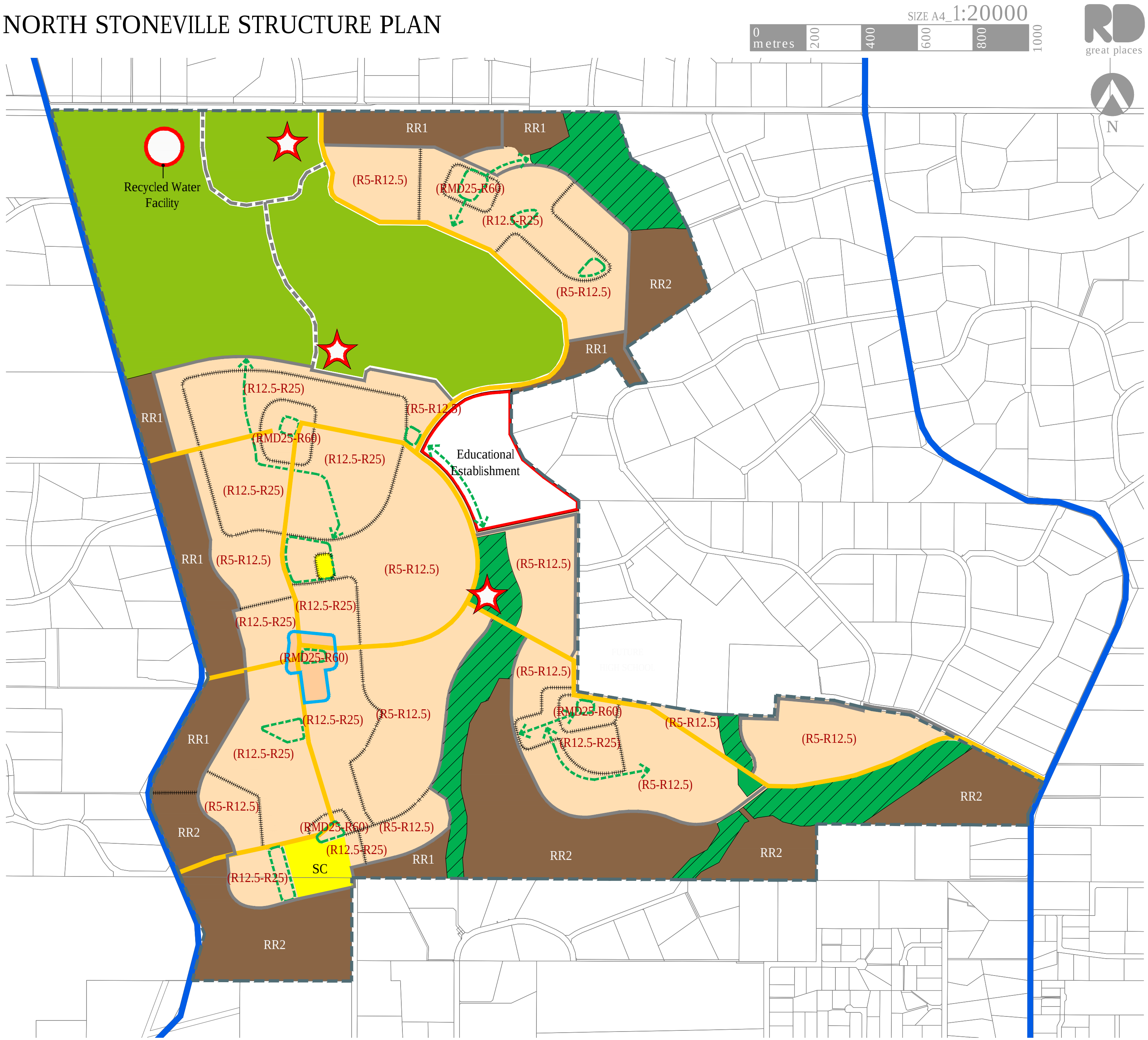
emerge ASSOCIATES

Appendix A

North Stoneville SP34

SATTERLEY

NORTH STONEVILLE STRUCTURE PLAN



LEGEND

Structure Plan Boundary

Reserves

Conservation / Recreation

Important Local Roads

Public Purposes

SC Public Purposes: School

Recreation

Zones

Residential

Rural Residential

Special Use

Local Centre

Other

Connector Road

Perimeter Road (Bushfire)

Fire Service Access Route

(R5-R12.5) R Codes

Suggested Recreation Reserve Location

Green Link

Potential Special Use Location

Recycled Water Facility (preferred location)

REF NO.	DRAW NO.	REV.
SAT STO	RD1 300	I

Appendix B

Geotechnical Investigations

Appendix C

Foreshore Assessment Report

FORESHORE AREA REPORT – STONEVILLE STRUCTURE PLAN

1.1 Purpose of foreshore area report

The Stoneville site contains five watercourses, three of which originate within the site. Clutterbuck Creek and a minor tributary pass through the site conveying upstream catchment runoff, eventually discharging to Jane Brook downstream of the site. Most of the watercourse areas are in highly degraded condition, however provide some measure of hydrological function.

This foreshore area report describes a biophysical assessment conducted to determine the following:

- The foreshore area required to protect the values of Clutterbuck Creek and the onsite waterways
- Whether any of the eroded valley floors should be considered waterways, which will then require consideration of a foreshore area/setback.

The location and extent of any foreshore area should align with the structure plan (SP) layout wherever possible. This will ensure that the SP accommodates appropriate foreshore areas within the land planning process. For example, by locating foreshore areas within public open space (POS) or a foreshore reserve (DoW 2012).

1.2 Policy context

Government policy and guidance relating to foreshore areas is primarily administered by Department of Water and Environmental Regulation (DWER). A number of guidance documents assist with the determination of foreshore areas. These documents include:

- *Operation Policy 4.3: Identifying and establishing waterways foreshore areas* (DoW 2012)
- *Guidance Note 6: Identifying and establishing waterways foreshore areas* (DoW 2013)
- *Water Note 23: Determining foreshore reserves* (WRC 2001).

Operational Policy 4.3: Identifying and establishing waterways foreshore areas (DoW 2012) outlines the processes for identifying and managing foreshore areas to ensure that environmental, social and economic values associated with waterways and adjoining lands are maintained. DoW (2013) recommend that the key document to assist in the identification of foreshore areas is *Water Note 23: Determining foreshore reserves* (WRC 2001).

2 BIOPHYSICAL ASSESSMENT

The following biophysical factors require consideration when identifying a foreshore area (WRC 2001):

- Geological features and landforms that influence the waterway.
- Soils, including those associated with riparian vegetation and those prone to erosion.
- Waterways, flood prone land and areas subject to channel changes.
- Riparian vegetation associated with the waterway.
- Function of the foreshore.
- Aquatic and riparian fauna habitat.
- Areas that may be harmed by land use pressures.
- Adjacent archaeological and ethnographic sites.

2.1 Climate

The site experiences a 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 1,079 mm on average annually with approximately half of the rainfall received between June and August (BoM 2018). The region experiences rainfall (>1 mm) on 87 days annually (on average) (BoM 2018).

2.2 Geomorphology, topography and soils

2.2.1 Geomorphology

The site occurs on the Darling Plateau, which is the geomorphic unit that characterises “the hills” region to the east of the Swan Coastal Plain (Gozzard 2007). The bedrocks of the plateau are overlain with lateritic materials and associated sands and gravels, which are the product of granite and dolerite erosion. The Darling Plateau has been deeply eroded by stream action which has led to the creation of the characteristic hills and valleys, which predominantly flow east to west towards the scarp.

2.2.2 Topography

The site is characterised by undulating topography with a prominent valley running laterally through the site. Topographic contours indicate that the site ranges from 247 metres Australian height datum (m AHD) to 316 m AHD. The highest point within the site is located on a crest within a section of remnant vegetation toward the centre of the site. The lowest point is located at the discharge of the central streamline on the southern boundary. Slope varies within the site to a maximum gradient of 15 %. The flattest areas within the site are generally located at higher elevations on saddles, ridgelines and crests.

The streamlines are incised to some measure, however the upper reaches of the streamlines which originate within site are poorly defined and are effectively valley floors. The lower sections of streamlines where they discharge from the site are evidenced by mildly incised channels 0.5 to 1.0m deep, or low-lying areas with no defined channel and culverted flow under boundary roads.

2.2.3 Soils

The site lies within the “surface of planation and lateric uplands” (Dp), and “narrow, shallow valley floors” (Fv), geological classifications (Smurthwaite 1986).

Regional geological mapping indicates that ground conditions throughout the site are largely comprised of laterite (LA1), which is known to exhibit poor drainage, low permeability and can be difficult to excavate. Laterites are hard and cemented up to 4 m thick, with an overlying layer of Gravel.

Streamline banks, lower lying areas and valleys throughout the site are generally underlain by sand and silt (G2) and fine to coarse grained granites (GR). Gravelly silty sand (Smg), white to grey in colour with fine gravel and common clay underlay streamlines.

Recent Geotechnical investigations at the site (Galt Geotechnics 2017) confirm that the site is underlain by materials consistent with the regional mapping, including:

- Gravelly sand/sandy gravel/gravel: fine to coarse grained sand, fine to medium pisolitic gravel, dark grey brown typically becoming pale brown, yellow brown or orange brown, typically dry and loose, trace very well cemented cobbles and boulders, present from ground surface and extending to depths ranging from 0.15 m to 1.2 m;
- Hardpan laterite: very well iron cemented, massive, typically dark red brown variably mottled yellow brown and off-white, becoming yellow brown and weakly to well cemented at depths

ranging from 1.8 m to 2.8 m, present from ground surface and extending to investigated depths ranging from 1.0 m to 3.3 m;

- Clayey sand/sandy clay (SC-CI): fine to coarse grained sand, between 15% to 50% low to medium plasticity fines, either mottled red-brown and yellow brown or off-white and yellow brown, varying between laterised clayey soils and extremely weathered granitic rock, present from depths as shallow as 1.5 m and extending to a depth of up to 2.8 m.

2.3 Historical land use

Approximately half of the site has historically been cleared for agricultural/grazing purposes, including the majority of streamline areas. Large sections of discontinuous remnant vegetation have been retained throughout the site.

Historical aerials show that the southern section of the site was partially cleared and the two dams/lakes along the southern site boundary were constructed prior to 1965 (earliest available imagery). The northern section of the site was cleared and the three significant dams constructed between 1965 and 1974. There have been no significant clearing activities observed within the site since 1974.

Between February and September of 2016 contour bunds were installed in three areas to the south west of the site, presumably to control erosion.

2.4 Waterways, drains and wetlands

2.5 Wetlands

There are no mapped geomorphic wetlands located within the site. There is however one location within the site that exhibits wetland-like characteristics. This area is located immediately downstream of the north-eastern dam. The location of the 'wetland' area within the site is shown on Figure 4 of the LWMS.

2.6 Surface water

2.6.1 Streamlines

The majority of the site is underlain by low permeability soils and an undulating topography grading towards shallow valleys. During rainfall events, runoff from the surrounding catchments are concentrated within streamlines. Clutterbuck Creek flows through the eastern portion of the site, and the main central catchment discharges to this Creek south of the site. Clutterbuck Creek is a tributary of Jane Brook and those catchments which discharge northwards eventually discharge to Susannah Brook. There are four main streamlines present within the site, all of which have had surface water capture dams constructed in the past (these are detailed in **Section 2.6.3**).

The locations of streamlines and site discharges is shown in Figure 4 of the LWMS.

2.6.2 Roadside swales

Roadside swales are present along the majority of the western and northern boundaries (Roland Road and Cameron Road respectively).

The roadside swale adjacent to Roland Road is located on the eastern side of the road and is conveyed under Roland Road via culverts. Topography grades from east to west in the vicinity of the Roland Road swale and runoff from the western facing portion of the site contributes runoff to the swale. Roland Road swale flows are concentrated and discharged southwards, towards Clutterbuck Creek (a tributary of Jane Brook) (at discharge location Out 7) or locally to a dam west of the site (discharge location Out 3).

The roadside swale within the site and adjacent to Cameron Road is located to the south of the road. The eastern section of the swale conveys runoff from the site towards a localised streamline which discharges under Cameron Road via a 900 mm culvert (discharge location Out 1). The western section of the swale directs flow from the site and an upstream catchment towards the low-lying wetland area and culvert (discharge location Out 2), which ultimately discharges to Susannah Brook. The locations of roadside swales and discharge locations are shown in Figure 4 of the LWMS.

2.6.3 Dams

Surface runoff storage dams have historically been constructed within natural streamlines and would have historically served as a water source for agricultural uses. The four main dams are described in detail in the LWMS (Section 3.5) and are shown in Figure 4 of the LWMS.

In addition to the main dams, there is a minor dam which intersects a streamline entering the site from the north.

Discharge from dams is conveyed offsite via incised streamlines which ultimately discharge into either Clutterbuck Creek (a tributary of Jane Brook) to the south or Susannah Brook to the north.

2.6.4 Pre-development surface runoff modelling

The pre-development environment within the site has been modelled using XPSWMM. The modelling and results are discussed in Section 3.5.4 of the LWMS. Detailed modelling assumptions are provided in the Modelling Assumptions Report which is provided in the LWMS (Appendix C).

Pre-development modelling has identified flood widths within representative cross sections throughout streamlines within the site. The cross sections were derived from topographical survey and channel measurements during site inspections by Emerge Associates. A number of cross sections were assessed within each streamline to allow for changes in hydrology (e.g. additional streamline flows, major changes in topography, contributing catchments, etc.).

The results of the modelling and cross-sectional analysis indicated that frequent event flows are predominantly contained within incised channels. The flooded width exceeded the incised channel width in locations where the conveyance capacity of the channel was exceeded, or a defined channel was absent, which lead to wider flooding. This occurred on the two northern discharging streamlines. Where wider flooding occurred, the flood width was estimated through interpolation between cross sections, as dictated by topography.

The estimated flooding extent within streamlines in the frequent event is shown in **Figure 1**.

2.7 Groundwater

The low permeability of underlying laterite soils exhibit poor drainage and act as an aquiclude. There is therefore not expected to be any substantial and/or connected aquifers within the site. It is possible that there may be fractured rock aquifers at some locations, however there is no evidence onsite of this occurring. Groundwater is not expected to significantly recharge an aquifer beneath the site, and therefore the quality of any limited groundwater contributions are therefore not relevant to the ongoing management of the site.

Runoff from rainfall events is conveyed as sheetflow over the steeply sloped terrain towards low lying areas and streamlines, resulting in localised inundation and increased streamflow. It is likely that there would be seasonal saturation of the shallow clayey soil profile, and that the moisture in this shallow layer would migrate to the lower parts of the site. This is evidenced by the vegetation that is sustained in the low points (valleys) of the site.

2.8 Flora and vegetation

The areas of intact vegetation found over the majority of the site can be described as comprising a woodland to open forest of *Corymbia calophylla* (marri) and *Eucalyptus marginata* (jarrah) over grass/forbland of pasture weeds. Where this vegetation occurs within or close to waterways, a sparse to closed shrubland of *Taxandria linearifolia* was noted to occur underneath the canopy.

Parkland cleared areas with scattered native and planted trees over isolated native shrubs over a closed grassland of pasture weeds are also present throughout the site.

Vegetation within and surrounding the two northern waterways tended to comprise a tall open to closed shrubland of *T. linearifolia*, *Astartea scoparia* and *Melaleuca* spp. over forbland of pasture weeds (or layer absent). Some patches of planted **Eucalyptus* spp. were also present, particularly to the south of the man-made dam near the north western waterway.

The vegetation was present in ‘good’ to ‘completely degraded’ condition according to the Keighery (1994) vegetation condition assessment scheme.

The portions of vegetation that are directly associated with the waterways are shown on **Figure 2**.

2.9 Heritage

2.9.1 Aboriginal heritage

S18 Approval under the Aboriginal Heritage Act 1972 has been provided for the development to proceed. The approval specifies that the waterways need to be provided within a 60 m corridor. A site inspection was undertaken to determine the point at which the shallow sheet flow within valleys was discernable as a channelized flow to determine the beginning of the streamline. The location was recorded using a GPS and used as the uppermost part of the ‘streamline’.

3 FORESHORE AREA DETERMINATION AND PROTECTION MEASURES

A waterway is defined as ‘*any river, creek, stream or brook, including its floodplain and estuary. This includes systems that flow permanently, for part of the year or occasionally; and parts of the waterway that have been artificially modified’* (DoW 2012).

The foreshore area is defined as ‘*the land that adjoins or directly influences a waterway. It is the area of transition between the edge of the waterway and the furthest extent of riparian vegetation, the floodplain and riverine landforms, or a negotiated area endorsed’* DWER (DoW 2012).

The results of the desktop study, hydrological modelling, and site visits has allowed identification of the waterway, and associated foreshore areas, across the site.

Minor eroded channels which are the upstream portions of streamlines within the site have low biophysical values. Consequently, these do not specifically need to be protected by a foreshore area. Their current hydrological functions (i.e. the conveyance of runoff) can be achieved through appropriate design of the SP. Notwithstanding that a foreshore area is not required for these portions, are still included within a 60 m corridor to meet the S18 approval requirements and these areas will therefore be protected.

The existing dams within the site are not necessary to protect the values of the waterways. While these will be retained within the 60 m corridor, they do not require a setback purely for hydraulic purposes. It is noted however that there is some measure of vegetation around these, and the vegetation should be considered as necessary to protect the overall values of the waterways.

The portions of the waterways which have trees and understorey vegetation immediately adjacent to the incised streamlines are not necessarily species typically associated with streamlines. These trees/vegetation are currently providing a stabilisation/erosion protection function and therefore retention of these would be necessary to protect the values of the waterway, however only to the extent that frequent event flooding would intersect these. The streamlines which convey Clutterbuck Creek and its tributaries have very little understorey.

The low lying areas adjacent to the two northern streamlines have some measure of understorey and riparian or wetland vegetation, and this should be retained.

The foreshore area and any area that could be considered as a 'foreshore reserve' should be considered to be the sum of:

- The extent of frequent event flooding within and adjacent to the streamlines
- The presence of trees and vegetation immediately adjacent to the dams/storage areas
- The extent of wetland/riparian vegetation adjacent to the streamlines
- Existing trees/vegetation adjacent to Clutterbuck Creek and its tributaries, to the extent that these are intersected by frequent event flooding
- An additional 10 m from the outermost of the above features to allow for side slope integration and management access. It is noted that where maintenance access and topographical integration can be addressed in an alternative manner this requirement would not be relevant.

The extent of the recommended 'foreshore reserve' area is shown spatially in **Figure 3**.

4 CONCLUSIONS

The biophysical factors and hydrological inputs have been assessed, and this allows determination of an appropriate foreshore area, as shown in **Figure 3**. This should be incorporated within POS/conservation areas wherever possible, however where it is not possible to do so an alternate approach could be taken which minimises the extent of clearing and which addresses maintenance access and topographical integration with the surrounding areas.

General References

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Department of Water (DoW) 2013, *Guidance Note 6: Identifying and establishing waterways foreshore areas*, Perth, Western Australia.

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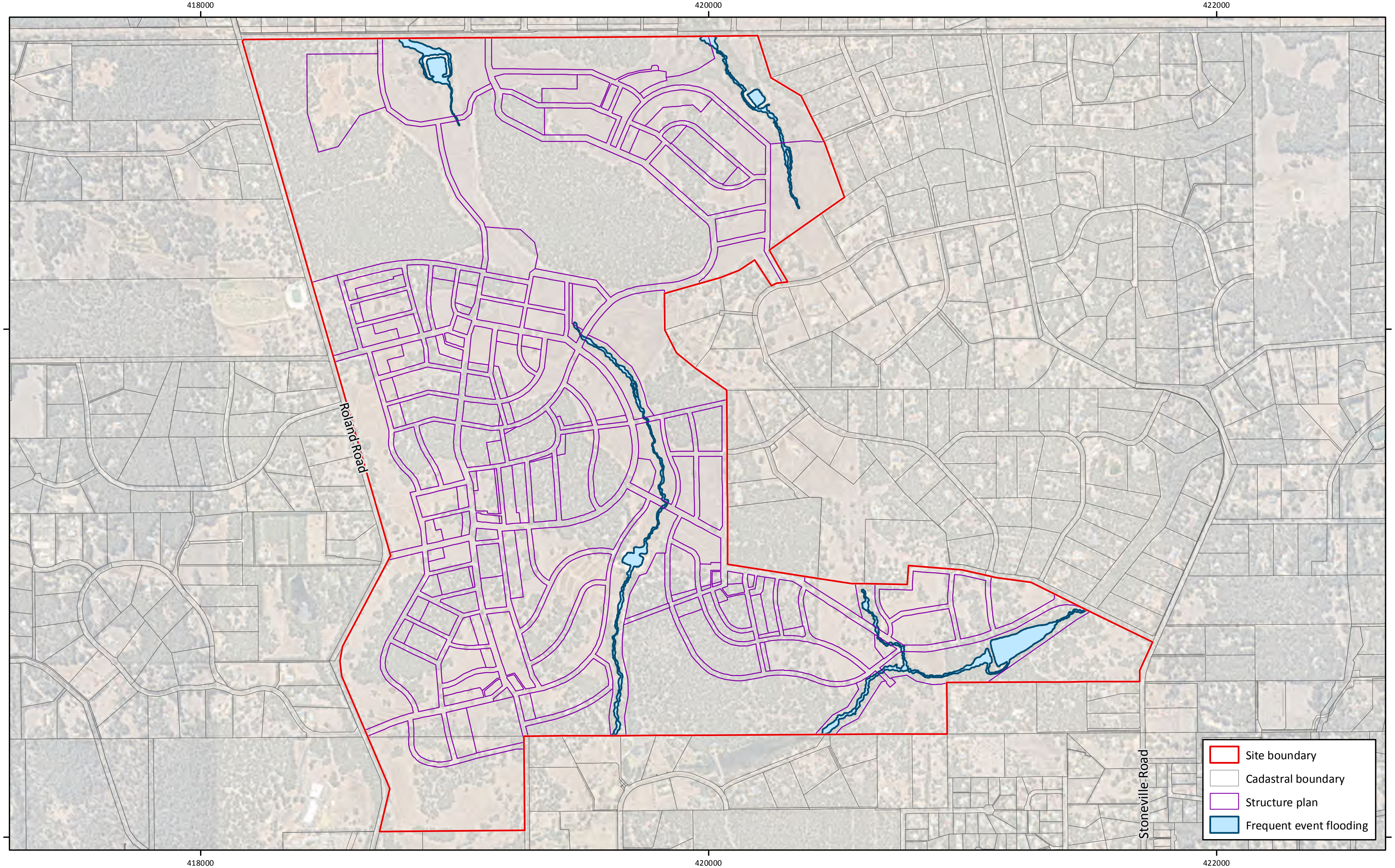

Figure 1: Frequent Event Flooding

Project: Stoneville Structure Plan Support

Client: Satterley

Plan Number: EP17-013(07)--F13
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Date: 11/06/2019

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GDA 1994 MGA Zone 50

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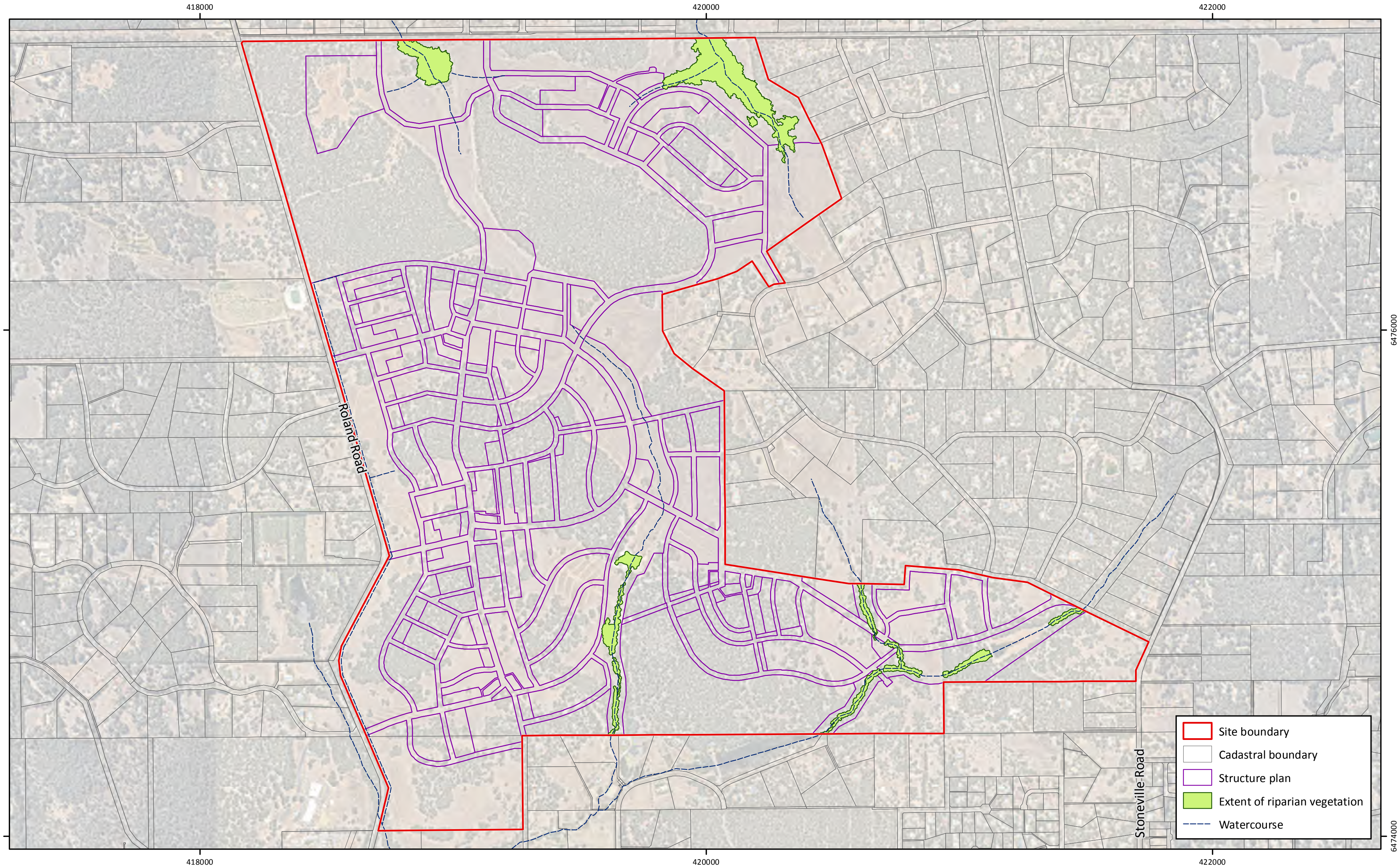

Figure 2: **Extent of Riparian Vegetation**

Project: Stoneville Structure Plan Support

Client: Satterley

Plan Number:
EP17-013(07)--F14
Drawn: KNM
Date: 11/06/2019
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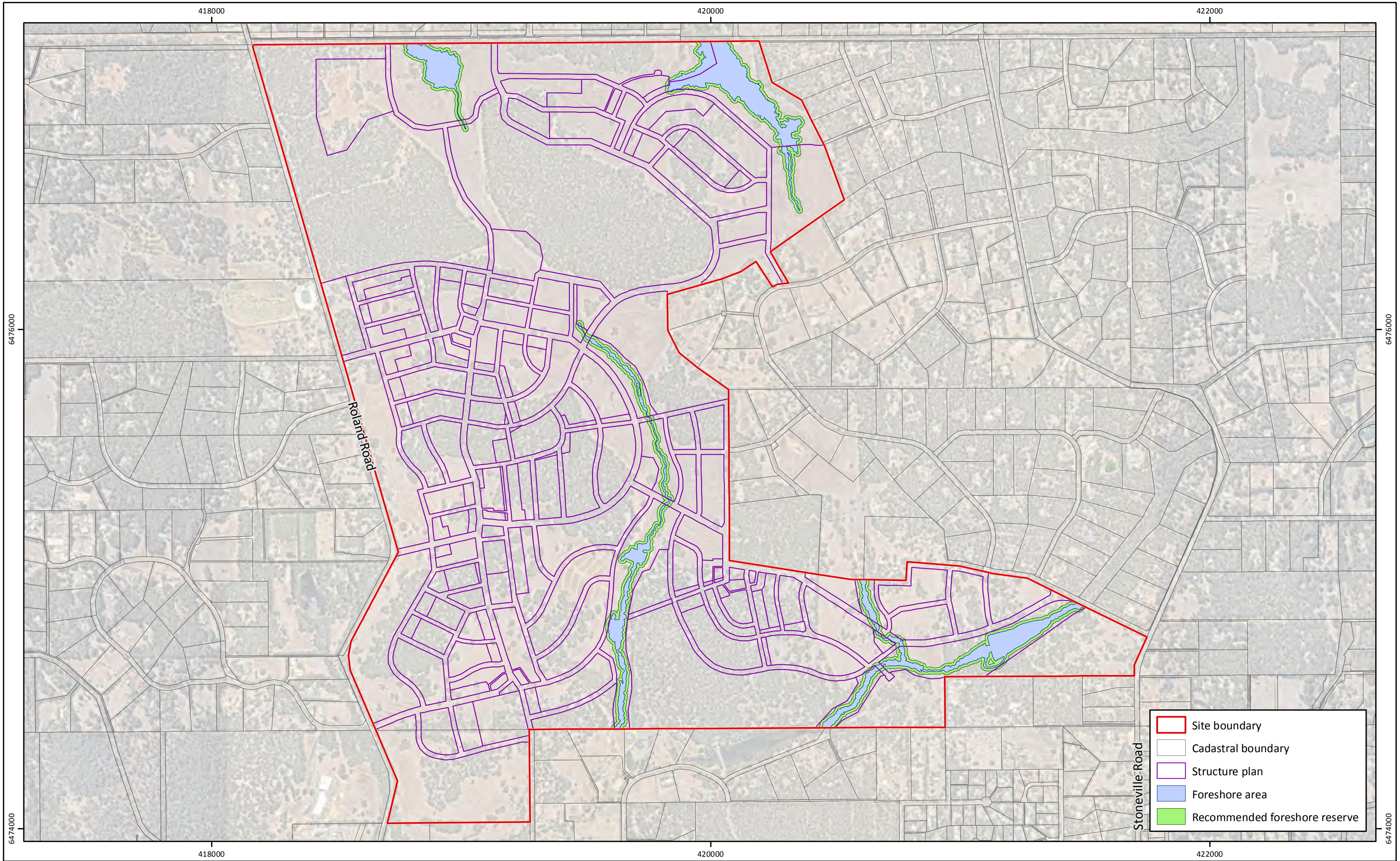

Figure 3: **Identified Foreshore Areas**

Project: Stoneville Structure Plan Support

Client: Satterley

Plan Number:
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Appendix D

Modelling Assumptions Report

North Stoneville SP34 Structure Plan Support

Modelling Assumptions Report

Project No: EP17-013(02)

Prepared for Satterley
November, 2018

Document Control

Doc name:	North Stoneville SP34 Structure Plan Support Modelling Assumptions Report				
Doc no.:	EP17-013(02)--013				
Version	Date	Author		Reviewer	
1	November 2018	Marley Butler	MGB	David Coremans	DPC
	To support North Stoneville LWMS				

Table of Contents

List of Tables

1 Introduction

Emerge Associates have been engaged to prepare a Local Water Management Strategy, to support structure planning of North Stoneville SP34, in Stoneville Western Australia. This modelling assumptions report has been prepared to support the *North Stoneville SP34 Local Water Management Strategy* (LWMS) (Emerge Associates 2018)

XPSWMM hydrologic and hydraulic modelling software has been used to model the existing site and proposed development to identify the peak flows leaving the site and inform the proposed drainage designs for the site. XPWMM software utilises the *Australian Rainfall and Runoff* (AR&R) (Ball J *et al.* 2016) flood estimation methodology and Bureau of Meteorology (BoM) *Intensity-Frequency-Duration* (IFD) rainfall estimates which are based on long term historical records across multiple monitoring locations. The use of hydrological modelling, incorporating long term rainfall record patterns, is considered best practice for drainage design.

1.1 Modelling Assumptions

The hydrologic component of the XPSWMM model uses the Laurenson 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 and regional topographical data.
- Infiltration rates and percentage imperviousness have been selected based on experience with model preparation for similar soil conditions, SP34 footprint and average lot sizes, calibrated data from a similar, nearby development area and regional geological mapping.

Runoff from each sub-catchment is routed through the catchment using the hydraulic component of XPSWMM. Generally, 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 nominal lengths and slopes; typically 10-20 m in length with slopes of 5 – 10% 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. In certain scenarios virtual links were required to have slightly different characteristics as dictated by natural terrain.
- Considering the scale of the site and the early stage of planning, links between sub-catchment storages are given nominal lengths and slopes with a suitable roughness representative of road surfaces for the purposes of conceptual conveyance.
- Artificial channels are designed with a width of 5 m, roughness of 0.014 (Manning's n) and are trapezoidal in shape. This allows for easy conveyance and represents concrete pipes and road surfaces within the model.
- Natural streamlines were represented by trapezoids with roughness, gradient and cross sections chosen to be representative of the streamline as determined by aerial photography and topography.
- Where relevant, median swales, bio-retention areas (BRAs), and flood storage areas (FSAs) are modelled as nodal-reservoirs with no infiltration.

2 Pre-development Model

2.1 Pre-development catchments

The pre-development catchment areas have been informed by:

- Topographical contours (regional 2 m contours)
- Existing roadside drainage
- Existing surface water features and streamline discharge locations.

Three pre-development land use types were identified using aerial photography and the extent of vegetation cover. Soil/ground conditions were generally consistent across the site, and are characterised by impervious clay and laterite at or close to the surface.

The pre-development model uses an "initial loss - continual loss" infiltration model. Land use loss assumptions were converted from calibrated loss assumptions of the same land types from a characteristically similar site.

Land use types and loss parameters are shown in **Table 1**, with total and segmented catchment areas shown in **Table 2.**

Table 1: North Stoneville pre-development land uses and loss parameters

Land type	Initial loss (mm)	Continual loss (mm)	Roughness (Manning's n)
Clay Sparse Vegetation	5	3.8	0.1
Clay Medium Vegetation	7	6.8	0.12
Clay Dense Vegetation	12	10.5	0.2

Table 2: North Stoneville pre-development catchment areas

Catchment	Slope	Area (ha)			
		Total area	Clay sparse	Clay medium	Clay dense
1	0.04	88.748	29.994	-	58.753
2	0.03	168.022	73.080	46.167	48.775
3	0.02	21.974	8.108	-	13.866
4	0.06	186.895	75.924	23.979	86.992
5	0.03	160.020	-	56.607	103.414
6	0.04	98.781	31.197	-	67.584
7	0.06	75.622	36.086	10.048	29.488
8	0.03	164.172	15.130	85.727	63.314
9	0.065	18.945	-	-	18.945
10	0.07	20.716	8.647	1.263	10.806

2.2 Pre-development flow paths

Flow paths and discharge locations have been identified through review of topographical contours and aerial imagery, topographical survey and through site visits by Emerge Associates hydrologists. Inflows from upstream catchments have been assumed to concentrate at the point at which the contributing streamline enters the site. Natural streamlines conveying flows from upstream catchments were designed with representative physical characteristics as discussed in **Section 1.1**. No streamlines were modelled for upstream contributing catchments. These catchments used the Laurenson method of runoff routing within XPSWMM to concentrate flows at discharge locations.

2.3 Critical duration analysis

A critical duration peak flow analysis was carried out for the 20% AEP (5 year ARI) and 1% AEP (100 year ARI) events with durations ranging from 15 minutes to 3 days. The pre-development critical durations for each discharge location for both the 20% and 1% AEP events are summarised below in **Table 3**.

Table 3: Pre-development critical duration flow analysis

Discharge location	Contributing pre-development catchments	Critical duration (mins) (1% AEP)	Critical duration (mins) (20% AEP)
Ct1	1	360	1,440
Ct2	2	360	2,280
Ct3	3	360	1440
Ct4	4	360	360
Ct5	5	360	360
Ct6	6	360	1,440
Ct7	7	360	1,440
Ct8	8	360	360
Ct9	9	360	1,440
Ct10	10	720	720
Dummy out	5, 6, 8	360	360

3 Post-development Model

3.1 Post-development catchments

The post-development catchment areas within the site were informed by:

- Topographical contours (surveyed 25 cm contours within the site and regional 2 m contours)
- North Stoneville Structure Plan 34 revision K
- Road layout and flow directions provided by civil engineers
- Existing roadside drainage
- Existing surface water features and streamline discharge locations.

A summary of the catchment areas are provided in **Appendix A**.

3.2 Post-development land uses and loss assumptions

The post-development model uses an "initial loss - continual loss" infiltration model.

Land use assumptions for post-development catchments were informed by:

- North Stoneville Structure Plan 34 revision K
- Topographical contours (surveyed 25 cm contours within the site and regional 2 m contours)
- Regional geological mapping
- Site visits by Emerge Associates hydrologists
- Preliminary civil design details.

The loss assumptions used were predominantly based upon the following assumptions:

- Lot assumptions
  - Lot areas that would remain largely unchanged in the post development environment (T1,T2, T3 the school lot and the wastewater treatment lot) were split into their underlying pre-development land uses.
  - Higher density lots that would be earthworked (T4, T5 and Centre) have higher loss parameters to represent imported fill and ripping of underlying soils (designated 'HD' in-model).
  - Open spaces assumed a clay sparse vegetation density land use.
  - A percentage of impervious area was deducted from each land use area to represent housing, paths and driveways for development lots. Percentage imperviousness was calculated by assuming a nominal lot impervious area of 300 m^2 for T2, T3, T4 and T5 lots, 6,000 m^2 for the wastewater treatment facility (based on available footprint plans) and 3 ha total impervious area for the combined school sites.
- Road reserves
  - Road reserves assumed a 60% impervious area.
  - There will be no infiltration on roads, pavements and driveways. There will however be some minor absorption storage loss which is accounted for in the initial loss value.
  - Road verge will assume similar loss characteristics to medium vegetated areas, but with a smoother roughness coefficient.

- No infiltration is assumed to occur within stormwater management features due to the largely impervious underlying ground conditions.
- 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, therefore XPSWMM default evapotranspiration assumptions are used.

A summary of the land uses allocated to structure plan lot types and associated land use loss assumptions are provided in **Table 4** and **Table 5** respectively.

Table 4: Land use distribution and imperviousness (Structure Plan allocation)

Land Type (structure plan)	Land use loss assumption allocation	Average lot impervious area (m^2)	Average Lot size (m^2)	% impervious
Road reserve	Split into road surface and verge	-	-	60
Open space	Clay Sparse Vegetation	-	-	0
Conservation (T1)	Split into existing pre-development land uses	-	-	0
T2	Split into existing pre-development land uses	300	22,000	1.4
T3	Split into existing pre-development land uses	300	1,400	21.4
T4	HD	300	820	36.6
T5	HD	300	500	60.0
School	Split into existing pre-development land uses	30000	-	16.4
Wastewater	Split into existing pre-development land uses	6000	-	5.8
Centre	HD	1.0867	-	95

Road reserve is assumed to be constituted of 60% road surface and 40% road verge.

Table 5: Land use loss assumptions

<table>
<tr><th colspan="2">Land Type</th><th>Initial loss (mm)</th><th>Continual loss (mm/hr)</th><th>Manning's number (n)</th></tr>
<tr><td colspan="2">Road surface</td><td>0.5</td><td>0</td><td>0.01</td></tr>
<tr><td colspan="2">Road verge</td><td>7</td><td>6.8</td><td>0.05</td></tr>
<tr><td colspan="2">HD</td><td>20</td><td>3.8</td><td>0.035</td></tr>
<tr><td colspan="2">Lot Impervious</td><td>1</td><td>0.1</td><td>0.014</td></tr>
<tr><td rowspan="3">Pre-development</td><td>Clay Sparse Vegetation</td><td>5</td><td>3.8</td><td>0.1</td></tr>
<tr><td>Clay Medium Vegetation</td><td>7</td><td>6.8</td><td>0.12</td></tr>
<tr><td>Clay Dense vegetation</td><td>12</td><td>10.5</td><td>0.2</td></tr>
</table>

3.3 Critical duration analysis

A critical duration peak flow and peak stage analysis was carried out for the 20% AEP (5 year ARI) and 1% AEP (100 year ARI) events with durations ranging from 15 minutes to 3 days. The pre-development critical durations for each discharge location and each FSA for both the 20% and 1% AEP events are summarised in **Table 6** and **Table 7**.

Table 6: Critical duration discharge flow analysis

Discharge location	Critical Duration (20% AEP)	Critical Duration (1% AEP)
Out 1	1440	360
Out 2	720	360
Out 3	1440	360
Out 4	720	360
Out 5	Inflow	
Out 6	Inflow	
Out 7	720	360
Out 8	360	360
Out 9	1440	360
Out 10	720	60

Table 7: Critical duration FSA stage analysis

<table>
<tr><th colspan="2">FSA</th><th>Critical Durations (20% AEP)</th><th>Critical Duration (1% AEP)</th><th>Discharge location</th></tr>
<tr><td colspan="2">FSA 13</td><td>360</td><td>360</td><td rowspan="2">Out 3</td></tr>
<tr><td colspan="2">FSA 14</td><td>720</td><td>360</td></tr>
<tr><td colspan="2">FSA 15</td><td>1,440</td><td>360</td><td rowspan="3">Out 7</td></tr>
<tr><td colspan="2">FSA 17</td><td>2,880</td><td>360</td></tr>
<tr><td colspan="2">FSA 26</td><td>360</td><td>360</td></tr>
<tr><td colspan="2">FSA 29</td><td>720</td><td>360</td><td>Out 10</td></tr>
<tr><td rowspan="4">Dams</td><td>FSA 5</td><td>1440</td><td>360</td><td>Out 1</td></tr>
<tr><td>FSA 10</td><td>720</td><td>360</td><td>Out 2</td></tr>
<tr><td>FSA 30</td><td>1440</td><td>360</td><td>Out 4</td></tr>
<tr><td>FSA 50</td><td>360</td><td>360</td><td>Out 8</td></tr>
</table>

4 References

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M and I, T. 2016, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia (Geoscience Australia), Canberra.

Emerge Associates, 2018, *North Stoneville SP34 Local Water Management Strategy,* report prepared for Satterley, Subiaco.

Appendices:

Post-development spatial, land use and slope catchment breakdown

Post development catchment	Land use	Area (ha)	Average slope (%)
Ct 1	Clay dense	51.559	6.2
Ct 1	Clay sparse	24.876	5.6
Ct 1	Impervious	0.600	10.0
Ct 1	Clay sparse	2.688	5.4
Ct 10	Clay dense	1.657	3.1
Ct 10	Clay med	1.410	3.7
Ct 10	Clay sparse	5.594	4.4
Ct 10	HD	1.361	4.3
Ct 10	Impervious	1.892	10.0
Ct 10	Road	2.924	4.4
Ct 11	Road	2.246	4.4
Ct 12	Clay dense	3.404	4.6
Ct 12	Clay sparse	0.160	2.8
Ct 12	Impervious	0.051	10.0
Ct 13	Clay dense	0.405	3.3
Ct 13	Clay sparse	0.758	3.2
Ct 13	HD	1.662	2.6
Ct 13	Impervious	1.276	10.0
Ct 13	Road	1.727	2.6
Ct 14	Clay dense	0.937	3.1
Ct 14	Clay sparse	0.544	2.5
Ct 14	HD	0.845	4.0
Ct 14	Impervious	0.598	10.0
Ct 14	Road	1.092	2.7
Ct 15	Clay dense	1.217	7.1
Ct 15	Clay sparse	10.244	5.2
Ct 15	HD	2.278	3.3
Ct 15	Impervious	1.927	10.0
Ct 15	Road	1.826	4.9
Ct 16	Clay dense	5.493	5.8
Ct 16	Clay sparse	8.289	5.2
Ct 16	HD	6.364	4.5
Ct 16	Impervious	6.704	10.0
Ct 16	Road	11.439	4.6
Ct 17	Clay dense	2.956	6.1

Post development catchment	Land use	Area (ha)	Average slope (%)
Ct 17	Clay sparse	6.190	5.0
Ct 17	HD	3.563	4.4
Ct 17	Impervious	4.168	10.0
Ct 17	Road	6.383	5.1
Ct 18	Clay dense	3.820	8.5
Ct 18	Clay med	0.115	3.9
Ct 18	Clay sparse	5.063	4.8
Ct 18	Impervious	1.765	10.0
Ct 19	Clay dense	4.123	10.4
Ct 19	Clay sparse	4.330	8.9
Ct 19	Impervious	2.082	10.0
Ct 19	Road	3.530	8.1
Ct 2	Clay dense	5.858	4.2
Ct 20	Clay dense	0.025	10.4
Ct 20	Clay sparse	6.019	5.3
Ct 20	Impervious	0.461	10.0
Ct 20	Road	0.181	6.8
Ct 21	Clay dense	0.751	7.4
Ct 21	Clay sparse	0.253	5.7
Ct 21	Impervious	0.197	10.0
Ct 21	Road	0.563	9.2
Ct 22	Clay dense	2.391	9.2
Ct 22	Clay sparse	0.562	5.9
Ct 22	Impervious	0.804	10.0
Ct 22	Road	1.565	7.6
Ct 23	Clay dense	5.090	9.2
Ct 23	Clay sparse	0.543	7.4
Ct 23	HD	0.384	5.5
Ct 23	Impervious	1.719	10.0
Ct 23	Road	3.563	8.7
Ct 24	Clay sparse	3.356	5.8
Ct 24	HD	0.303	7.6
Ct 24	Impervious	1.198	10.0
Ct 24	Road	2.796	5.6
Ct 25	Clay dense	4.114	11.5
Ct 25	Clay med	0.133	12.8
Ct 25	Clay sparse	4.498	12.0
Ct 25	Impervious	0.124	10.0
Ct 26	Clay dense	2.823	8.7

Post development catchment	Land use	Area (ha)	Average slope (%)
Ct 26	Clay med	4.209	9.4
Ct 26	Clay sparse	3.520	5.8
Ct 26	HD	2.316	5.6
Ct 26	Impervious	3.188	10.0
Ct 26	Road	5.371	7.8
Ct 27	Clay dense	0.106	12.1
Ct 27	Clay med	1.453	12.5
Ct 27	Clay sparse	1.808	13.5
Ct 27	Impervious	0.048	10.0
Ct 28	Clay dense	3.282	13.0
Ct 28	Clay sparse	6.000	11.5
Ct 28	Impervious	0.132	10.0
Ct 29	Clay dense	1.751	8.4
Ct 29	Clay med	0.546	4.8
Ct 29	Clay sparse	2.858	10.4
Ct 29	Impervious	0.349	10.0
Ct 29	Road	1.346	8.1
Ct 3	Clay dense	13.377	3.8
Ct 3	Clay sparse	1.553	5.7
Ct 30	Clay dense	1.873	11.5
Ct 30	Clay med	2.127	8.9
Ct 30	Clay sparse	1.862	9.6
Ct 30	HD	0.440	7.2
Ct 30	Impervious	1.850	10.0
Ct 30	Road	1.664	10.3
Ct 31	Clay dense	0.060	13.0
Ct 31	Clay med	2.294	9.0
Ct 31	Clay sparse	1.828	10.4
Ct 31	Impervious	1.139	10.0
Ct 31	Road	1.141	10.1
Ct 32	Clay dense	1.305	9.5
Ct 32	Clay med	2.626	10.0
Ct 32	Clay sparse	3.401	6.6
Ct 32	HD	4.155	6.3
Ct 32	Impervious	4.776	10.0
Ct 32	Road	5.948	6.8
Ct 33	Clay dense	1.974	10.1
Ct 33	Impervious	0.028	10.0
Ct 34	Clay dense	1.622	6.7
Ct 34	Clay sparse	9.621	8.9
Ct 34	Impervious	0.030	10.0
Ct 35	Clay dense	2.271	14.9
Ct 35	Clay sparse	0.116	12.5
Ct 35	Impervious	0.034	10.0
Ct 36	Clay dense	0.833	11.5
Ct 36	Clay sparse	1.483	7.1
Ct 36	HD	0.300	10.4
Ct 36	Impervious	0.682	10.0
Ct 36	Road	1.433	9.6
Ct 37	Clay dense	1.173	6.3
Ct 37	Clay sparse	0.207	9.6
Ct 37	HD	0.319	6.4
Ct 37	Impervious	0.504	10.0
Ct 37	Road	0.650	9.5
Ct 38	Clay dense	9.280	13.6
Ct 38	Impervious	0.569	10.0
Ct 39	Clay dense	11.669	11.6
Ct 39	Impervious	0.354	10.0
Ct 4	Clay dense	15.693	3.8
Ct 4	Clay med	0.279	3.2
Ct 4	Clay sparse	3.797	3.4
Ct 4	Road	0.190	6.9
Ct 40	Clay dense	1.723	5.4
Ct 40	Clay sparse	1.202	7.2
Ct 40	HD	0.776	6.8
Ct 40	Impervious	1.435	10.0
Ct 40	Road	2.362	5.4
Ct 41	Clay dense	5.936	8.4
Ct 41	Clay sparse	4.647	5.2
Ct 41	HD	0.595	6.1
Ct 41	Impervious	2.793	10.0
Ct 41	Road	4.062	6.9
Ct 42	Clay dense	2.857	6.8
Ct 42	Clay sparse	0.106	2.0
Ct 42	Impervious	0.042	10.0
Ct 43	Clay sparse	1.308	5.4
Ct 44	Clay dense	0.416	6.0
Ct 44	Clay med	0.098	7.7

Post development catchment	Land use	Area (ha)	Average slope (%)
Ct 44	Clay sparse	1.267	5.5
Ct 44	Impervious	0.485	10.0
Ct 44	Road	0.987	6.4
Ct 45	Clay dense	0.664	7.7
Ct 45	Clay med	1.944	7.6
Ct 45	Clay sparse	2.487	5.2
Ct 45	Impervious	1.387	10.0
Ct 45	Road	2.726	5.9
Ct 46	Clay sparse	1.963	3.7
Ct 47	Road	0.182	2.4
Ct 48	Clay dense	1.571	4.5
Ct 48	Clay med	4.764	2.9
Ct 48	Clay sparse	0.500	2.3
Ct 48	Impervious	0.097	10.0
Ct 49	Clay sparse	7.435	6.1
Ct 5	Clay dense	3.043	4.8
Ct 5	Clay sparse	1.901	3.9
Ct 5	Impervious	0.579	10.0
Ct 5	Road	2.115	4.2
Ct 50	Clay dense	0.179	7.8
Ct 50	Clay med	2.673	7.8
Ct 50	Impervious	0.776	10.0
Ct 50	Road	1.065	7.6
Ct 51	Clay sparse	1.714	5.0
Ct 52	Clay dense	0.625	6.0
Ct 52	Clay med	2.340	5.0
Ct 52	Impervious	0.042	10.0
Ct 52	Road	0.876	5.2
Ct 53	Clay dense	2.184	5.2
Ct 53	Clay med	2.517	3.5
Ct 53	Impervious	0.067	10.0
Ct 54	Clay med	1.809	2.1
Ct 54	Impervious	0.026	10.0
Ct 54	Road	0.317	0.5
Ct 6	Clay dense	3.128	6.1
Ct 6	Clay sparse	3.857	5.7
Ct 6	Impervious	0.099	10.0
Ct 7	Clay dense	1.140	4.4
Ct 7	Clay sparse	5.858	3.9

Post development catchment	Land use	Area (ha)	Average slope (%)
Ct 7	HD	1.919	3.8
Ct 7	Impervious	2.739	10.0
Ct 7	Road	5.105	4.2
Ct 8	Clay med	0.316	6.4
Ct 8	Clay sparse	20.009	5.6
Ct 8	Impervious	0.120	10.0
Ct 9	Clay dense	2.217	7.4
Ct 9	Clay sparse	1.030	7.2
Ct 9	HD	0.760	10.3
Ct 9	Impervious	1.323	10.0
Ct 9	Road	1.085	8.4
US Ct 2a	Clay dense	8.574	4.4
US Ct 2a	Clay med	31.132	4.4
US Ct 2a	Clay sparse	0.794	4.4
US Ct 2b	Clay dense	7.144	4.4
US Ct 2b	Clay med	11.476	4.4
US Ct 2b	Clay sparse	24.130	4.4
US Ct 4a	Clay dense	0.176	6.9
US Ct 4a	Clay med	5.175	6.9
US Ct 4a	Clay sparse	4.026	6.9
US Ct 4b	Clay dense	4.794	6.9
US Ct 4b	Clay sparse	0.010	6.9
US Ct 5	Clay dense	103.440	4.2
US Ct 5	Clay med	56.644	4.2
US Ct 6	Clay dense	67.557	5.3
US Ct 6	Clay med	0.024	5.3
US Ct 6	Clay sparse	30.482	5.3
US Ct 8a	Clay dense	11.352	4.1
US Ct 8a	Clay med	58.969	4.1
US Ct 8a	Clay sparse	0.037	4.1
US Ct 8b	Clay dense	16.483	4.1
US Ct 8b	Clay med	6.665	4.1

Appendix E

Surface Water Quality Monitoring Results

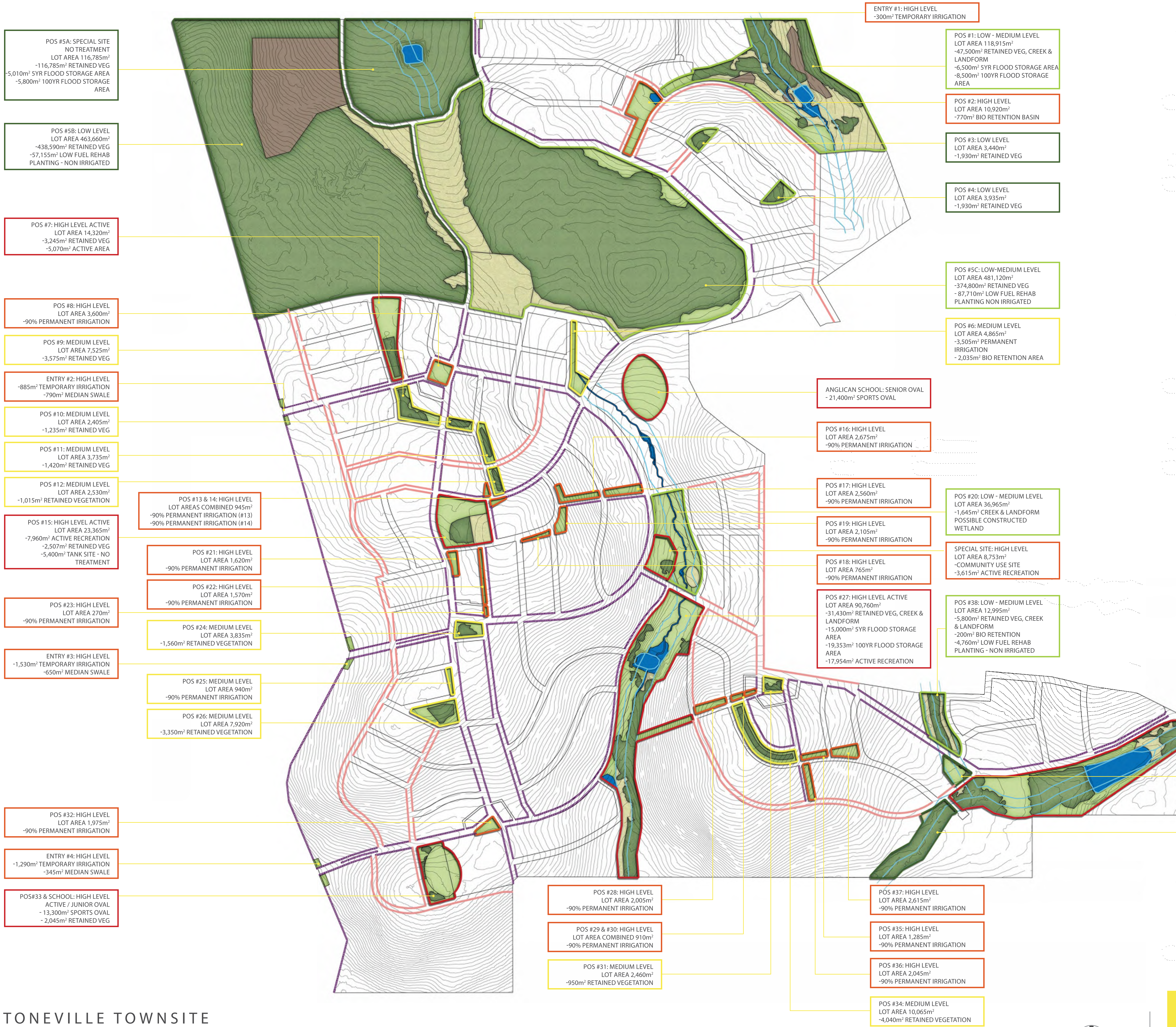
Surfacewater Monitoring Results 2017-2018

		Field						Inorganics	Nutrients							
		pH (field)	EC (field)	DO	DO (saturated)	Redox (field)	Temperature	TSS	NH3 as N	NO2- as N	NO3- as N	NOx	TKN	TN	Reactive P as P	TP
		pH units	µS/cm	mg/L	%	mV	oC	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Site Code	**Date of Sampling**															
SW1	14/07/2017	7.23	1380	4.22	40.5	183	13.2	-	0.02	<0.01	0.15	0.15	0.1	0.2	<0.01	0.02
SW1	30/08/2017	6.44	717	7.75	76.1	48.5	14.4	-	0.02	<0.01	0.04	0.04	0.1	0.1	<0.01	0.02
SW1	14/09/2017	6.41	740	5.67	57	94.7	15.6	5	0.03	<0.01	<0.01	<0.01	0.1	0.1	<0.01	0.01
SW1	5/07/2018	5.15	824	8.81	82.1	74.9	12.1	-	0.01	<0.01	1.86	1.86	0.6	2.5	<0.01	<0.01
SW1	26/07/2018	5.98	590	8.16	82.1	53.3	15.6	-	0.01	<0.01	1.47	1.47	0.4	1.9	<0.01	<0.01
SW2	14/07/2017	7.83	818	7.91	78.5	153	15	-	<0.01	<0.01	0.5	0.5	0.2	0.7	<0.01	0.04
SW2	30/08/2017	6.41	463	7.86	78.2	46	15.2	-	0.02	<0.01	0.92	0.92	0.3	1.2	<0.01	0.01
SW2	14/09/2017	6.71	399	6.21	63.2	69	16.3	<5	0.03	<0.01	0.76	0.76	0.2	1	<0.01	0.01
SW2	5/07/2018	5.66	428	10.4	97.6	58	12.5	-	0.02	<0.01	5.05	5.05	<0.5	5	<0.01	<0.05
SW2	26/07/2018	6.22	346	8.15	81.1	44	15	-	0.03	<0.01	3.16	3.16	0.6	3.8	<0.01	<0.02
SW3	14/09/2017	6.37	435	6.64	69.2	96	17.6	<5	0.03	<0.01	<0.01	<0.01	0.1	0.1	<0.01	<0.01
SW3	26/07/2018	5.56	307	7.78	76.2	74	14.5	-	0.01	<0.01	0.08	0.08	0.1	0.2	<0.01	<0.01
SW3	30/08/2018	6.43	419	8.43	85.4	54	15.9	-	<0.01	<0.01	0.02	0.02	<0.1	<0.1	<0.01	<0.01
SW4	14/07/2017	7.38	405	7.38	80.5	195	15	-	0.01	<0.01	3.64	3.64	0.4	4	<0.01	<0.02
SW4	30/08/2017	6.53	254	6.53	88.9	49	16.5	-	<0.01	0.01	2.5	2.51	0.2	2.7	<0.01	<0.02
SW4	14/09/2017	6.91	267	6.91	103.1	87	18.7	<5	0.03	<0.01	2.64	2.64	0.3	2.9	<0.01	0.04
SW4	5/07/2018	5.31	323	5.31	96.5	65	12.3	-	0.03	<0.01	4.3	4.3	0.5	4.8	<0.01	<0.02
SW4	26/07/2018	6.21	251	6.21	86.4	64	-	-	0.03	<0.01	3.33	3.33	0.6	3.9	<0.01	0.09
SW5	30/08/2017	6.45	388	9.73	100	56	16.8	-	0.01	0.03	1.57	1.6	0.4	2	<0.01	<0.01
SW5	14/09/2017	6.35	396	7.39	76.6	97	17.2	<5	0.02	<0.01	1.39	1.39	0.3	1.7	<0.01	0.02
SW5	5/07/2018	5.3	335	8.17	78.9	69	12.7	-	0.01	<0.01	3.85	3.85	0.7	4.6	<0.01	0.03
SW5	26/07/2018	5.61	339	7.49	73.4	70	14.5	-	0.01	<0.01	4.7	4.7	0.6	5.3	<0.01	<0.02
SW6	26/07/2018	5.55	226	7.38	71.3	74	13.7	-	0.02	<0.01	6.64	6.64	1.6	8.2	<0.01	<0.05

Minimum Concentration		5.15	226	4.22	40.5	44	12.1	<5	<0.01	<0.01	<0.01	<0.01	<0.1	<0.1	<0.01	<0.01
Maximum Concentration		7.83	1380	10.4	103.1	195	18.7	5	0.03	0.03	6.64	6.64	1.6	8.2	<0.01	0.09
Average Concentration		6.3	480	7.4	79	81	15	3	0.018	0.0063	2.1	2.1	0.38	2.5	0.005	0.018
Median Concentration		6.37	399	7.49	78.9	69	15	2.5	0.02	0.005	1.57	1.6	0.3	2	0.005	0.01
Standard Deviation		0.69	265	1.4	14	41	1.8	1.1	0.0095	0.0053	1.9	1.9	0.33	2.2	0	0.019

Appendix F

Landscape Concepts



LEGEND

- RETAINED VEGETATION OR LANDFORM INTEGRATED INTO OPEN SPACE
- EXISTING HERITAGE SITE TO BE PROTECTED
- EXISTING CREEKLINE & BUFFER
- PROPOSED IRRIGATED POS AREAS
- PROPOSED IRRIGATED KEY STREETSCAPES
- PROPOSED IRRIGATED SECONDARY STREETSCAPES ESTABLISHMENT IRRIGATION (2YRS)
- PROPOSED DRAINAGE AREAS ESTABLISHMENT IRRIGATION (2YRS)
- PROPOSED LOW FUEL ZONES, MANAGED REHAB PLANTING, LOW HEIGHT AT MATURITY NON-IRRIGATED

POS TYPOLOGIES

HA
High Level ACTIVE: Manicured POS with irrigated turf kick-about areas and/or ovals used for sports. Irrigated native and exotic (hardy) garden beds and shade trees of larger stature. Circulating paths, feature walls, shade structures & park furniture provide passive recreation with play equipment and potential art or sculpture located at key nodes. These spaces are commonly located within schools, special use community sites or large areas of dedicated POS.

H
High Level: Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.

M
Medium Level: Manicured POS with a parkland setting including irrigated turf pockets, native garden beds and new trees integrated with existing trees, vegetation and landform. Circulating paths, some walls, smaller or low-key shade structures & park furniture. The areas are generally the connecting greenlink portions of POS evident through the centre of the site.

L-M
Low-Medium Level: Some seasonally irrigated turf, temporary irrigated garden beds and new tree planting integrated with rehabilitation planting, retained vegetation and landform. Walking trails, signage, resting nodes with park furniture and potential bike trails are proposed. Spaces generally include some drainage function.

L
Low Level: Retention of existing vegetation and landform to the majority of the site. Some manicured buffer landscape treatments with minimal turf & temporary irrigation works to native garden beds. Walking paths and rest points to be provided

Creek line Corridor: Retention of existing vegetation and water bodies including creeks and dams where possible.
New drainage basins and manicured buffer landscape treatments with turf & temporary irrigation works to native garden beds. Walking trails, signage, resting nodes with park furniture and potential bike trails are proposed.

NORTH STONEVILLE TOWNSITE

LANDSCAPE MASTERPLAN
NOVEMBER 2018

JOB NO. 1612601 | M1.101 | REV B
1:6000 @ A1

0 60 120 240 360 600m

PLAN E
LANDSCAPE ARCHITECTS
414 ROKEBY RD SUBIACO WA 6008
T: (08) 9388 9566 E: mail@plane.com.au

CROSS SECTION C-C

CENTRAL DAM: CROSS SECTION D-D

NORTH STONEVILLE TOWNSITE

PREPARED FOR SATTERLEY PROPERTY GROUP

CENTRAL DAM POS: CROSS SECTIONS (CONCEPT)

JOB NO. 1612602 C1.102 REV B NOV 2018

1:200 @ A1

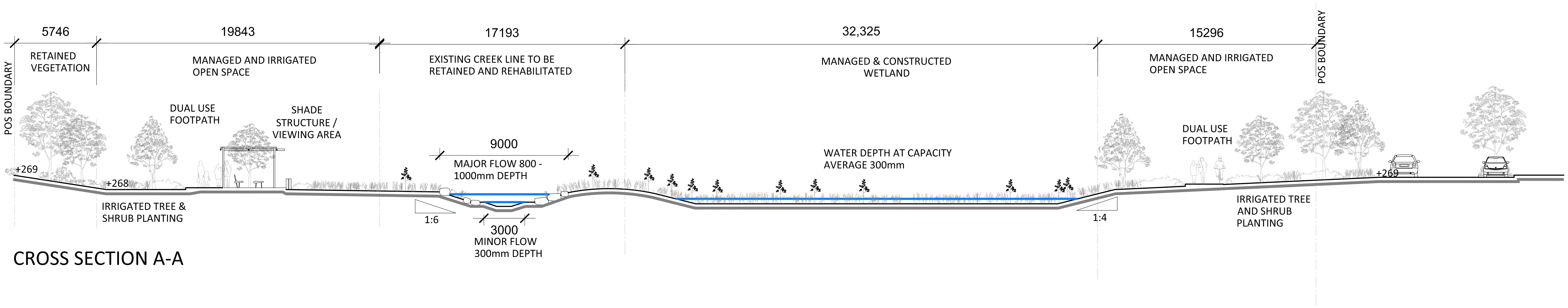
PLAN \ E

LANDSCAPE ARCHITECTS
414 ROKEBY RD SUBIACO WA 6008
T: (08) 9388 9566 E: mail@plane.com.au
LANDSPACE PTY LTD ACN 056 538 679

FILE LOCATION: L:\PROJECTS\2016 PROJECTS\16126 NORTH STONEVILLE TOWN SITE\1612602\PROJECT\P5 DRAWINGS\CONCEPTS\ACAD\1612602 C1.101 DAM CROSS SECTIONS.DWG

PLOTTED BY: KDAWSON

PLOT DATE: 19/11/2018 4:21:38 PM



CROSS SECTION A-A

CROSS SECTION B-B

NORTH STONEVILLE TOWNSITE

PREPARED FOR SATTERLEY PROPERTY GROUP

CENTRAL DAM POS: CROSS SECTIONS (CONCEPT)

JOB NO. 1612602 C1.101 REV B NOV 2018

1:150 @ A1

PLOTTED BY: KDAWSON

PLAN \ E

LANDSCAPE ARCHITECTS

414 ROKEBY RD SUBIACO WA 6008
T: (08) 9388 9566 E: mail@plane.com.au
LANDSPACE PTY LTD ACN 056 538 679

PLOT DATE: 19/11/2018 4:20:50 PM

FILE LOCATION: L:\PROJECTS\2016 PROJECTS\16126 NORTH STONEVILLE TOWN SITE\1612602\PROJECT\PS DRAWINGS\CONCEPTS\ACAD\1612602 C1.101 DAM CROSS SECTIONS.DWG

NORTH STONEVILLE TOWNSITE

SATTERLEY PROPERTY GROUP
DRAWING [1612601 C101] REVISION [B]

1612601
REV D

IRRIGATION CALCULATIONS

DWER LAND USE CLASSIFICATION					NATURE AREAS (M2)	IMPERVIOUS AREAS (M2)	NATIVE GARDEN (M2)	RECREATION AREAS, (RED HIGHLIGHTED ARE SPORTS GROUNDS M2)	ASSUME 50% NATIVE GARDEN AND 50% NON NATIVE GARDEN (M2)	NATIVE GARDEN (M2)		SPORT GROUNDS KL
POS AREA	TYPOLOGY / CLASSIFICATION	LOT AREA M2	VERGE AREA M2 (8%-10%)	TOTAL AREA M2	RETAINED VEGETATION, LANDFORM OR CREEKLINE M2 (NON IRRIGATED)	HARD WORKS M2	LOW FUEL ZONE, DRAINAGE BASIN OR OTHER NON IRRIGATED AREA M2	PERMANENT TURF IRRIGATION M2	PERMANENT TREE & SHRUB IRRIGATION M2	TEMPORARY (2yr) ESTABLISHMENT IRRIGATION M2	PERMANENT PASSIVE AREAS: ALLOCATION kl/Ha/Yr (@ 6,750kl/ha/yr)	PERMANENT ACTIVE AREAS: ALLOCATION kl/Ha/Yr (@ 7,500kl/ha/yr)
1	**Low-Medium Level:** Some seasonally irrigated turf, temporary irrigated garden beds and new tree planting integrated with rehabilitation planting, retained vegetation and landform. Walking trails, signage, resting nodes with park furniture and potential bike trails are proposed. Spaces generally include some drainage function.	118,915	9,513.20	128,428	47,500	6,421	39,840	13,866.72	10,400	10,400	16,380	-
2	**High Level ACTIVE:** Manicured POS with irrigated turf kick-about areas and / or ovals used for sports. Irrigated native and exotic (hardy) garden beds and shade trees of larger stature. Circulating paths, feature walls, shade structures & park furniture provide passive recreation with play equipment and potential art or sculpture located at key nodes.	10,920	1,092	12,012	-	1,201	420	6,234.23	4,156		2,805.40	4,675.67
3	**Low Level:** Retention of existing vegetation and landform to the majority of the site. Some manicured buffer landscape treatments with minimal turf & temporary irrigation works to native garden beds. Walking paths and rest points to be provided	3,440	344	3,784	1,930	378	132	537	806	-	906.63	-
4	**Low Level:** Retention of existing vegetation and landform to the majority of the site. Some manicured buffer landscape treatments with minimal turf & temporary irrigation works to native garden beds. Walking paths and rest points to be provided	3,935	394	4,329	1,930	433	151	725.66	544	544	857.19	-
5A	**Low Level:** Retention of existing vegetation and landform to the majority of the site. Some manicured buffer landscape treatments with minimal turf & temporary irrigation works to native garden beds. Walking paths and rest points to be provided	116,785	9,342.80	126,128	116,785	6,306	3,036	-	-	-	-	-
5B	**Low Level:** Retention of existing vegetation and landform to the majority of the site. Some manicured buffer landscape treatments with minimal turf & temporary irrigation works to native garden beds. Walking paths and rest points to be provided	463,660	37,093	500,753	438,590	5,008	57,155	-		-	-	-
5C	**Low-Medium Level:** Some seasonally irrigated turf, temporary irrigated garden beds and new tree planting integrated with rehabilitation planting, retained vegetation and landform. Walking trails, signage, resting nodes with park furniture and potential bike trails are proposed. Spaces generally include some drainage function.	481,120	38,490	519,610	374,800	5,196	87,710	7,786	22,059	22,059	20,145	-
6	**Medium Level:** Manicured POS with a parkland setting including irrigated turf pockets, native garden beds and new trees integrated with existing trees, vegetation and landform. Circulating paths, some walls, smaller or low-key shade structures & park furniture. The areas are generally the connecting greenlink portions of POS evident through the centre of the site.	4,855	486	5,341	-	801	2,135	721.33	1,683	-	1,623	-

7	**High Level ACTIVE:** Manicured POS with irrigated turf kick-about areas and / or ovals used for sports. Irrigated native and exotic (hardy) garden beds and shade trees of larger stature. Circulating paths, feature walls, shade structures & park furniture provide passive recreation with play equipment and potential art or sculpture located at key nodes. These spaces are commonly located with schools, special use community sites or large areas of dedicated POS.	14,320	1,432	15,752	3,245	1,575	788		5,072	2,536	2,536	1,712	3,804
8	**High Level:** Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	3,600	360	3,960	-	594	198		950.40	2,218	-	2,138	
9	**Medium Level:** Manicured POS with a parkland setting including irrigated turf pockets, native garden beds and new trees integrated with existing trees, vegetation and landform. Circulating paths, some walls, smaller or low-key shade structures & park furniture. The areas are generally the connecting greenlink portions of POS evident through the centre of the site.	7,525	753	8,278	3,575	828	414		1,038	1,211	1,211	1,518	
10	**Medium Level:** Manicured POS with a parkland setting including irrigated native garden beds and new trees integrated with existing trees, vegetation and landform. Circulating paths, some walls, smaller or low-key shade structures & park furniture. The areas are generally the connecting greenlink portions of POS evident through the centre of the site.	2,405	241	2,646	1,235	265	265		-	881	-	595	
11	**Medium Level:** Manicured POS with a parkland setting including irrigated native garden beds and new trees integrated with existing trees, vegetation and landform. Circulating paths, some walls, smaller or low-key shade structures & park furniture. The areas are generally the connecting greenlink portions of POS evident through the centre of the site.	3,735	374	4,109	1,420	411	205		-	2,072		1,399	
12	**Medium Level:** Manicured POS with a parkland setting including irrigated native garden beds and new trees integrated with existing trees, vegetation and landform. Circulating paths, some walls, smaller or low-key shade structures & park furniture. The areas are generally the connecting greenlink portions of POS evident through the centre of the site.	2,530	253	2,783	1,015	556.60	139		-	1,072		724	
13 & 14	**High Level:** Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	945	95	1,040	-	103.95	104		249	582	-	561	
15	**High Level ACTIVE:** Manicured POS with irrigated turf kick-about areas and / or ovals used for sports. Irrigated native and exotic (hardy) garden beds and shade trees of larger stature. Circulating paths, feature walls, shade structures & park furniture provide passive recreation with play equipment and potential art or sculpture located at key nodes. These spaces are commonly located with schools, special use community sites or large areas of dedicated POS.	23,365	2,337	25,702	5,075	2,570	6,685		7,960	3,411	-	2,303	5,969.92
16	**High Level:** Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	2,675	268	2,943	-	441.38	147		1,177.00	1,177	-	1,589	
17	**High Level:** Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	2,560	256	2,816	-	422.40	141		901.12	1,352	-	1,521	

18	**High Level:** Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	765	77	842	-	168.30	42		315.56	316	-	426	
19	**High Level:** Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	2,105	211	2,316	-	463.10	116		694.65	1,042	-	1,172	
20	**Low-Medium Level:** Some seasonally irrigated turf, temporary irrigated garden beds and new tree planting integrated with rehabilitation planting, retained vegetation and landform. Walking trails, signage, resting nodes with park furniture and potential bike trails are proposed. Spaces generally include some drainage function. Creek line Corridor: Retention of existing vegetation and water bodies including creeks and dams where possible. New drainage basins and manicured buffer landscape treatments with turf & temporary irrigation works to native garden beds. Walking trails, signage, resting nodes with park furniture and potential bike trails are proposed.	36,965	3,697	40,662	1,645	4,066.15	8,380		10,628.14	7,971	7,971	12,554	
21	**High Level:** Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	1,620	162	1,782	-	356.40	178		498.96	-	748	337	
22	**High Level:** Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	1,570	157	1,727	-	345.40	86		518.10	777	-	874	
23	**High Level:** Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	270	27	297	-	59.40	15		89.10	134	-	150	
24	**Medium Level:** Manicured POS with a parkland setting including irrigated turf pockets, native garden beds and new trees integrated with existing trees, vegetation and landform. Circulating paths, some walls, smaller or low-key shade structures & park furniture. The areas are generally the connecting greenlink portions of POS evident through the centre of the site.	3,835	384	4,219	1,560	421.85	211		810.29	-	1,215	547	
25	**Medium Level:** Manicured POS with a parkland setting including irrigated turf pockets, native garden beds and new trees integrated with existing trees, vegetation and landform. Circulating paths, some walls, smaller or low-key shade structures & park furniture. The areas are generally the connecting greenlink portions of POS evident through the centre of the site.	940	94	1,034	-	103.40	52		351.56	264	264	415	
26	**Medium Level:** Manicured POS with a parkland setting including irrigated turf pockets, native garden beds and new trees integrated with existing trees, vegetation and landform. Circulating paths, some walls, smaller or low-key shade structures & park furniture. The areas are generally the connecting greenlink portions of POS evident through the centre of the site.	7,920	792	8,712	3,350	871.20	436		1,622.08	2,433	- 0	2,737	

27	**High Level ACTIVE**: Manicured POS with irrigated turf kick-about areas and / or ovals used for sports. Irrigated native and exotic (hardy) garden beds and shade trees of larger stature. Circulating paths, feature walls, shade structures & park furniture provide passive recreation with play equipment and potential art or sculpture located at key nodes. These spaces are commonly located with schools, special use community sites or large areas of dedicated POS. Creek line Corridor: Retention of existing vegetation and water bodies including creeks and dams where possible. New drainage basins and manicured buffer landscape treatments with turf & temporary irrigation works to native garden beds. Walking trails, signage, resting nodes with park furniture and potential bike trails are proposed.	90,760	9,076	**99,836**	31,430	9,983.60	13,535		17,954.96	13,466	13,466	9,089.70	13,466
28	**High Level**: Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	2,005	201	**2,206**	-	330.83	110		**705.76**	1,059	-	1,191	
29 & 30	**High Level**: Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	910	91	**1,001**	-	150.15	50		**320.32**	480	-	541	
31	**Medium Level**: Manicured POS with a parkland setting including irrigated turf pockets, native garden beds and new trees integrated with existing trees, vegetation and landform. Circulating paths, some walls, smaller or low-key shade structures & park furniture. The areas are generally the connecting greenlink portions of POS evident through the centre of the site.	2,460	246	**2,706**	950	405.90	135		**485.92**	729	-	820	
32	**High Level**: Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	1,975	198	**2,173**	-	325.88	109		**695.20**	1,043	-	1,173	
33	**High Level ACTIVE**: Manicured POS with irrigated turf kick-about areas and / or ovals used for sports. Irrigated native and exotic (hardy) garden beds and shade trees of larger stature. Circulating paths, feature walls, shade structures & park furniture provide passive recreation with play equipment and potential art or sculpture located at key nodes. These spaces are commonly located with schools, special use community sites or large areas of dedicated POS.	23,965	2,397	**26,362**	2,045	2,636.15	1,216		13,301.94	7,163	-	4,834.74	9,976
34	**Medium Level**: Manicured POS with a parkland setting including irrigated turf pockets, native garden beds and new trees integrated with existing trees, vegetation and landform. Circulating paths, some walls, smaller or low-key shade structures & park furniture. The areas are generally the connecting greenlink portions of POS evident through the centre of the site.	10,065	1,007	**11,072**	4,040	1,660.73	554		**1,926.88**	1,445	1,445	2,276	
35	**High Level**: Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	1,285	129	**1,414**	-	212.03	141		**318.04**	371	371	465	
36	**High Level**: Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	2,045	205	**2,250**	-	337.43	225		**506.14**	590	590	740	

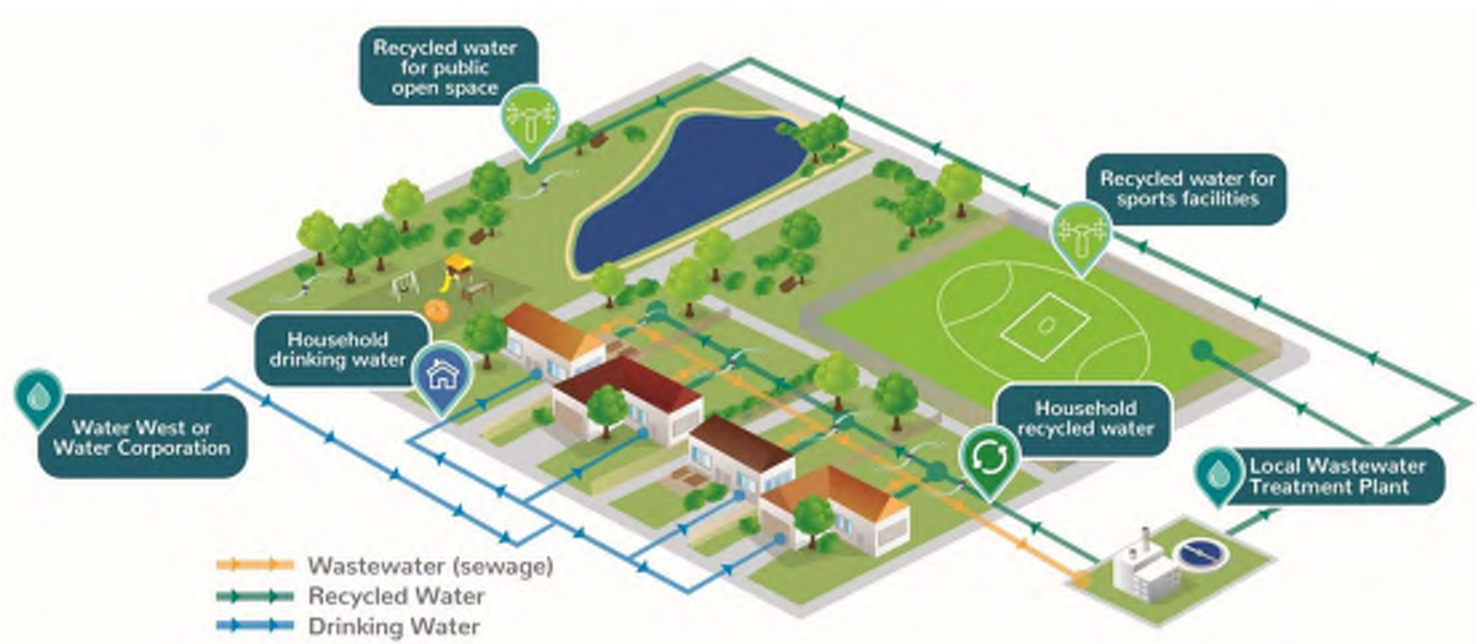
37	**High Level:** Significant areas of hardstand, irrigated turf and large trees with some irrigated native and exotic (hardy) garden beds. Shade structures or arbors, park furniture, and incidental play or sculptures considered at key focal points. Commonly seen in town centre locations or adjacent key community facilities.	2,615	262	2,877	-	431.48	144		690.36	805	805	1,010	
38	**Low-Medium Level:** Some seasonally irrigated turf, temporary irrigated garden beds and new tree planting integrated with rehabilitation planting, retained vegetation and landform. Walking trails, signage, resting nodes with park furniture and potential bike trails are proposed. Spaces generally include some drainage function.	12,995	1,040	14,035	5,800	1,403.46	4,760		-	2,071	-	1,398.02	
39	**Low Level:** Retention of existing vegetation and landform to the majority of the site. Some manicured buffer landscape treatments with minimal turf & temporary irrigation works to native garden beds. Walking paths and rest points to be provided	4,100	410	4,510	495	451.00	226		1,001.55	1,168	1,168	1,465	
40	**Low Level:** Retention of existing vegetation and landform to the majority of the site. Some manicured buffer landscape treatments with minimal turf & temporary irrigation works to native garden beds. Walking paths and rest points to be provided	19,725	1,973	21,698	19,195	2,169.75	1,085		-	- 376	- 376	- 254	
41	High Level ACTIVE: Manicured POS with irrigated turf kick-about areas and / or ovals used for sports. Irrigated native and exotic (hardy) garden beds and shade trees of larger stature. Circulating paths, feature walls, shade structures & park furniture provide passive recreation with play equipment and potential art or sculpture located at key nodes. These spaces are commonly located with schools, special use community sites or large areas of dedicated POS. Creek line Corridor: Retention of existing vegetation and water bodies including creeks and dams where possible. New drainage basins and manicured buffer landscape treatments with turf & temporary irrigation works to native garden beds. Walking trails, signage, resting nodes with park furniture and potential bike trails are proposed.	95,435	7,635	103,070	43,210	10,306.98	3,092		20,907.33	25,553	- 0	17,248.54	15,680
OTHER													
SPECIAL SITE	**High Level::** Possible Community Facility such as Cidery. Irrigated turf, garden beds & trees with paths and park furniture.	8,753	700	9,453	1,645	105.04	473		3,615.27	3,615	-	2,440.31	2,711
ANG-SCH	**Medium - High Level:** Senior School oval retained Additional 1.Ha general landscape treatments for school interior included.	31,400	-	31,400					25,400.00	6,000		4,050	19,050.00
ROLAND RD STREETSCAPE	**Key Streets, High Level :** Retained Trees, possible verge swale Irrigated garden beds and large trees planted.	-	7,295	7,295	1,440	729.50	365		-	2,380.38	2,380	1,607	
STREETSCAPES	**Key Streets, High Level :** Boulevard treatments with hard treatments, Irrigated turf, garden beds, large trees.	-	63,550	63,550	-	6,355	6,355		15,252.00	20,972	9,744	36,223.50	
STREETSCAPES	**Secondary Streets, Medium Level :** Temporary Irrigated garden beds, 100Ltr trees.	-	50,020	50,020	-	5,002	5,002		-		37,015	-	
ENTRY AREAS	**High Level :** Signage and Sculpture with temporary Irrigated turf, garden beds, large trees.	-	-	-	-	-	-		-	-	5,790	-	
	SUB TOTAL	1,633,773	255,149	1,888,922	1,113,905	83,364	246,758		165,829	157,633	119,350	162,309	75,334
	SUB TOTAL (Ha)	163.38	25.51	188.89	111.4	8.3	24.7		16.6	15.8	11.93		
	SUB TOTAL (ML)										119	162	75

Appendix G

Stoneville Wastewater Servicing Concept Design Assessment

NORTH STONEVILLE WASTEWATER SERVICING

CONCEPT DESIGN ASSESSMENT



Prepared for

Satterley Property Group

May 2019

PROPRIETARY AND CONFIDENTIAL INFORMATION

The attached document contains proprietary and confidential information and is submitted under a confidential relationship for the purpose defined below.

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This report has been prepared in consultation with Permeate Partners

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1 EXECUTIVE SUMMARY

The purpose of this report has been to further develop the wastewater servicing scheme for the proposed subdivision of Lot 48 Stoneville Road and Lot 1 Roland Road in Stoneville. The key findings of the investigations undertaken by Water West are presented below.

- The optimal approach to ensure the North Stoneville project can be serviced with or without the inclusion of the potential subdivision of the new Parkerville townsite is to construct one (1) recycled water plant (RWP) in a staged manner which enables the RWP to be expanded if Parkerville proceeds, without materially impacting on the cost of construction or operation of the overall RWP scheme for the North Stoneville project as a discrete, or stand-alone, concept.
- The preferred location of the RWP and storage dams is in the north-west of the estate, with direct access from Cameron Road.
- Management of the recycled water produced via the RWP from the collection of wastewater from each of the North Stoneville and Parkerville subdivisions should be undertaken on-site within each of the North Stoneville and Parkerville estates, with the volume of recycled water to be managed (i.e. storage and disposal) within each estate being proportional to the wastewater generated by each estate.
- There is sufficient recycled water generated by the North Stoneville estate across the year to meet the irrigation requirements for the proposed open space areas within the North Stoneville estate.
- Storage of recycled water will be required in winter in order to meet the “summer” irrigation demands of the open space areas.
- Management agreements will be required between Water West and the relevant party responsible for managing the open space (e.g. public open space, school ovals, wetland) to ensure the recycled water is irrigated as required by Water West in order to maintain the integrity of the water balance.

2 Introduction

Satterley Property Group proposes to undertake subdivision of Lot 48 Stoneville Road and Lot 1 Roland Road, Stoneville, in partnership with the land's owner, the Perth Diocesan Trust and together, the "Developer".

The land is zoned Urban under the Metropolitan Region Scheme and requires further planning approvals in the form of a Structure Plan and Subdivision, prior to creation of first lot Titles which is anticipated to occur in early 2020.

The key constraint to previously obtaining planning approvals for the subdivision of the land was the absence of a wastewater servicing solution. Satterley Property Group has engaged Water West to address wastewater servicing of the land and Water West's previous desktop investigations of the proposed project indicated that Water West could deliver a solution that was technically and commercially feasible.

The servicing approach previously identified by Water West is still considered to be the optimal solution for the proposed subdivision and is based on the on-site tertiary treatment of wastewater (via a recycled water plant – "RWP") and the re-use of recycled water to meet irrigation demand.

This report has expanded upon the previous preliminary investigations undertaken by Water West, by considering in significant detail the water balance for the project based on the current subdivision concept of ~1,400 residential plus commercial uses and two (2) schools. The water balance has been used to develop a number of scenarios for managing the recycled water generated by the RWP, including irrigation of open space and storage.

The results of the above are presented in the following sections of this report and are intended to form the basis for progressing to the next stage of detailed design, approvals, construction and the final commercial agreement between Water West and the Developer.

Figure 1 – North Stoneville Aerial

3 Inclusion of Parkerville Subdivision

Previous discussions have been undertaken with Satterley Property Group regarding the opportunities/issues of including the future Parkerville estate in the concept planning for the North Stoneville estate.

There is uncertainty at this time as to whether the Parkerville estate will proceed and if so, the timing of subdivision commencement and how many lots would be created per year.

Water West's view is that should both projects proceed, operational optimisation would be achieved through one (1) RWP only.

Consequently, the approach taken for this report has been to develop a wastewater scheme that focuses on North Stoneville only, but which makes allowance for the inclusion of Parkerville, without additional cost or land-take for the North Stoneville project.

The design philosophy adopted has therefore been:

- Only one (1) RWP is constructed and that this is at North Stoneville
- The RWP be designed to enable construction in three (3) stages (treatment plant only), with two (2) stages dedicated to North Stoneville and one (1) stage to Parkerville
- Winter surplus recycled water generated by the Parkerville estate be stored in dams on the Parkerville estate and/or otherwise disposed of within the Parkerville estate
- Raw sewage and recycled water conveyance pipes be constructed between the Parkerville estate and the RWP at North Stoneville, the costs of which will be the subject of a commercial agreement between the Parkerville developer and Water West

4 North Stoneville Estate Development Assumptions

The findings outlined in this report are based on the lot yield, lot size and public open space assumptions adopted from the North Stoneville Masterplan prepared by Roberts Day Group and dated 15 November 2018.

The Masterplan is included as Figure 2 on the following page. The Plan E irrigation plan is included as Figures 3 on the following pages.

Commentary regarding the Parkerville estate is provided elsewhere in this report; for relevance, a lot yield of 750 lots was adopted and no assumptions have been made as to the area proposed for public open space within the estate nor to available areas for excess recycled water storage or disposal.

4.1 Residential Lot Yield

Table 1 summarises the residential lot yield and lot type assumptions:

Table 1 - Lot Yield and Type

Lot Type	Lot Size Range	Number of Lots
T1	> 2.0ha	60
T2	800m^2-2,000m^2	1,100
T3	350m^2-800m^2	200
T4	<350m^2	50
Total		1,410

An assumption of 2.8 persons per dwelling has been adopted in the report and it is assumed that all lots are single-dwelling lots.

4.2 Open Space Irrigation Area

Irrigation of open space areas with recycled water has been assumed to occur in various locations throughout the estate in accordance with the Plan E POS Typologies plan contained in Figure 3.

The total irrigation area is 34ha.

The water balance has assumed an average irrigation rate across the 34ha, although it is anticipated that some open spaces such as playing fields will have higher irrigation rates than other open spaces. Given the estate will be developed on a stage-by-stage basis over ~15 years, there will be an opportunity to massage the storage and delivery of the water balance in accordance with more detailed irrigation planning as the subdivision of the estate progresses.

Earlier versions of the North Stoneville Masterplan proposed less POS available for irrigation (now 34ha) which in turn required a different approach to managing the annual water balance for the site; specifically a portion of residential lots being provided an allocation of recycled water for outside irrigation and the concept of sending a small amount of recycled water to a constructed wetland once a year every 3 to 5 years depending on seasonal/rainfall variations. Given the POS available for irrigation has now been increased to 34ha, no recycled water will be provided for residential irrigation and no recycled water will be sent to a constructed wetland. All of the recycled water will be solely used for POS irrigation.

Figure 2 – North Stoneville Masterplan

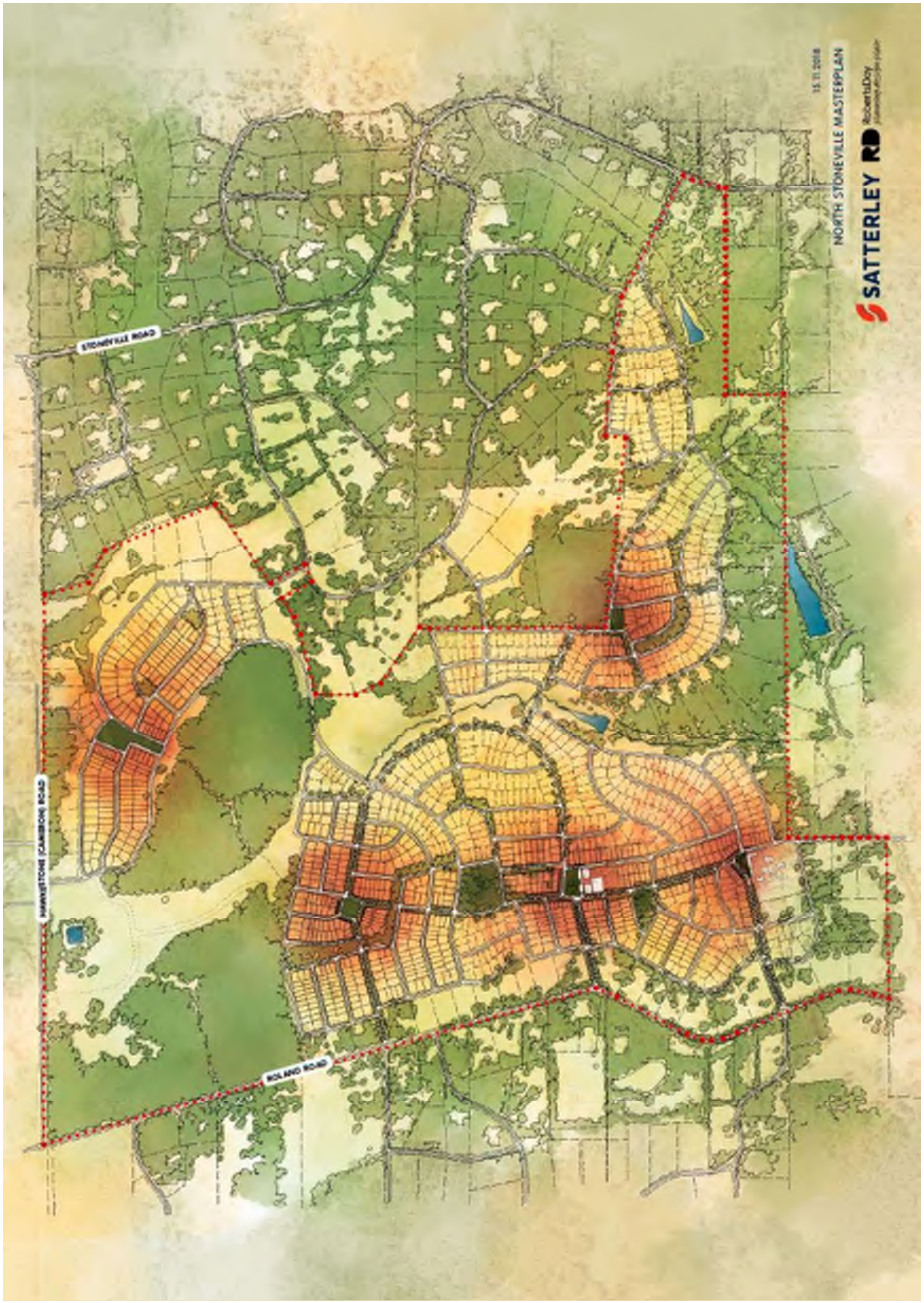
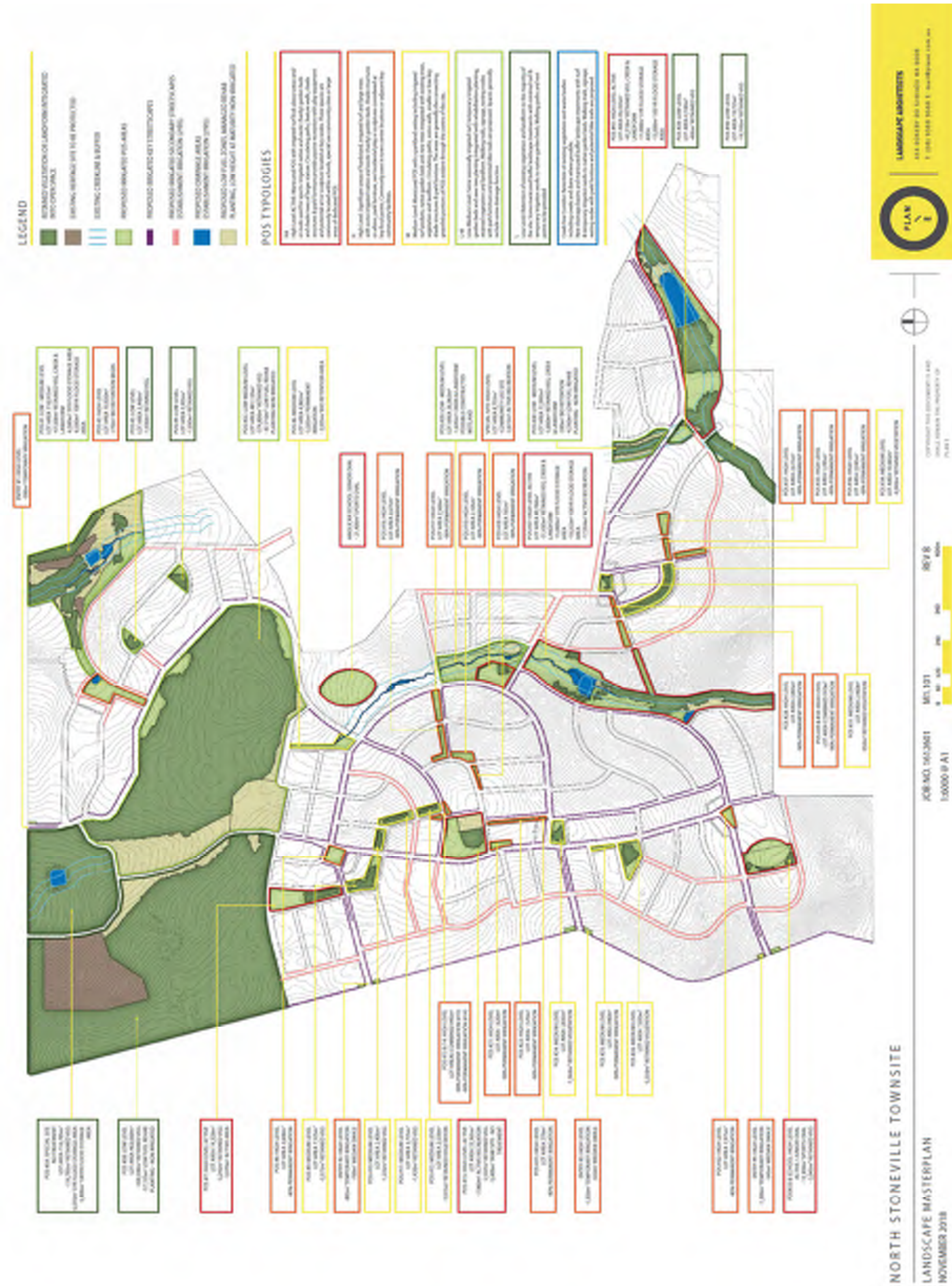


Figure 3 – Landscape POS Typologies



5 WATER BALANCE AND RECYCLED WATER MANAGEMENT

5.1 Overview

Preparing the water balance for the project was the essential first step to determine:

1) the design requirements for the RWP; and,
2) the amount of recycled water available for POS irrigation within the estate.

Specifically, the assumptions and findings of the water balance, which are detailed below, have driven the key design elements of:

- RWP site area requirements;
- RWP technology sizings (e.g. number of membranes, size of concrete bioreactor, etc.);
- open space irrigation rates; and
- size of winter surplus storage dams;

The water balance is sensitive to the driving assumptions of how many lots are being serviced and how many persons per lot (or, per dwelling - ppd) will be characteristic of the estate; number of persons drives the wastewater generated (the water balance is based on 165 litres/person/day of wastewater generated).

The analysis has been undertaken on the assumption of 2.8ppd and ~1,400 lots for the North Stoneville estate. The assumed lot yield for the Parkerville estate is 750 lots.

The water balance is also sensitive to soil composition and annual rainfall assumptions as both these assumptions drive how much water can be applied to public open space, other open space and/or passed through a wetland; there is a limitation as to the quantity of nutrients that can be sent to the "receiving environment", therefore either volume of recycled water irrigated is set at a maximum or the quality (nutrient "loading") of recycled water is amended (via further treatment).

Notwithstanding the assumptions detailed above, there will be an opportunity to analyse real data (e.g. actual household size and irrigation demand) once the subdivision of the estate is underway and adjust future RWP staging/capacity, storage and irrigation areas accordingly. Similarly, capacity/irrigation can also be adjusted to cater for a revised lot yield of approximately +10% with certain operational attenuations to the plant operation.

The information and the assumptions used to prepare the water balance are detailed in 2.

Table 2 – Water balance assumptions

Parameter	Unit	Value	Comment
Stoneville number of lots	-	1410	Information provided by Developer
Parkerville number of lots	-	750	Information provided by Developer
Equivalent persons per lot	EP/Lot	2.8	Accepted standard based on similar communities
Sewage flow	L/EP/day	165	Accepted standard based on similar communities.
POS Irrigation Area	Ha	32.4	Irrigable area in community nominated by the Developer
Design Peak Daily Flow (PDF)	ML/day	N/A	Dictated by the approach for sewer extraction. Design will allow for short periods of higher flow to accommodate fluctuations in demand or process upsets.

Irrigation rate – Active POS	ML/Ha/yr	7.5	Irrigation rates supplied by Plan E
Irrigation rate – Passive POS	ML/Ha/yr	6.75	Irrigation rates supplied by Plan E

When the North Stoneville estate is fully developed, the RWP will generate 237ML of recycled water per year. The open space layout within the Masterplan has been designed to absorb 237ML of irrigation water at standard irrigation rates.

Given irrigation demand is not constant across all months, 84ML of storage in dams (recycled water dams) will be provided to cater for lower irrigation demand in cooler/wetter months (e.g. winter) and higher irrigation demand in warmer/drier months (e.g. summer). Irrigation of POS will gradually draw down on this 84ML storage volume across spring, summer and autumn.

Two recycled water dams will be constructed (total 84ML). The second recycled water dam will not be constructed until the townsite has reached approximately 50% subdivision; if it has become apparent during the early stages of subdivision and operation of the first recycled water dam that volume/storage requirements are greater than currently forecast, the design of the second dam can be revised to cater for an increased volume. Additionally, once the second dam is completed and the subdivision of the townsite has reached – or is close to reaching – full completion and further storage is deemed necessary, the site has sufficient land area available for additional storage to be constructed.

The water balance of the recycled water will be managed across the irrigation season (generally September to May) to ensure required irrigation rates are met (e.g. December to March are forecast to require higher irrigation rates than the "shoulder" seasons). If, by March/April, there is a higher volume of recycled water remaining in the storage dams than forecast, scheduled irrigation rates during these months (and into May) can be adjusted to ensure the remaining recycled water levels of the dams are sufficiently low to cater for winter collection and storage (when there is little to no irrigation demand). The volume of recycled water being stored/irrigated on an annual basis does not change.

The water balance has been completed for the North Stoneville development only. The results can be assumed to be proportional for Parkerville. As previously noted, the preferred approach where the RWP is sized to cater for the Parkerville estate is for Parkerville to undertake all of its recycled water management on its own site – i.e. be it 3rd pipe, winter storage dams, constructed wetland or a combination of these.

6 RECYCLED WATER PLANT

All wastewater produced from the North Stoneville estate will be processed through an on-site recycled water treatment plant (RWP). The recycled water produced by the RWP will be treated to a fit-for-purpose standard that will facilitate re-use within the estate for irrigation of public open space.

6.1 Location and Access

The RWP will be located in the north-west of the estate, in line with direction from Satterley Property Group. The overall layout and location of the RWP is shown in Figure 5 on the following page.

This location is the site of a former quarry and has been significantly cleared of vegetation. Some additional clearing of vegetation will be required.

Access to the RWP is proposed to be from Cameron Road and will be via a sealed access road which utilises the alignment of the access track which was previously cleared for the quarry operations. Operational vehicle movements to/from the RWP will therefore be discrete from the estate. Investigations with the Shire as to approval for access to Cameron Road have not been undertaken at this stage.

The boundaries of the RWP site have not been defined, however a fenced site area which incorporates the key design elements of the RWP as depicted in 5 will be required.

6.2 Tenure

The Department of Health (DoH) will require that the RWP is ultimately located on a separate freehold-titled lot which is owned by and under the control of Water West. The DoH might permit the RWP to be initially located on a defined parcel of land with leasing arrangements that provide indefinite control over - and access to - the land in favour of Water West, however this would likely only be accepted as an interim measure.

Water West recommends that a separate lot for the RWP site be created as part of the stage 1 subdivision of the estate.

Figure 4 – Pitt Town RWP, Sydney

Figure 5 – RWP & Storage Dams Site Arrangement and Access

Prepared by Permeate Partners

6.3 Design Philosophy

The RWP will be a tertiary-treatment facility utilising membrane technology and biological processes, typically referred to as a membrane bio-reactor (MBR) and similar to the facilities viewed by the North Stoneville project team at Pitt Town and Pennant Hills golf course in Sydney.

Storage of winter surplus recycled water is required, with storage in two lined dams sited adjacent to the RWP. .

6.4 Capacity and Staging

The RWP will be designed to service the current forecast flows of ~650kL/day generated by the North Stoneville project, with the option to further expand capacity by ~350kL/day to cater for the Parkerville estate in the event the Parkerville project proceeds.

Given the total wastewater generation of both projects approximates to a split of two-thirds (2/3) for North Stoneville and one-third (1/3) for Parkerville, the RWP will be designed to enable construction in three stages (or modules). This allows for three scenarios:

1) Parkerville never proceeds, or proceeds but with its own RWP – only stages 1 and 2 of the RWP are constructed;
2) Parkerville proceeds, but only after North Stoneville is fully subdivided – stage 3 of the RWP is constructed when needed;
3) Parkerville proceeds concurrently with North Stoneville –stage 3 is constructed when the combined wastewater generation from both estates reaches the treatment capacity for stages 1 and 2.

There will be initial works that will need to be undertaken irrespective of whether stage 3 is constructed; these include civil works for the RWP site area, services (power and water), RWP building and control room and access (to both Cameron Road and around the RWP).

6.5 Layout

The proposed location of the plant has been selected in consultation with the project team. The concept design has been developed to optimise the footprint of the overall plant whilst ensuring the plant is accessible and maintainable.

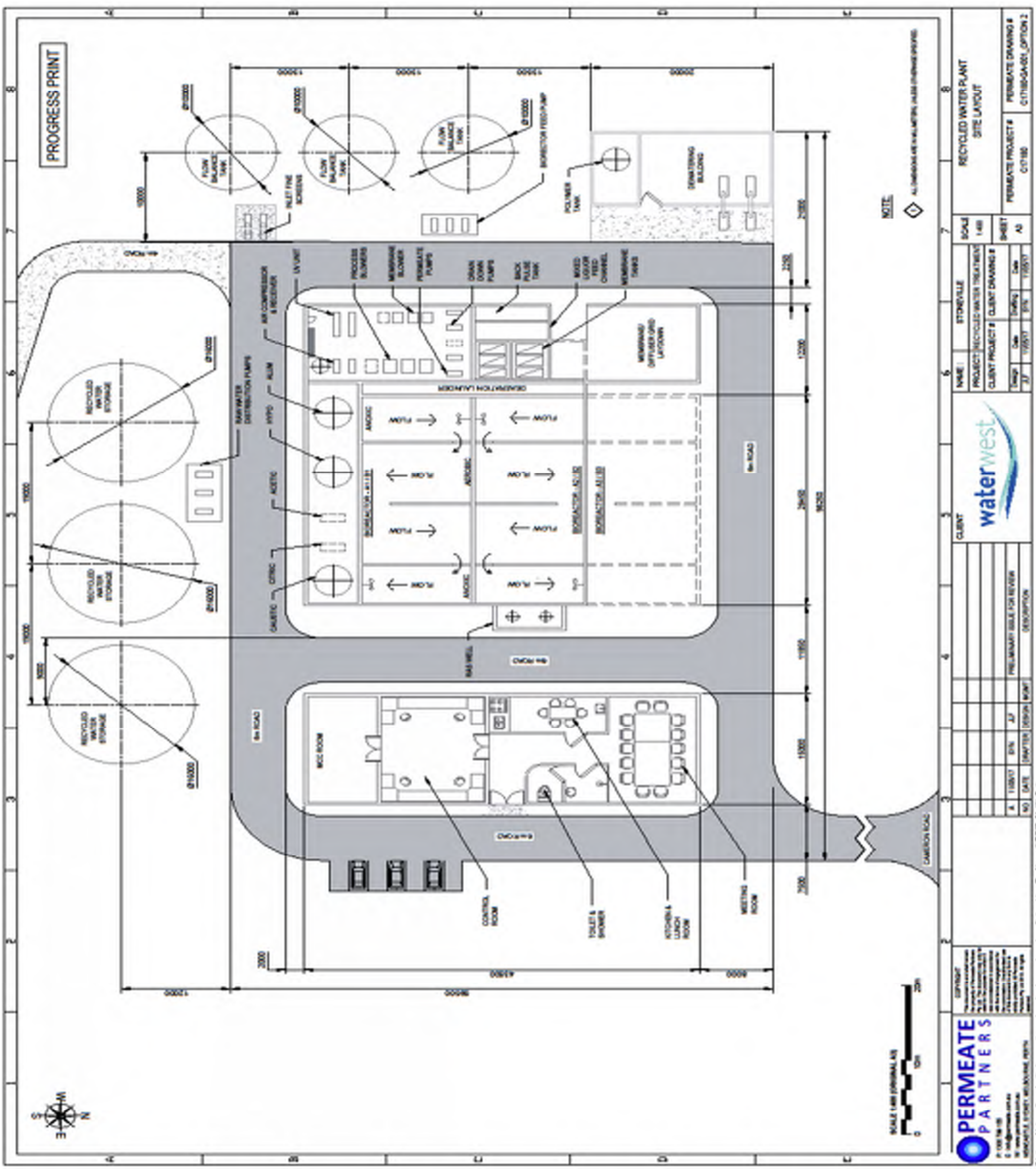
The land proposed for the RWP slopes from RL 300m AHD at the south-west corner to RL 280m AHD at the north-east corner. The RWP will be located on a levelled pad with plan dimensions of approximately 140m by 120m. Earthworks for this pad will therefore require excavation of up to 10m at the western end and fill placement of 1m to 2m at the north-east corner to form a level pad at design level. Estimated volume of cut is 14,100 bcm and the estimated volume of fill is 36,300 bcm.

The proposed RWP layout is shown in Figure 6.

As detailed in section 6, the majority of the RWP elements are designed for construction in three (3) stages – e.g. recycled water storage tanks, bioreactor, membrane units, flow balance tanks.

Elements such as control room, hardstand (access/parking) and building which need to be constructed at the commencement of the scheme, will be required irrespective of a two (2) stage RWP or a three (3) stage RWP (noting there may be some extra costs for these elements by initially designing for three stages, though these are not overly material in the context of the overall RWP design costs.

Figure 6 – RWP Plant Concept Layout



6.6 Flowsheet

The flowsheet for the proposed RWP is summarised below.

6.6.1 *Inlet Fine Screens*

All incoming sewage will pass through a set of fine screens with an aperture size of 2mm or less. This removes solids and inorganic matter from the waste stream and provides protection for the down-stream membranes. The screens are installed as duty/standby. The fine screens are connected to the odour scrubber for treatment of foul air.

The screened sewage is discharged to a Flow Balance Tank (FBT).

The screenings are discharged to a waste bin for disposal off-site

6.6.2 *Flow Balance Tank*

The FBT receives screened sewage and buffers the diurnal flows from the community to provide a relatively steady flow to the treatment plant. The FBT also provides a storage buffer should there be a reason to temporarily stop any downstream process. The FBT is equipped with a mixer to ensure the sewage stays mixed and any solids stay in suspension. From the FBT, the screened sewage is pumped to the biological reactor (bioreactor).

6.6.3 *Biological Reactor*

The bioreactor consists of a biological nutrient removal activated sludge process. The movement of the wastewater between anoxic and aerobic zones enables nitrogen and BOD (biochemical oxygen demand) reduction. Coagulant is added to assist in the removal of phosphorous.

6.6.4 *Anoxic Zone*

Raw sewage combines with the return activated sludge in the deaeration launder before entering the anoxic zone. An internal recycle also returns sewage from the end of the aerobic zone to the start of the anoxic zone. Mixers are installed in the anoxic zone to suspend the solids and provide good contact between the incoming wastewater and the mixed liquor. The anoxic zone is baffled to ensure a plug flow through the bioreactor.

Figure 7 - Bioreactor during commissioning

6.6.5 *Aerobic Zone*

The mixed liquor from the anoxic zone overflows into the aerobic zone. The aerobic zone is aerated with fine bubble diffusers installed in the base of the bioreactor. Similar to the anoxic zone the aerobic zone is baffled to encourage plug flow through the zone. The mixed liquor from the aerobic zone is either returned to the start of the anoxic zone via the internal recycle, or overflows into the RAS (return activated sludge) well, where it is pumped to the membrane tanks.

To ensure the treated wastewater quality is achieved, key process indicators for the biological reactor such as flow, dissolved oxygen (DO), mixed liquor suspended solids (MLSS) and pH are continuously monitored.

6.6.6 *Membrane Filtration*

Membrane filtration will be used to separate the treated wastewater from the MLSS. The small pore size of the membrane results in the rejection of solids and pathogens at the membrane surface whilst treated water passes through.

Membrane permeability is maintained by:

- Aeration at the base of the membranes to dislodge solids from the membrane surface.
- Periodic relaxing and/or backpulsing of the membranes.
- Periodic chemical cleaning of the membranes.

The permeate pump operates based on biological reactor level and directs filtered water to the chlorine contact tank via the Ultra Violet (UV) disinfection units. The mixed liquor from the membrane tank is returned to the deaeration launder via an overflow. To ensure membrane filtration performance is maintained, key process indicators such as flow, trans-membrane pressure (and permeability) and permeate turbidity are continuously monitored.

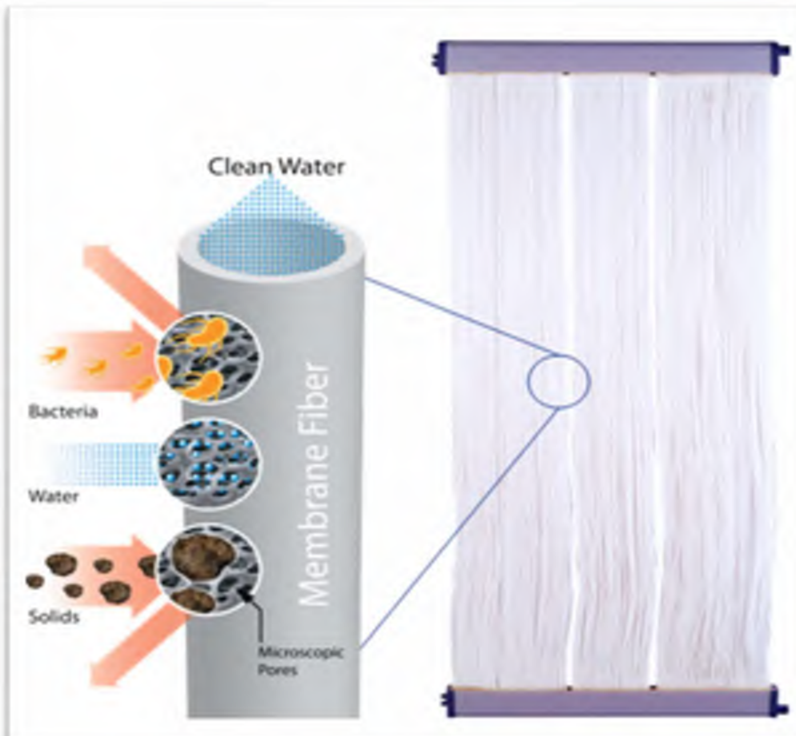


Figure 8 – Membrane Process

6.6.7 *UV Disinfection*

Permeate from the membranes is pumped directly through a UV system to provide an additional disinfection barrier. UV light inactivates pathogens by disrupting their genetic information and rendering them harmless. The UV disinfection system will be installed N+1 to match the plant capacity. UV transmissivity and intensity are continuously measured online to ensure the appropriate dosage is applied.

6.6.8 *Chlorination*

The permeate from the UV system is discharged to the chlorine contact tank where it is dosed with sodium hypochlorite to provide chlorine disinfection. The chlorine contact tank is baffled to ensure plug flow and the appropriate contact time is achieved. Treated water from the discharge of the chlorine contact tank is then pumped to the recycled water storage tanks.

Instrumentation installed at the end of the chlorine contact tank measures the residual free chlorine and controls the dosing rate of the pumps. Dosing pumps for the chlorine contact tank are installed N+1.

6.6.9 *Chemical Storage and Dosing*

Various chemicals are typically required for sewage treatment, recycled water production and cleaning. These chemicals will be stored in appropriately sized tanks, taking into consideration the chemical type and consumption rates. The tanks along with the associated chemical dosing pumps will be located within separate bunded areas. The chemicals that are included in the base case design are described in the table below:

Table 3 – Chemical type and purpose

Chemical	Purpose
Alum	Used as a coagulant to precipitate phosphorous
Sodium Hypochlorite	Used for the final disinfection of the treated recycled water and for membrane cleaning
Citric Acid	Used for membrane cleaning
Sodium Hydroxide	Used to control pH in the biological process

The chemical storage tanks and dosing pumps are designed and bunded in accordance with AS3780. Storage capacity is designed for a nominal 30 days storage. Dosing pumps are installed N+1.

6.6.10 *Odour Scrubbing*

Biofiltration-based odour scrubbing systems are proposed to treat foul air from the inlet screens and the plant sump.

The biofilters are packed with customised media to biologically oxidise the odorous gases in the foul air stream and achieve an H_2S removal efficiency of >99%. Mist sprays in the biofilter ensure the correct level of humidity is achieved at all times within the system.

6.6.11 *Recycled Water Storage and Distribution*

The recycled water storage tanks (as opposed to the storage dams) provide a buffer between the recycled water production and recycled water supply to the community.

A distribution pump set has been included for distribution of the recycled water to the network. Distribution pumps are installed in an N+1 configuration.

Figure 9 – Recycled water storage tanks at Pennant Hills, Sydney

The storage tanks are included for storage of excess recycled water during periods where the production of recycled water is greater than the demand. A pump station has been included to transfer the water from the dam back to the RWP for re-processing prior to distribution.

6.6.12 *Sludge Dewatering*

Waste activated sludge (WAS) from the RWP will be dewatered for disposal. The dry solids are disposed off-site whilst the centrate is returned to the process. A centrifuge system with accompanying polymer dosing system has been included in the concept design.

6.7 Storage Dams

The water balance for the North Stoneville project reveals that there will be a need to store recycled water over winter to meet irrigation requirements for public open space in spring, summer and autumn.

The minimum storage requirement to meet POS irrigation demand is estimated at 84ML.

Figure 10 – Aerial view of Royal Melbourne Golf Course 40ML Recycled Water Storage Dam

Water West considers the optimal location for the storage dams is adjacent to the RWP, on the site of the former quarry.

Figure 5 details the proposed location of the storage dams and presents a design based on two (2) dams of ~40ML in size. The final dam configuration – and the storage options discussed in this report – may vary in design/size from the notional layouts presented in Figure 5.

The dams will be lined with high-density polyethelyne (HDPE) which has high durability and is highly resistant to UV exposure and penetration. Whilst no compromise of the integrity of the liners is anticipated, it is worth noting that the water levels will have real-time water level moniors installed as part of standard operations to assist with the POS irrigation regime and therefore any irregularity in water level changes will be quickly identified, allowing short-term remediation of a breach to the integrity of the liners.

Reconfiguration of storage design has been discussed in section 5.1.

Figure 11 – Ground view of Royal Melbourne Golf Course 40ML Recycled Water Storage Dam

6.8 Raw Sewage Characteristics

For the infrastructure design, the raw sewage characteristics have been assumed to align with typical residential sewage characteristics. The design range for the sewage characteristics are summarised in Table 4 below.

Table 4 – Raw sewage characteristics

Parameter	Unit	Value
5-day Biological Oxygen Demand (BOD_5)	g/person/day[1]	75
	mg/L	307
Total suspended solids (TSS)	g/person/day[1]	75
	mg/L	307
Total Nitrogen (TN)	g/person/day[1]	19
	mg/L	78
Total Phosphorous (TP)	g/person/day[1]	4
	mg/L	16
Total dissolved solids (TDS)	mg/L	<2,000mg/L
pH	-	6.0 to 9.0

6.9 Treated Water Characteristics

The treated water characteristics are presented in *Table 5*.

Table 5 – Treated water characteristics

Parameter	Unit	State	National	Design
5-day Biological Oxygen Demand (BOD_5)	mg/L	<10	-	<10
Total suspended solids (TSS)	mg/L	<10	-	<10
Total Nitrogen (TN)	mg/L	-	-	15
Total Phosphorous (TP)	mg/L	-	-	3-5
pH	-	6.5-8.5	-	6.5-8.5
E.coli	cfu/100mL	<1	<1	<1
Clostridium perfringens	cfu/100mL	<1	-	<1
Somatic coliphage	pfu/100mL	<1	-	<1
Log removal - Bacteria	-	-	≥5	≥5
Log removal – Protozoa & Helminths	-	-	≥5	≥5
Log removal - Viruses	-	-	≥6.5	≥6.5
Free chlorine residual	mg/L	0.2-2.0	-	-
Turbidity	NTU	<2 95%ile <5 100%ile	-	<0.3
Alkalinity	mg/L	-	-	<50

6.10 Temporary/Interim RWP

Water West initially considered the option of a temporary RWP for the first stages of the estate however given the proposed lot creation rate, the limitations on the capacity of a temporary RWP would have required construction of the permanent RWP within three (3) to four (4) years of the creation of the Stage 1 subdivision of the estate. The benefit from deferring capital expenditure on the permanent RWP for this period of time was not considered to outweigh the additional capital expenditure required for the temporary RWP.

If a temporary RWP was to be pursued, the optimal location would have been on the same site as a subsequent permanent RWP. There would therefore be works common to both the temporary and permanent plants, notably access, site works and wastewater/recycled water pumps/distribution, thereby requiring some of the capital expenditure required for the permanent RWP to be undertaken in any event.

7 Sewer and Recycled Water Reticulation Networks

7.1 Sewer Reticulation Network

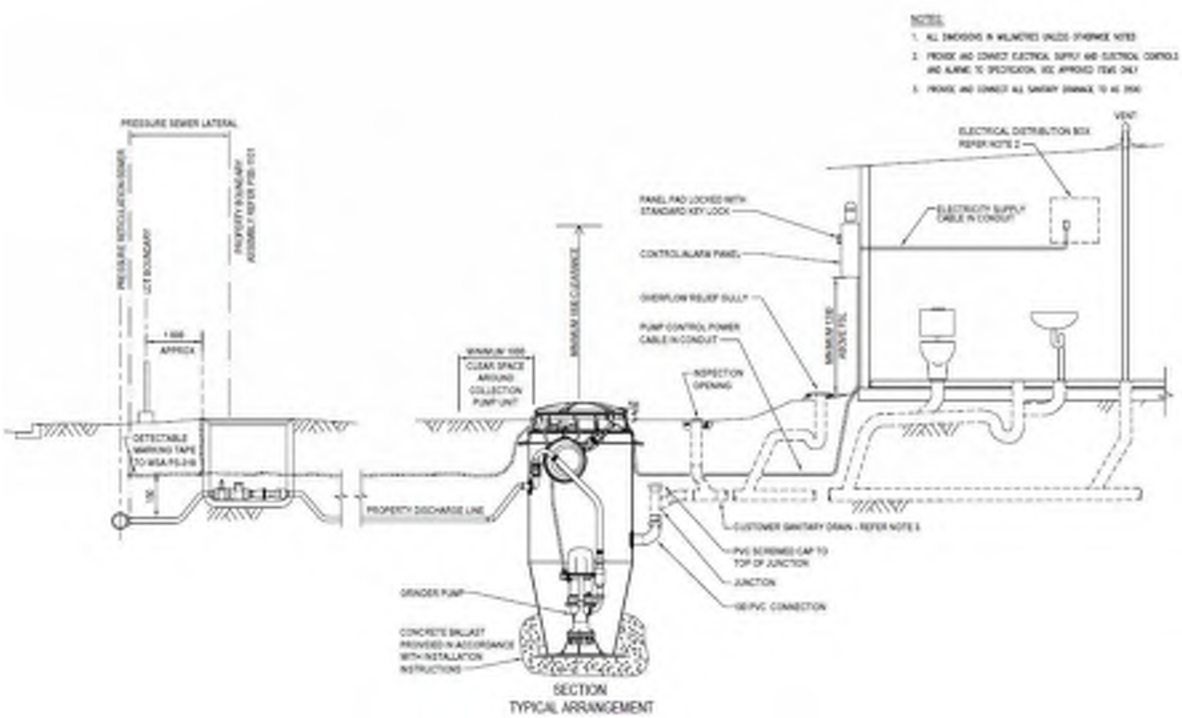
Pressure sewer is the preferred option for North Stoneville given the unknown, though likely significant, amount of rock that may be encountered if deep trenching of a gravity system was undertaken.

A pressure sewer system will provide the following benefits to the North Stoneville project:

- can be constructed at a consistent depth below the finished subdivision level, thereby eliminating deep trenching;
- avoids wet weather infiltration reducing overall hydraulic treatment capacity requirements, thereby also minimising the potential for excess sewage and / or recycled water during wet weather events;
- assists in minimising contamination risks through improved contaminant traceability back to the lot owner;
- enables tracking of individual household sewer production via system telemetry.

Most conventional wastewater treatment facilities have an option to bypass raw sewage during extreme wet weather events directly to the point of discharge (i.e. river or ocean). Given the North Stoneville project needs to be self-contained in terms of treated wastewater (recycled water) management, it is best if extreme wet weather flows are avoided as these are likely to directly add to the costs of the storage dams (greater storage area required) and/or alternative disposal mechanisms such as a constructed wetland or subsurface irrigation.

Figure 12 - PSS On-property Typical Arrangement (Extracted from WSA-07, drawing PSS - 1101)



Water West will ultimately own and maintain the sewer reticulation network. Water West and the Developer will need to confirm the approach for handover of the asset; this detail can be further discussed during the structure planning phase of the project.

7.2 Recycled Water Reticulation Network

A distribution network for the recycled water will be required in selected parts of the estate.

It has been assumed that recycled water will be provided to selected public open space and school ovals.

A distribution system inclusive of pipes and booster pumps will need to be constructed between the RWP and these locations. Given the conceptual stage of the design and project decision making process, Water West has not undertaken an analysis of infrastructure requirements, alignments or costs. This will need to be undertaken during the structure planning phase of the project and will be reliant on inputs from the project engineer, landscape architect and possibly the irrigation consultant.

The Developer will be responsible for the design, construction and delivery cost of the recycled water network.

Water West will ultimately own and maintain the sewer reticulation network.

8 RECYCLED WATER DISPOSAL – OPEN SPACE AND ENVIRONMENTAL

Disposal of the recycled water produced by the RWP is an essential component of the overall wastewater scheme and must be carefully managed to ensure the water balance is maintained across the year. Whilst there is some leeway in the design of the scheme to allow for monthly and seasonal variances, it is essential to the integrity of the scheme that the nominated disposal areas take the recycled water when required.

Given these areas will be located on land which will likely not be under the ownership of Water West, appropriate management agreements will need to be in place to ensure Water West has the ability to manage recycled water disposal as required. Further consideration of the form of these agreements will need to be undertaken during the structure planning process.

Further discussion in regard to the identified options for recycled water disposal is provided in the following sections.

8.1 Public Open Space and School Ovals

The assumptions as to how much public open space and school ovals will be available for irrigation was detailed in section 5. There will be the opportunity to adjust the water balance storage approach as the estate is progressively subdivided.

Given establishment of public open space per subdivision stage will typically precede recycled water availability (i.e. wastewater flows from lots will be required to generate the recycled water), consideration could be given to pumping water from the existing farm dam at Cameron Road (which is not lined and loses its volume through seepage across summer) and storing this in the lined RWP storage dams, thereby increasing the volume of water available for public open space establishment (and civil works dust suppression). The storage dams will have excess capacity until the estate is fully built out.

Water West understands the Developer will be responsible for establishment of the public open space and for the initial years of maintenance and that after an agreed time period, maintenance of the public open space will pass to the Shire.

The design of the irrigation system (e.g. surface or subsurface) should be determined during the structure planning phase in collaboration between Water West and the project team. The system will need to be designed to ensure low maintenance/replacement requirements whilst also providing a high level of reliability for irrigation of recycled water when required.

The cost for installation and maintenance of the irrigation system in the public open space will be by the Developer as per standard industry practice and future maintenance will be the responsibility of the Shire of Mundaring. The cost for installation and ongoing maintenance of the school ovals will be by the relevant school authority.

Appropriate management arrangements between Water West and the party responsible for managing the public open space and the school ovals will be required. This may include, but not be limited to, the ability for Water West to irrigate these areas, within reason, as required by Water West in order to manage the estate water balance across the year.

The volume usage charge to the Developer (and eventually the Shire of Mundaring) for non-potable water provided by Water West to irrigate the public open space areas would typically be $1.00/kL, However, specific to the North Stoneville project and business case, Water West proposes offering a rebate to this charge to effect a net cost of $0.00/kL to the Developer and Shire. A charge of $1.00/kL will apply to all non-potable supplied to the primary and secondary schools in the development.

9 Scheme Infrastructure Management and Responsibility Matrix

The following table provides an overview of management and responsibility for various infrastructure components of the scheme. The designations do not necessarily imply cost responsibility.

Table 6 – Scheme Infrastructure Management and Responsibility Matrix

		Approvals	Construction/ Installation	Ownership	Ultimate Operation/ Maintenance
RWP Core	RWP Site	Water West	Water West	Water West	Water West
	RWP	Water West	Water West	Water West	Water West
	Storage Dams	Water West	Water West	Water West	Water West
RW Disposal	Public Open Space	Developer	Developer	Council	Council**
	School Ovals	School	School	School	School**
Residential 3rd Pipe	Subdivision Network	Developer	Developer	Water West	Water West
	Lot Meters	Lot Owner	Water West	Water West	Water West
	Internal Lot Plumbing/Irrigation	Lot Owner	Lot Owner	Lot Owner	Lot Owner
Wastewater	Subdivision Network	Developer	Developer	Water West	Water West
	Meter (if PSS)	Lot Owner	Water West	Water West	Water West
	Tank/Pump (if PSS)	Lot Owner	Lot Owner	Lot Owner	Lot Owner
	Internal Lot/Dwelling Plumbing	Lot Owner	Lot Owner	Lot Owner	Lot Owner

** Management agreement required with Water West

Appendix H

Interim Position Statement: Constructed Lakes - Audit

Interim Position Statement Constructed Lakes Audit

Interim position requirements	Emerge Associates response
Land use planning for drainage and water management	
Has the constructed lake been approved in regional or district planning?	The retained dams (i.e. constructed lakes) are existing surface water features.
Is the constructed lake clearly indicated on the local structure plan, subdivision application and subdivision plan?	The retained dams are shown within the LWMS and SP34.
General requirements	
If the constructed lake is proposed solely for irrigation storage, has the developer or landowner demonstrated why alternatives such as groundwater bores or tanks, are not viable options?	Retained dams will be used as they are existing, and they will initially be used for irrigation storage.
If the constructed lake is proposed as a component of the stormwater management system, is it consistent with the *Decision Process for Stormwater Management in WA*	The retained dams form an integral part of the stormwater management strategy as they provide detention storage for a significant proportion of site runoff. The stormwater management design criteria and objectives (see Section 4.3 of the LWMS) have been informed by, and align with those presented in the *Decision Process for Stormwater Management in WA* (DWER 2017).
If the constructed lake is proposed as a component of the stormwater management system, does the design demonstrate how the constructed lake will provide stormwater management benefits?	The retained dams will provide detention storage for site runoff, thereby maintaining pre-development hydrological characteristics (peak flow rates) and protecting downstream environments. Stormwater management within the large, existing storages maximises the amenity that can be achieved within the development while demonstrating site-specific design responses in line with best practise WSUD principles. It will also minimise the extent of clearing and earthworks required.
Has the developer or landowner demonstrated consideration of the local conditions when deciding whether the lake will be lined or unlined?	The dams are already constructed from local low permeability clay materials.
Water use efficiency	
Does the design minimise surface area and use other design methods to reduce water loss through evaporation?	As the dams have previously been established, existing vegetation is able to be retained which will provide initial protection from some degree of solar irradiance. The dams intersect the existing streams within the site. The dams will tie into the landscaping of the living streams and will provide an attractive community feature. This will involve revegetation of banks which will provide further sun protection and reduce evaporation.
Has a water balance calculation been provided, which demonstrates that the net loss of water will be acceptable?	On-site investigations and review of aerial imagery have determined that the dams remain inundated throughout the year. The dams are intended to be solely recharged by stormwater (as is the current regime) and will therefore have no impact on water usage.
If the constructed lake is proposed for the purpose of irrigation storage, has the developer or landowner	The use of the dams for irrigation storage is a temporary measure and will only be required for construction and

demonstrated that landscaping has been designed to minimise the amount of water required for irrigation.	initial development stages. A long term analysis of long term water uses is not relevant to the retention of the dams.
If the constructed lake is proposed for the purpose of irrigation storage, has the developer or landowner demonstrated that the volume of water in the constructed lake is consistent with the irrigation requirements?	The use of the dams for irrigation storage is a temporary measure and will only be required for construction and initial development stages. A long term analysis of long term water uses is not relevant to the retention of the dams.
If required, has the developer or landowner applied for a *Rights in Water and Irrigation* (RIWI) Act 1914 licence?	DWER have advised that a licence under the RIWI Act will not be required.
Protection of natural wetlands, waterways and other water dependent ecosystems	
Will the proposal impact on natural wetlands, waterways and other water dependent ecosystems located near to, or downstream of, the constructed lake?	The dams are pre-existing. However, all dams will need to be configured with the appropriate outlet required to provide stormwater management and some may require repair. Hydrological modelling has been undertaken to determine that the reconfiguration of dam outlets and some minor adjustments would provide the required detention storage, thereby maintaining pre-development peak flow rates and protecting receiving environments.
Have adequate wetland buffer areas and waterway foreshore areas been designated to protect any wetlands and waterways located adjacent to, or downstream of, the constructed lake?	A foreshore assessment report (FAR) has been prepared by Emerge for all streamlines within the site (see **Appendix C** of the LWMS). This assessment includes consideration of the dams, which are on-line and are therefore inherently included in the waterways. The FAR has determined the appropriate foreshore area in consideration of riparian and wetland vegetation.
Has maintenance of the hydrologic regimes of nearby and downstream wetlands, waterways and other water dependent ecosystems been adequately considered?	Hydrological modelling has been undertaken to determine that the reconfiguration of dam outlets and some minor adjustments will provide the required detention storage to maintain the existing hydrological regime and will mitigate any potential impacts to receiving environments.
Does the proposal avoid modifications to Conservation and Resource Enhancement management category wetlands?	There are no mapped geomorphic wetlands located within the site. Riparian and wetland-like areas have been identified in the FAR and will be protected within foreshore reserves.
If it is proposed to modify a Multiple Use management category wetland, has the Department of Environment and Conservation granted approval (i.e. based on the merits of the proposal)?	There are no mapped geomorphic wetlands located within the site. Riparian and wetland-like areas have been identified in the FAR and will be protected within foreshore reserves.
If required, has the developer or landowner applied for a RIWI Act permit?	N/A
If required, has a RIWI Act licence been granted, or is it likely to be granted?	N/A
Does the proposal avoid directly connecting the constructed lake to natural wetlands and waterways (e.g. via pipes, constructed channels or drains)?	The retained dams are currently situated within existing streamlines and low-lying areas and are therefore inherently connected to and integrated within existing streamlines and wetland-like areas. The existing hydrological regime will be largely maintained; some repair and configuration of dam outlets will be required to ensure that additional runoff attributable to urban development will not impact receiving environments. This will not require any major alteration of the hydrological regime nor

	additional connection to or disconnection from wetlands or waterways.
Algal and aquatic weed blooms	
Has the developer or landowner demonstrated (e.g. by modelling) that the turnover (i.e. rate of water exchange) and circulation of the constructed lake will be adequate to significantly minimise the risk of algal and aquatic weed blooms?	The dams are existing and therefore new habitat that could be susceptible to algal blooms is not being created. Notwithstanding, the design and maintenance of the dams will retain the significant depth (limiting temperature rises) pre-treatment of runoff to remove nutrients (via the WSUD measures proposed) and ongoing management would include aeration and manual removal if necessary.
Has the developer or landowner demonstrated that the water quality will not contribute to algal and aquatic weed blooms?	The dams are existing and therefore new habitat that could be susceptible to algal blooms is not being created.
Has the developer or landowner used appropriate non-structural and structural methods to maintain or treat water quality?	Yes. The LWMS proposes structural and non-structural methods to be utilised for mitigation of pollutant loading (see Section 7). Proposed structural measures include bio-retention areas (BRAs), tree pits, vegetated swales and living streams (these are discussed in detail in Section 7.2 of the LWMS).
Acid sulfate soils and iron monosulfides	
Has the developer or landowner identified whether there is a risk of acid sulfate soils (ASS) being present?	Preliminary and supplementary geotechnical investigations undertaken by Galt Geotechnics (2017) did not encounter ASS. There is no known risk of ASS occurring within 3 m of the natural soil in the surrounding area, including the John Forrest National Park, and it is therefore inferred that the site will contain a similarly low level of ASS risk. Furthermore, the features in question are pre-existing and will not require dewatering.
If ASS have been identified, are the proposed management practices consistent with relevant guidelines in the DEC's ASS Guidelines Series?	N/A
Is appropriate management proposed to minimise the risk of iron monosulfides forming in the sediments of drainage systems?	The dams are existing and therefore new areas where MBO could occur are not being created. Notwithstanding, the design and maintenance of the dams will retain the significant depth and side slopes will be revegetated to promote stabilisation and aeration (via root contact).
Has the developer or landowner demonstrated that inflow water quality (i.e. sulfate and ferrous iron) will not contribute to the formation of iron monosulfides?	The dams are existing and if MBO was going to form under the site conditions this would already have occurred if it were going to (and it has not).
Other issues considered, but not the specific responsibility of the Department (e.g. on-going maintenance, life-cycle costs, mosquitoes and midges)	
Has the developer or landowner adequately considered the requirements for on-going maintenance?	Yes. Amalgamation of stormwater detention storage within the retained dams will significantly reduce the maintenance requirement for drainage infrastructure within the site. On-going maintenance requirements have been considered and are discussed in Section 10 of the LWMS, and will be further detailed in the future UWMP.
Has the developer or landowner adequately considered the life-cycle cost of maintenance and retrofitting or replacement, including all associated infrastructure?	Yes. The landscape designs that will be developed in close consultation with the Shire will allow a more detailed analysis of future maintenance costs. These will be provided to the Shire at the appropriate time in the future.

Has the developer or landowner proposed to avoid using algicides and algistats or using them only where appropriate, for the management of algal and aquatic weed blooms?	Yes, and the approach to this will be documented in future more detailed management plans (e.g. UWMP)
Has the local government provided support for the proposal?	Yes, the Shire is supportive of SP34
Has the developer or landowner demonstrated that the design and management of the proposed constructed lake will minimise the risk of mosquitoes and midges?	The dams are existing and therefore new habitat that could provide mosquito habitat is not being created. Notwithstanding, the design and maintenance of the dams will retain the significant depth and will limit the extent of emergent vegetation in shallow water. The orientation of the dams cannot be changed as they are existing. Ongoing management of the dams and surrounds will include consideration of mosquito habitat and where relevant may include monitoring of mosquito larvae and appropriate response.

emerge
ASSOCIATES