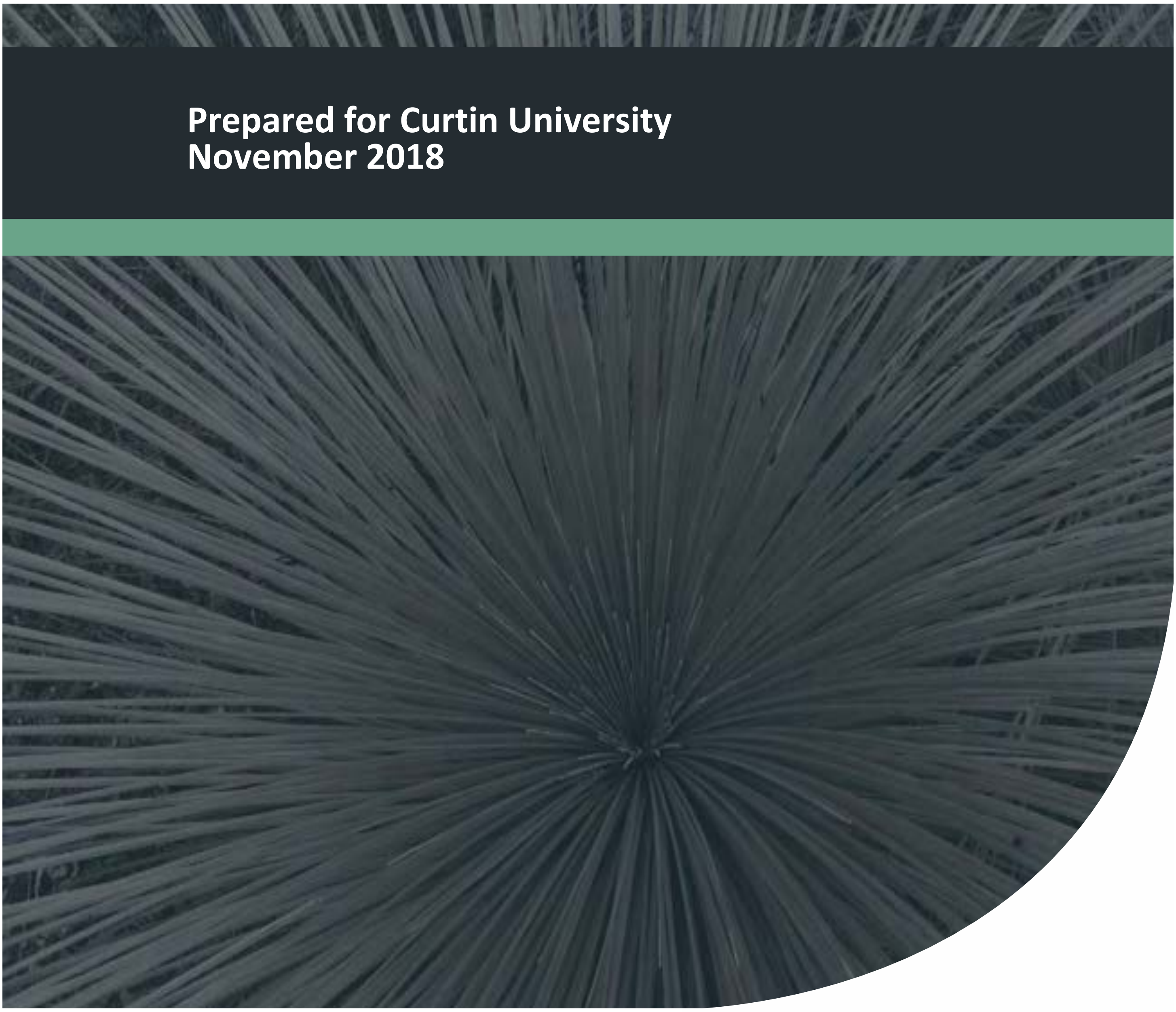
Local Water Management Strategy

Greater Curtin

Project No: EP18-089(01)



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Executive Summary

Curtin University (the proponent) proposes to progressively develop portions of their Bentley campus, located at Lot 1884 Kent Street (Plan 213723 Volume/Folio Lr3093/106) within the Town of Victoria Park (ToVP). The Bentley campus will be developed reflecting the vision detailed within the Greater Curtin Master Plan (GCMP) (Curtin University 2014).

This local water management strategy (LWMS) is intended to support the proposed land use within the GCMP development area. The LWMS has been developed in consideration of the objectives and principles detailed in *Better Urban Water Management* (WAPC 2008) and other guidelines and policies relevant to the site.

The GCMP will be implemented in four stages over the next 20 years. An LWMS which covers Stage 1 of the GCMP area was prepared by Emerge Associates (2018a), and a UWMP which covers a portion of Stage 1 has also been prepared (Emerge Associates 2018b). This document excludes this portion of Stage 1 from further consideration, however presents a consistent approach to the manner in which water is managed across the entire GCMP development area – herein referred to as the 'site'.

Water will be managed using an integrated water cycle management approach. The first step in applying integrated water cycle management in urban catchments is to establish agreed environmental values for receiving waters and their ecosystems. In summary, the environmental investigations conducted to date indicate that:

- The site receives an average annual rainfall of approximately 818 mm, with over 50% of rainfall received between May and August.
- Topography within the site ranges from approximately 4 m Australian height datum (AHD) to 22.5 m AHD.
- The site is underlain by Bassendean Sands.
- Acid sulfate soil (ASS) risk mapping indicates that the site is classified as having a moderate to low risk of ASS occurring within 3 m of the natural surface.
- Vegetation within the site has historically been highly modified, with the earliest aerial photographs showing the land being used for a plantation of pine trees. No flora listed under the *Environmental Protection and Biodiversity Conservation Act 1999* or gazetted threatened flora under the *Wildlife Conservation Act 1950* were identified during a vegetation survey conducted in 2012.
- There are no classified geomorphic wetlands within the Bentley campus.
- Surface water features on site include the University Compensating Basin and Kent Street Compensating Basin, temporary Kent Street basin, Jack Finney Lake, former Barblett Oval swale and basin, Eastern Busport basin and Stage 1 drainage infrastructure.
- Jack Finney Lake is a remnant of historical wetlands and currently receives stormwater runoff from a catchment of approximately 58.7 ha.
- The estimated MGL beneath the site ranges from 4.4 mAHD to 5.6 mAHD.
- Groundwater quality displays low to moderate total nitrogen, and elevated total phosphorous concentrations.

The general built form within the Stage 1 development lots will include new activity generators including residential and retail/commercial facilities. The site will accommodate up to 2,000 new dwellings including apartments, short stay accommodation and hotels, and halls of residence. Retail offerings will include grocery stores, cafes and general retail outlets. The commercial uses will include a small scale 'innovation incubator' and collaborative work spaces which align with the proponent's innovation and research platform. Future stages will build on the amenity provided by Stage 1 development, and will diversify the core of Greater Curtin, include alternative transport options and further establish partnerships with research and industry

The overall objective for integrated water cycle management is to minimise the use of potable water, use non-potable water resources efficiently, and prevent pollution. The design objectives seek to deliver best practice outcomes using a water sensitive urban design (WSUD) approach, including detailed management objectives for:

- Water supply and conservation
- Stormwater management
- Groundwater management.

The water management design criteria for the GCMP aims to achieve the following major objectives:

- Provide a broad level stormwater management framework to support development of the proposed Stages, which aligns with future development within Greater Curtin.
- Develop water conservation and demand management strategies for the proposed Stages that will ensure the efficient use of all water resources, and which aligns with the longer term Greater Curtin water conservation strategy.
- Maintain post development stormwater discharges to Water Corporation (WC) infrastructure to within pre-development flow rates and volumes.
- Maintain stormwater quality through passive water treatment via a swale/living stream network.
- Protect the underlying groundwater resource by actively managing groundwater use within licensed allocations.
- Improve groundwater levels and quality or at least maintain these relative to pre-development conditions.
- Gain support from the Department of Water and Environmental Regulation (DWER) for the proposed stormwater management strategy and infrastructure within the proposed Stages and immediately downstream areas.
- Gain support from the WC for the proposed scheme and waste water servicing and infrastructure approach within the proposed Stages.

The overall approach to potable water supply is to utilise scheme water and implement water conservation measures (e.g. water efficient fixtures, use of WSUD measures, and smart water metering and monitoring) to reduce water requirements. Waterwise irrigation systems will be adopted and non-potable water for irrigation purposes will be supplied by groundwater and supplemented by harvested rain- and stormwater. The use of groundwater for irrigation will be reduced after the establishment of waterwise plant species.

Stormwater management focuses on the treatment of the first 15 mm of rainfall and retention of the major (1% annual exceedance probability - AEP) event within Greater Curtin. Key elements of the WSUD approach include:

- Retention and use of existing major flood detention/retention features (Jack Finney Lake, WC assets).
- Creation of a living stream to hydraulically connect catchments to the major flood detention/retention features.
- Smaller scale WSUD approaches within catchments to minimise the amount of traditional drainage infrastructure. These will provide treatment through appropriate planting with species suitable for nutrient removal and biofilters design principles.

Groundwater management focuses on protecting finished floor levels of habitable buildings from inundation by groundwater, and maintaining groundwater quality.

Groundwater quality is maintained by reducing the total nutrient load into groundwater through use of waterwise gardening principles in landscapes areas and treatment of stormwater runoff.

The proposed design criteria and the manner in which they are proposed to be achieved are presented in **Table E1**. This table provides a readily auditable summary of the required outcomes which can be used in the future detailed design stage to demonstrate that the agreed objectives for water management have actually been achieved.

This LWMS demonstrates that, by following the recommendations detailed in the report, the GCMP is capable of being developed in a manner reflecting an integrated water cycle management approach.

Table E1: *Water management criteria and compliance*

Management aspect	Criteria number	Criteria description	Manner in which compliance will be achieved	Responsibility for implementation	Timing of implementation
Water Conservation	WC1	Reduce potable water consumption within development lots by 25% on the Green Star Design and As Built Water Calculator.	Use of water efficient fixtures.	Lot developers	Building design and post-construction
			No potable scheme water to be used for irrigation within development areas	Lot developers	Building design and post-construction
			Implementation of fault/ water leak detection.	Lot developers	Building design and post-construction
	WC2	Zero scheme water use for irrigation purposes.	Scheme water is not to be used for irrigation purposes.	Curtin University & Lot Developers	Landscape design and maintenance.
	WC3	All lot irrigation requirements will be met by fit for purpose approaches using non-potable water.	Individual lots may elect to implement a rainwater harvesting system to supply water for irrigation purposes.	Lot developers	Building design and post-construction.
	WC4	Reduce the use of groundwater for irrigation of open space and public spaces within the GCMP site over time.	Land areas requiring irrigation will be reduced with implementation of the GCMP.	Curtin University	Landscape maintenance
			Future development lots will not irrigate with groundwater	Lot developers	Building design and post-construction
			The use of soil moisture probes will determine the actual amount of water required. Irrigation rates will be adjusted.	Curtin University	Landscape maintenance
			Use of a weather station linked to the irrigation system to prevent the use of water during and following rain events.	Curtin University	Landscape maintenance
			Use of soil wetting agents to increase the adsorption of water into hydrophobic soils and therefore reduce the demand.	Curtin University	Landscape maintenance
			Use of waterwise gardening principles in all landscaped areas.	Curtin University & lot owners	Landscape design and maintenance
			Irrigation rates will be reduced following establishment	Curtin University	Landscape maintenance

Table E1: *Water management criteria and compliance (continued)*

Management aspect	Criteria number	Criteria description	Manner in which compliance will be achieved	Responsibility for implementation	Timing of implementation
Water Conservation	WC5	Water metering will be installed for all individually developed lots, with all major water users to be sub-metered, as applicable.	Installation of lot scale water meters, with sub-meters where required for major water users.	Curtin University and lot developers	Construction
Stormwater Management	SW1	Manage (retain and/or detain) stormwater runoff from impervious areas generated by the first 15 mm of rainfall within development lots at source.	At a minimum, individual development lots will retain the first 15 mm of rainfall.	Lot developers	Building design and construction
	SW2	Convey all flows above the first 15 mm rain event and up to the 1% AEP event to the living stream and swale network via appropriately sized stormwater infrastructure.	Rain gardens and informal verge/swale areas will retain the first 15 mm from road pavement where appropriate. Runoff in excess of this from road pavement will be diverted to downstream flood storage area (FSAs) (e.g. Jack Finney Lake) via the living stream or piped drainage network.	Curtin University	Drainage design
			The piped drainage network has been designed to accommodate the 20% AEP event, and the living stream has been designed to accommodate the 1% AEP event.	Curtin University	Drainage design
	SW3	Detained stormwater (first flush) should be fully infiltrated within 12 hours.	Rain gardens have been designed with a maximum depth of 300 mm. Based on the sandy conditions (described in **Section 3.2.2**), water retained in the rain gardens will fully infiltrate within 12 hours once rainfall stops.	Curtin University	Drainage design
	SW4	Appropriate pre-treatment of hydrocarbons, gross pollutants and sediment is required from carparks and any other point source development areas.	The retention of the first 15 mm in rain gardens and on lot will provide a volumetric treatment efficiency of 99.5%.	Curtin University	Drainage design
	SW5	Non-structural controls are to be implemented to improve water quality.	Non-structural measures proposed include the maintenance of WSUD features, minimised use of fertilisers in landscaped areas and the use of drought resistant plant species.	Curtin University	Drainage and landscape design

Table E1: *Water management criteria and compliance (continued)*

Management aspect	Criteria number	Criteria description	Manner in which compliance will be achieved	Responsibility for implementation	Timing of implementation
	SW6	Habitable floor levels for new developments shall be at least 300 mm above the 1% AEP flooding levels.	Detailed designs for the individual development lots will demonstrate a 300 mm clearance between habitable floor levels and 1% AEP top water levels within FSAs. This will be documented in future UWMPs.	Lot Developers	Building design
	SW7	The piped drainage network shall be designed to accommodate runoff generated during the 20% AEP event.	The piped drainage network has been (and will be for future areas) designed to accommodate the 20% AEP event.	Curtin University	Drainage design
	SW8	Stormwater runoff up to the 1% AEP will be detained and/or retained within GCMP area.	The stormwater network, including the living stream, Jack Finney Lake and minor (non-WC) storage basins have been designed to fully retain the 1% AEP event.	Curtin University	Drainage design
	SW9	Stormwater runoff flow rates for the 1% AEP to existing Water Corporation infrastructure will be maintained within current or approved levels.	Runoff modelling of the catchments that will contribute to the WC basins demonstrates that the basins will be able to accommodate the required volumes.	Curtin University	Drainage design
Groundwater Management	GW1	Finished floor levels of habitable buildings should have a minimum 500 mm clearance from MGL.	Detailed designs for the individual development lots will demonstrate a 500 mm clearance between habitable floor levels and MGL. This will be documented in future UWMPs.	Lot developers	Building design
	GW2	Inverts of flood detention and retention structures to be set at or above MGL.	The least clearance to MGL at the WC basins is the Kent Street basin which is ~ 0.4 m above MGL. The least clearance at any of the university controlled FSAs is 1.3 m, at Jack Finney Lake.	Curtin University	Drainage design
	GW3	Groundwater quality leaving the GCMP development area (downstream) shall be maintained at similar levels to the quality of groundwater entering the GCMP development area (upstream).	The retention of the first 15 mm in rain gardens and on lot will provide a volumetric treatment efficiency of 99.5% (Engineers Australia 2006).	Curtin University	Drainage design

***Table E1:** Water management criteria and compliance (continued)*

Management aspect	Criteria number	Criteria description	Manner in which compliance will be achieved	Responsibility for implementation	Timing of implementation
Groundwater Management	GW3	Groundwater quality leaving the GCMP development area (downstream) shall be maintained at similar levels to the quality of groundwater entering the GCMP development area (upstream).	Rain gardens, the living stream and Jack Finney Lake will be planted with nutrient stripping plant species to provide additional treatment to stormwater prior to infiltrating to groundwater.	Curtin University/lot developers	Landscape design
			Non-structural measures such as the maintenance of WSUD features and minimised use of fertilisers in landscaped areas will provide further treatment to stormwater.	Curtin University	Drainage and landscape design
				Lot developers	Building and landscape design

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Abbreviations Tables

***Table A1:** Abbreviations – General terms*

General terms	
ANZECC	Australian and New Zealand Environment and Conservation Council
ABS	Australian Bureau of Statistics
AEP	Annual exceedance probability
ARI	Average recurrence interval
ASS	Acid sulfate soils
BUWM	Better Urban Water Management
FSA	Flood storage area
GCMP	Greater Curtin Master Plan
HIRM	Hydraulic Infrastructure Road Map
IUWMS	Integrated Urban Water Management Strategy
IWSS	Integrated water supply scheme
LWMS	Local Water Management Strategy
MGL	Maximum groundwater level
NWQMS	National Water Quality Management Strategy
RWT	Rainwater tanks
SEPS	Sewer ejecting pumping station
TN	Total nitrogen
TP	Total phosphorous
TWL	Top water level
UWMP	Urban Water Management Plan
WELS	Water efficiency labelling and standards
WIR	Water Information Reporting
WWG	Water wise gardens

***Table A2:** Abbreviations – Organisations*

Organisations	
BoM	Bureau of Meteorology
DBCA	Department of Biodiversity Conservation and Attractions
DoW	Department of Water (now DWER)

Organisations	
DPaW	Department of Parks and Wildlife (now DBCA)
DWER	Department of Water and Environmental Regulation
ToVP	Town of Victoria Park
WAPC	Western Australian Planning Commission
WSUD	Water sensitive urban design

Table A3: *Abbreviations – units of measurement*

Units of measurement	
cm	Centimetre
ha	Hectare
m	Metre
m^2	Square metre
m AHD	Metres in relation to the Australian Height Datum
mm	Millimetre
°C	Degrees Celsius
mg/L	Milligrams per litre
mS/cm	Millisiemens per centimetre

1 Introduction

Curtin University (the proponent) proposes to progressively develop portions of their Bentley campus, located at Lot 1884 Kent Street (Plan 213723 Volume/Folio Lr3093/106) within the Town of Victoria Park (ToVP). The Bentley campus will be developed reflecting the vision detailed within the Greater Curtin Master Plan (GCMP) (Curtin University 2014).

This local water management strategy (LWMS) is intended to support the proposed land use within the GCMP development area. The LWMS has been developed in consideration of the objectives and principles detailed in *Better Urban Water Management* (WAPC 2008) and other guidelines and policies relevant to the site.

The GCMP will be implemented in four stages over the next 20 years. A portion of Stage 1 of the GCMP area was addressed in the Greater Curtin Stage 1 LWMS prepared by Emerge Associates (2018a). An urban water management plan (UWMP) was subsequently prepared to support development within a portion of Stage 1 (Emerge Associates 2018b). This document excludes this portion of Stage 1 from further consideration, however presents a consistent approach to the manner in which water is managed across the entire GCMP development area – herein referred to as the 'site'.

The location of the GCMP development are shown in **Figure 1**, and the GCMP is provided in **Appendix A**.

1.1 Planning context

The Bentley campus in its entirety has been zoned 'Public Purposes - University' under both the Metropolitan Region Scheme (MRS) (WAPC 2017) and the ToVP Town Planning Scheme No. 1 (TPS No. 1) (ToVP 2017).

The WAPC has published an *Activity Centre Structure Plan* for the Bentley-Curtin Specialised Activity Centre (WAPC 2018) for public comment. The intended role of the Bentley campus and surrounding area as described in this document is consistent with *Directions 2031 and Beyond* (WAPC 2010) and *Draft Central Sub-regional Planning Framework* (WAPC 2015).

1.2 Policy framework

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

- *TPS No. 1, Amendment #75* (ToVP 2017)
- *State Water Strategy* (Government of WA 2003)
- *State Water Plan* (Government of WA 2007)
- *State Planning Policy 2.9 Water Resources* (WAPC 2006a)
- *State Planning Policy 2.10: Swan and Canning River System* (WAPC 2006b)
- *Liveable Neighbourhoods Edition 4* (WAPC 2007)
- *Planning Bulletin No. 64: Acid Sulfate Soils* (WAPC 2009).

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 developments should aim to achieve. These are key inputs that relate either directly or indirectly to the development and include:

- *Australian Rainfall and Runoff (Engineers Australia 2016)*
- *National Water Quality Management Strategy* (NWQMS) (ANZECC 2000)
- *Australian Runoff Quality* (Engineers Australia 2006)
- *Stormwater Management Manual for Western Australia* (DoW 2007)
- *Better Urban Water Management* (WAPC 2008)
- *Developing a Local Water Management Strategy* (DoW 2008)
- *Draft Decision Process for Stormwater Management in Western Australia* (DoW 2016)
- *Swan and Canning Water Quality Improvement Plan (SCWQIP)* (SRT 2009)
- *Greater Curtin Stage One Development Guidelines* (Curtin University 2016b).

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

1.3 Previous studies

1.3.1 Greater Curtin Integrated Urban Water Management Strategy (Syrinx Environmental 2013)

The Greater Curtin Integrated Urban Water Management Strategy (IUWMS) is a high level strategy document which outlines the existing and estimated future water requirements to service the GCMP and protect environmental and public health values (Syrinx Environmental 2013), and the approaches proposed in the IUWMS relate to the entire (and future) Curtin Bentley campus. The IUWMS has been supported by DWER for the purposes of a District Water Management Strategy (DWMS) and proposed a number of water conservation initiatives at a mix of precinct and local scale. These include:

- High efficiency water appliances and efficient irrigation practices
- Rainwater harvesting and storage that may be used to supplement the scheme supply and offset potable indoor demand.
- Use of alternative water sources to satisfy or offset cooling tower water demand.
- Design new sporting fields to enable capture and recycling of irrigation water and associated nutrient loads, where possible.
- Stormwater treatment, storage, conveyance and reuse via a swale and living stream network to achieve zero discharge and become the core landscape feature through the site.
- Installation of vegetated roof top gardens along the biodiversity and public open space (POS) corridors.
- Reduce groundwater abstraction for irrigation and focused use of groundwater to restore Jack Finney Lake.

1.3.2 Greater Curtin Stage 1 Local Water Management Plan (Emerge Associates 2018)

The Greater Curtin Stage 1 LWMS was prepared for Curtin University in 2018 and outlines the strategy for supporting the proposed land use within Stage 1 of the GCMP area, being a transport oriented facility located toward the northern portion of the Bentley Campus. The strategy is based on the major objectives presented in **Section 1.4**, and the design criteria proposed in the Stage 1 LWMS have formed the basis for those proposed in this LWMS. In summary, the Stage 1 LWMS management criteria include:

Water Conservation

- Reduce potable water consumption within development lots by 25% on the Green Star Design and As Built Water Calculator.
- Zero potable scheme water use for irrigation purposes.
- All lot irrigation requirements to be met by fit for purpose approaches using non-potable water.
- Use of groundwater for irrigation of open space and public spaces within Stage 1 will be reduced over time.
- Water metering will be installed for all individually developed lots, with all major water users to be sub-metered.

Stormwater management

- Manage (retain and/or detain) stormwater runoff from impervious areas generated by the first 15 mm of rainfall within development lots at source.
- Convey all flows above the first 15 mm rain event and up to the 1% annual exceedance probability (AEP) event to the living stream and swale network via appropriately sized stormwater infrastructure.
- Detained stormwater (first flush) should be fully infiltrated within 12 hours.
- Appropriate pre-treatment of hydrocarbons, gross pollutants, sediment is required from carparks and any other point source development areas.
- Non-structural controls are to be implemented at all scales of the development area.
- Minimise risk of disease vector and nuisance insects breeding.
- Habitable floor levels for new developments shall be at least 300 mm above the 1% AEP flooding levels.
- The piped drainage network shall be designed to accommodate runoff generated during the 20% AEP event.
- Stormwater runoff up to the 1% AEP will be retained within Stage 1, the living stream, Jack Finney Lake and former Barblett Oval.

Groundwater management

- Finished floor levels of habitable buildings should have a minimum 500 mm clearance from the maximum groundwater level (MGL).
- Inverts of flood detention and retention structures to be set at or above MGL.
- Groundwater quality leaving Stage 1 (downstream) shall be maintained at similar levels to the quality of groundwater entering Stage 1 (upstream).

1.4 LWMS objectives

This LWMS has been developed in consideration of the objectives and principles detailed in the IUWMS (see **Section 1.3.1**), *Better Urban Water Management* (WAPC 2008) and the approved Stage 1 LWMS. It is intended to support the development within the GCMP, and is based on the following major objectives:

- Provide a broad level stormwater management framework to support development of the proposed Stages, which aligns with future development within Greater Curtin.
- Develop water conservation and demand management strategies for the proposed Stages that will ensure the efficient use of all water resources, and which aligns with the longer term Greater Curtin water conservation strategy.
- Maintain post development stormwater discharges to Water Corporation (WC) infrastructure to within pre development flow rates and volumes.
- Maintain stormwater quality through passive water treatment via the swale/living stream network.
- Protect the underlying groundwater resource by actively managing groundwater use within licensed allocations.
- Improve groundwater levels and quality or at least maintain these relative to pre-development conditions.
- Gain support from the Department of Water and Environmental Regulation (DWER) for the proposed stormwater management strategy and infrastructure within the proposed Stages and immediately downstream areas.
- Gain support from the WC for the proposed scheme and waste water servicing and infrastructure approach within the proposed Stages.

Detailed design criteria for water management within the GCMP development are further discussed in **Section 4.**

2 Proposed Development

The Greater Curtin Vision establishes the goal for Greater Curtin and formed the basis for the GCMP (Curtin University 2016a). The broader design principles proposed within the GCMP, as relevant to the site, are briefly described in **Section 2.1**. The GCMP development and relevant design components are described in **Section 2.2**. The GCMP is provided in **Appendix A**.

A portion of Stage 1 of the GCMP area was addressed in the Greater Curtin Stage 1 LWMS prepared by Emerge Associates (2018). The current document includes the Stage 1 area, however where any approaches present an evolution of the design approach this will not be retrospectively applied to Stage 1. Regardless of the progress of Stage 1, this LWMS presents a consistent approach to the manner in which water is managed across the remaining GCMP development area.

2.1 Greater Curtin Master Plan

The GCMP presents the broader vision and strategic framework for developing the Bentley campus and provides direction for growth, land use planning and intended development to 2031 (Curtin University 2016a). The GCMP was developed in 2013 and established a set of structuring elements to drive the future development of a cohesive, integrated public realm (Curtin University 2016b). The structural elements proposed within the GCMP, which relate to the site, are described in **Table 1**, and the GCMP is provided in **Appendix A**.

Table 1: *Structural elements of the Greater Curtin Master Plan (Curtin University 2016b)*

Element	Description
Main Street	Primarily associated within Stage 1, this will connect the two key points of arrival and activity while forming a central, organising spine and focus for Greater Curtin.
Living Knowledge Stream	The proposed stormwater management system for the GCMP has in part been guided by a broader 'Living Knowledge Stream' ideology. The Living Knowledge Stream refers to the broader design principles, which aims to integrate the local indigenous cultural and environmental heritage with a range of urban design elements to create an urban system which satisfies hydraulic and ecological requirements. A component of this will include the construction of a living stream and its use in the management of stormwater, while focusing on cultural interpretation, aquatic and ecological initiatives, water play and biophilic design. The living stream will be designed in consideration of relevant DWER guidelines (see **Section 7.4**).
The Greens	These will provide much of the open space for recreation and are divided into active sport and passive recreation areas. Where possible stormwater infrastructure will be incorporated in to The Greens.
The Links East-West	The typology of the development and facilitating activation and movement through the existing campus and the proposed GCMP area, the Links incorporate the road-verge, urban built form, and landscape creating a critical part of the water management strategy through the integration of surface flow with swales in order to reduce traditional stormwater infrastructure.
Cultural Nodes	At the intersection between the Greens, Living Stream and the Links grid, a community, educational, commercial and ecological thematic arises from the built form, leveraging opportunities for character and amenity, civic space and community infrastructure, event and play space and educative areas, and ecological corridors and canopies.

2.2 Greater Curtin Development

Development within the site will utilise the structural elements described within the GCMP to define key relationships which are fundamental to the development of place, built form and infrastructure (Curtin University 2016b). This will ensure that the connections within the GCMP are maintained as development progresses through each subsequent stage.

This LWMS has been prepared to support the development of Stage 1 through to Stage 4 and associated infrastructure. The development Stages have been documented in the GCMP document, (included in **Appendix B**) and described briefly in the following sections.

A number of 'activity generators' are currently under development. These include the existing academic neighbourhood, Curtin Stadium and sporting facilities upgrades and the bus interchange. The stadium and bus interchange are located within Stage 1. Under the control of the *Greater Curtin Stage One Development Guidelines* (Curtin University 2016b), the built form within Stage 1 will house new activity generators including residential and retail/commercial facilities.

2.2.1.1 Stage 1

Stage 1 will accommodate up to 2,000 new dwellings including apartments and student accommodation. These will be centred on development lots F01 to F04 (student accommodation), F05 to F06 (university education) and F07 (apartments, short stay, retail/commercial). The retail and commercial uses within Stage 1 will primarily be located in Lots F04 - F06 and F11. Retail offerings will include grocery stores, cafes and general retail outlets. The commercial uses will include a small scale 'innovation incubator' and collaborative work spaces which align with the proponent's innovation and research platform.

In total, Stage 1 is comprised of eight development lots, with six further lots slated for future development (Curtin University 2016b).

2.2.1.2 Stage 2

Stage 2 is described in the GCMP (Curtin University 2014) and is proposed to be developed in six to 10 years. It diversifies the core of Greater Curtin; further defining the Main Street as a central spine framed by commercial and community development. Key east-west bands of development are established, extending the traditional academic core, blurring the boundary between city and university, framing key parkland and strengthening the ceremonial heart.

Increased residential development is intended to Greater Curtin's population and supports the expansion of the indoor sporting centre. Key parking structures will be delivered; further unlocking redevelopment potential and supporting a movement hierarchy that prioritises people over cars.

2.2.1.3 Stage 3

Stage 3 is described in the GCMP (Curtin University 2014) and is planned for years 11-15. Stage 3 will further extends east-west bands of development, framing key streets and parkland. In the southern portion of the site, the southern transit node is augmented with the establishment of a strong arts and research presence.

The delivery of additional parking structures liberates further land for redevelopment. A light rail stabling facility will be delivered which provides the opportunity to further establish partnerships in research and industry.

2.2.1.4 Stage 4

Stage 4 is described in the GCMP (Curtin University 2014) for years 16-20. Stage 4 augments the diversification of Greater Curtin's residential population, with the establishment of a variety of living options throughout the city. Additional office commercial and retail development is proposed to be added to Main Street and a community hub will be created around the resources and chemistry research hub.

2.2.2 Living environment

The living environment proposed for the GCMP illustrates Curtin's commitment to the establishment of coherent, adaptive and integrated strategies for the development of a sustainable infrastructure network. The key features of the living environment include water sensitive urban design (WSUD), acknowledgment and understanding of cultures past and present, and acknowledgement of the dual botanical heritage (remnant vegetation associated with the Swan Coastal Plain and historic pine plantation) (Curtin University 2016b).

The living environment features which are relevant to this LWMS are associated with the approach to WSUD. The particular WSUD features proposed include:

- Rain gardens sized to retain runoff from minor rainfall events within road reserves.
- Localised infiltration from roof areas. This will occur within soakage structures or informally in the permeable areas around buildings.
- Piped drainage network for Curtin Bentley designed to accommodate the 20% AEP event.
- Living stream designed to accommodate/convey up to the 1% AEP event via infiltration and conveyance to Jack Finney Lake.
- Flood storage areas (FSAs) (Jack Finney Lake and minor catchment storage areas) designed to accommodate the 1% AEP storm event.
- Enhancement of Kent Street Compensating Basin (CB) so that all contributing catchments are accommodated within the proposed design, and to remove the current temporary structure adjacent to the Kent Street CB.
- Enhancement and maintenance of the University CB (on Hayman Rd) to ensure that it continues to provide the required capacity.
- Localised subsurface infiltration storage for the central university catchment.
- Rationalised earthworks approach for the central catchment to minimise the extent of mechanical stormwater management (e.g. pump).

The living stream and some FSAs (e.g. Jack Finney Lake, former Barblett Oval) while relevant to the Stage 1 LWMS (Emerge Associates 2018), remain integral to the development within the wider GCMP site and have therefore been described within this LWMS. Other features of the GCMP development which are relevant only to Stage 1 are described in the aforementioned documentation (e.g. busport flood storage).

3 Existing Environment

3.1 Climate

The south west of Western Australia experiences a Mediterranean climate of hot dry summers and cool wet winters. An average annual rainfall of approximately 818 mm is recorded (Gosnells City weather station, number 009106). Average monthly rainfall of 100 mm or greater is recorded between the months of May and August (BoM 2018), equating to more than 50 % of the annual rainfall cumulatively. Average daily evaporation in the region is 5.7 mm per day, equating to an annual evaporation of 2,080 mm per annum (Perth Airport weather station, number 009021).

3.2 Geotechnical conditions

3.2.1 Topography

The topography of the Bentley campus is variable with an elevated ridge along the eastern boundary grading downward towards interdunal depressions in the west. Existing ground levels within the Bentley campus range from 22.5 m Australian height datum (AHD) to 4 m AHD.

Topographic contours are shown in **Figure 2**.

3.2.2 Geology and soils

Regional geological mapping indicates that the Bentley campus (and therefore all stages of the GCMP) is underlain by Bassendean Sand (S_8) (Gozzard 1986; Jordan 1986), as shown in **Figure 3**.

An intrusive soil investigation was conducted by Syrinx Environmental (2014). The soil types encountered were generally consistent with the regional geological mapping (Gozzard 1986; Jordan 1986), and are described in the groundwater monitoring bore logs provided in **Appendix C**.

3.2.3 Acid sulfate soils

Regional acid sulfate soils (ASS) risk mapping indicates that the Bentley campus (and therefore all stages of the GCMP) is classified as having a moderate to low risk of ASS occurring within 3 m of the natural surface (DWER 2018a). ASS mapping is shown in **Figure 4**.

The intrusive soil investigation conducted by Syrinx Environmental (2014) indicated that field pH screening suggested both potential and actual ASS conditions may exist at some locations. Laboratory analysis indicated no obvious presence of potential or actual ASS with the exception of two locations, however those two locations were at the south west and southern boundary of the Bentley campus.

3.3 Existing and historical landuse

Historical aerial photography dating from 1948 onwards indicates that the Bentley campus was historically part of a pine plantation. The 1978 photographs indicate that the plantation across most of the Bentley campus had been cleared, with some buildings and sports facilities constructed. Photographs from 1988 onwards show the progressive construction of buildings, sporting and recreational facilities, and access roads and car parks associated with the existing land use as a tertiary educational institution with associated sporting and research facilities.

3.4 Flora and vegetation

Vegetation within Bentley campus and surrounding land has historically been highly modified, with the earliest aerial photographs showing the land being used for a plantation of pine trees. Prior to this, the native vegetation would most likely have been consistent with descriptions of the Bassendean Complex - Central and South (Heddle *et al.* 1980). This vegetation complex is characterised by Jarrah, Sheoak and Banksia on the elevated dunal areas to a low woodland of *Melaleuca* spp. and sedge lands in low lying areas (Heddle *et al.* 1980).

A vegetation survey conducted by Syrinx Environmental (2012) recorded a total of 80 native species within the Bentley campus and 88 introduced species. One priority 2 taxon (*Johnsonia pubescens* subsp. *cygnorum*) was recorded at three locations. No flora listed under the *Environmental Protection and Biodiversity Conservation Act 1999* or gazetted threatened flora under the *Wildlife Conservation Act 1950* were present.

3.5 Surface water

3.5.1 Wetlands

The *Geomorphic Wetlands Swan Coastal Plain dataset* (DBCA 2018) indicates that there are no classified wetlands within the Bentley campus. The closest classified wetland is a conservation category wetland (CCW) (UFI #15359), associated with the Canning River foreshore. The locations of this and other nearby classified wetlands are shown in **Figure 5**.

3.5.2 Existing drainage network

There are a number of storage basins within the Bentley campus. These include three purpose built drainage basins which existed prior to the implementation of the GCMP Stage 1, two new purpose built drainage basins designed in relation to GCMP Stage 1 (Emerge Associates 2018), and Jack Finney Lake. These are described in the following sections, and shown in **Figure 6**.

3.5.2.1 University Compensating Basin

The University CB is a WC asset which accepts runoff from catchments within Curtin, Hayman Road and substantial catchments north of Hayman Road. This basin is approximately 8,745m^2 in size and provides sufficient flood retention capacity for the currently assumed catchments, shown in the link-node diagram provided by WC contained in **Appendix D**.

3.5.2.2 Kent Street Compensating Basin and temporary basin

The Kent Street CB receives runoff from the southern portion of the Curtin campus, plus some of Kent Street and the adjacent residential area. The WC modelling for the Kent Street CB assumes that all of these catchments contribute to the basin, and that the basin is augmented to achieve a combined surface area of 12,940 m^2 and detention capacity of 8,170 m^3. In reality however much of the southern portion of the Curtin campus is directed to a temporary Kent Street basin, located immediately adjacent to the Kent Street CB. The future assumed catchments are shown in the link-node diagram provided by WC contained in **Appendix D**.

3.5.2.3 Jack Finney Lake

Jack Finney Lake is a remnant of historical wetlands located centrally on the western boundary. It is understood that stormwater runoff generated within the central portion of the Bentley campus in excess of the capacity of soakwells and impervious infiltration areas (i.e. gardens and lawns) is directed to Jack Finney Lake via a piped drainage network.

There are currently three pipes which discharge into Jack Finney Lake. These convey stormwater runoff from nearby sporting facilities, academic buildings, and carparks. It is understood that the main carpark, located west of the academic buildings, is low lying and serviced by pumps which transfer stormwater to Jack Finney Lake. Stage 1 has been designed to discharge towards Jack Finney Lake, initially via piped infrastructure but in the long term this will be converted to a living stream which will convey runoff from Stage 1 to the Lake.

3.5.2.4 Former Barblett Oval

The former Barblett Oval has been reshaped to provide runoff detention for a portion of Stage 1 (primarily University Boulevard). This storage will need to be either augmented or redesigned in the future to accommodate surrounding catchments and to allow development proposed by the GCMP.

3.5.2.5 Stage 1 infrastructure

Stage 1 drainage infrastructure has recently been constructed (in 2018) and includes roadside swales/bio-retention, a detention swale within the new busport and some portions of traditional pipe network that receive runoff from road pavement and overflow from development lots (i.e. above the first 15 mm).

3.5.2.6 Eastern busport basin

A minor basin exists at the easternmost point of the campus, adjacent to the Hayman Road busport. The Eastern Busport basin receives runoff from an adjacent carpark and minor catchment area within Curtin, plus from a small area of Hayman Road pavement.

3.5.2.7 Other drainage infrastructure

The Bentley campus has some sections of pipe network beneath road pavement throughout the campus. Many roads and paths have informal drainage or rely on infiltration in to immediately adjacent permeable areas.

3.6 Groundwater

3.6.1 Groundwater levels

3.6.1.1 Regional groundwater level data

The *Water Register* (DWER 2018d) indicates that groundwater beneath the CGMP area is a multi-layered system comprised of the following:

- Perth – Superficial Swan unconfined aquifer
- Perth – Leederville confined aquifer
- Perth – Yarragadee North confined aquifer.

The *Historic Maximum Groundwater Contours* dataset (DWER 2018b) shows groundwater levels across the Bentley campus ranging between 5 and 7.5 m AHD, suggesting that groundwater flows in a south westerly direction towards the Canning River.

3.6.1.2 Local groundwater level data

The DWER maintains groundwater level information at a number of sites across the Perth metropolitan region within their Water Information Reporting (WIR) database (DWER 2018c). A search of the WIR database revealed three shallow groundwater monitoring locations near the Bentley campus (reference numbers 61610356, 61610369 and 61611218) with long term groundwater level records. The locations of these monitoring bores are shown in **Figure 5**, with hydrographs provided in **Appendix E**.

The long term data at these locations suggests that groundwater levels have steadily declined by an average of approximately 1.5 m over the last 60 years, however the groundwater levels at 61610356 and 61611218 have demonstrated a gradual recovery of approximately 0.6 m since 2011. The maximum recorded groundwater elevations at these locations are summarised in **Table 2**.

Table 2: *Local maximum groundwater levels, WIR database (DWER 2018c)*

Period of Records	Maximum Recorded Groundwater Elevations (m AHD)		
	61610356	61610369	61611218
All Records	6.95	10.85	5.62
Since 2000	5.78	8.51	4.95

3.6.1.3 Site specific groundwater level data

Groundwater monitoring bores exist within the GCMP development, but in limited proximity to the site; however, groundwater data from 15 monitoring bores across the wider Bentley campus is available. These monitoring bores were installed during previous investigations. The locations of the monitoring bores are shown in **Figure 5**, and the construction and lithological logs are provided in **Appendix C**.

Groundwater levels at the monitoring bores within the Bentley campus have been measured on two occasions, which are considered representative of the 2013 and 2016 winter peak groundwater elevations. These are summarised in **Table 3**.

Table 3: *Groundwater level summary, bentleycCampus (adapted from Syrinx 2014)*

Bore ID	Coordinates (MGA zone 50)		Groundwater elevation (m AHD)		
	Easting	Northing	17 October 2013	21 September 2016	Referenced MGL
GW01	395268.761	6459101.168	5.19	5.07	5.45
GW02	395243.667	6457856.429	4.35	4.29	4.61
GW03	395035.290	6458553.077	4.85	4.72	5.11
GW04	395691.314	6458094.205	5.06	4.95	5.32
GW05	395075.416	6458298.376	4.76	4.62	5.02
GW06	395821.859	6458316.204	5.43	5.37	5.69
GW07	394993.892	6458040.227	4.45	4.34	4.71
GW08	394920.046	6457680.569	3.85	3.82	4.11
GW09	395262.335	6457772.336	4.25	4.18	4.51
GW10	395424.265	6457664.417	4.05	4.01	4.31
MW01	395537.828	6458384.841	5.15	--	5.41
MW02	395537.839	6458400.135	5.14	--	5.40
MW03	395626.749	6458432.818	5.24	5.16	5.50
MW04	395625.522	6458455.471	5.32	--	5.58
MW05	395635.261	6458460.249	5.27	--	5.53

The groundwater level measurements at these locations have been referenced to the longer term records held by the DWER's WIR database (see **Section 3.6.1.2**) to provide an estimate of the maximum groundwater level (MGL) at each location. The WIR records from 2000 onwards were used to estimate the MGLs, with the intention of minimising the potential influence of longer term climatic changes.

The estimated MGLs across the Bentley campus range from 4.11 m AHD at GW08 (south western corner) to 5.69 m AHD at GW06 (eastern boundary). The estimated MGL at GW01 and GW03, the monitoring bores closest to Stage 1, are 5.45 m AHD and 5.11 m AHD, respectively. The estimated MGLs are shown on **Figure 5**.

3.6.2 Groundwater quality

Groundwater quality monitoring was undertaken across the extent of the Bentley campus as part of the *Baseline Groundwater Investigation and Preliminary Soil Assessment* between 14-16 October 2013 (Syrinx Environmental 2014). The physical parameters measured in situ and results of nutrient analysis are summarised in **Table 4**.

Table 4: *Groundwater quality summary, October 2013 (Syrinx Environmental 2014)*

Bore ID	Temperature (°C)	pH (pH units)	Electrical conductivity (µS/cm)	Dissolved oxygen (mg/L)	Redox (mV)	Total nitrogen as N (mg/L)	Nitrite NO2-N (mg/L)	Nitrate NO3-N (mg/L)	Ammonia NH3-N (mg/L)	Total kjeldahl nitrogen (mg/L)	Total phosphorous (mg/L)	Reactive phosphorous (mg/L)
GW01	19.9	5.04	192.1	4.71	111.2	0.3	<0.01	0.03	0.02	0.3	0.08	<0.01
GW02	19.8	6.61	595	3.99	100.5	32.2	<0.01	28.3	<0.01	5.3	0.32	0.36
GW03	19.9	5.16	603	3.31	193.3	3.5	0.01	2.31	0.02	1.2	0.14	<0.01
GW04	22	5.85	594	6.02	83.8	9.9	<0.01	8.57	<0.01	1.3	0.09	<0.01
GW05	18.4	5.3	138.6	0.54	-62	0.3	<0.01	<0.01	<0.01	0.3	0.02	<0.01
GW06	21.7	4.39	618	4.72	202.8	3.9	0.01	3.42	0.04	0.5	0.07	<0.01
GW07	19.3	4.79	865	2.38	93.8	0.7	<0.01	0.34	0.02	0.4	0.02	<0.01
GW08	20	4.28	1070	0.84	147.8	2.7	<0.01	<0.05	0.03	2.7	0.08	0.01
GW09	21.1	5.46	124.5	--	-10.3	--	--	--	--	--	--	--
GW10	19.7	5.44	903	3.49	60.7	2	0.01	0.72	0.02	1.3	0.12	0.02
MW01	20.8	6.78	445.9	6.44	118.8	--	--	--	--	--	--	--
MW02	20.2	6.33	358.4	4.76	148.2	--	--	--	--	--	--	--
MW03	20.3	6.29	444	3.43	144.1	--	--	--	--	--	--	--
MW04	20.7	5.76	229	5.41	163.5	--	--	--	--	--	--	--
MW05	20.3	6.28	525	--	-111.2	0.9	0.12	0.56	0.02	0.2	<0.01	<0.01

3.7 Summary of existing environment

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

- The site receives an average annual rainfall of approximately 818 mm, with over 50% of rainfall received between May and August.
- Topography within the site ranges from approximately 4 m Australian height datum to 22.5 m AHD.
- The site is underlain by Bassendean Sands.
- ASS risk mapping indicates that the proposed Stages are classified as having a moderate to low risk of ASS occurring within 3 m of the natural surface.
- Vegetation within the site has historically been highly modified, with the earliest aerial photographs showing the land being used for a plantation of pine trees. No flora listed under the *Environmental Protection and Biodiversity Conservation Act 1999* or gazetted threatened flora under the *Wildlife Conservation Act 1950* were identified during a vegetation survey conducted in 2012.
- There are no classified geomorphic wetlands within the Bentley campus.

- Surface water features on site include the University CB and Ken Street CB, temporary Kent Street basin, Jack Finney Lake, former Barblett Oval swale and basin, Eastern Busport basin and Stage 1 drainage infrastructure.
- Jack Finney Lake is a remnant of historical wetlands and currently receives stormwater runoff from a catchment of approximately 58.7 ha.
- The estimated MGL beneath the site ranges from 4.4 mAHD to 5.6 mAHD.
- Groundwater quality displays low to moderate total nitrogen (TN) concentrations, and elevated total phosphorous (TP) concentrations.

4 Design Criteria and Objectives

4.1 Integrated water cycle management

The *State Water Strategy* (Government of WA 2003) and *Better Urban Water Management* (WAPC 2008) endorse the promotion of integrated water cycle management and application of WSUD principles to provide improvements in the management of stormwater, and to increase the efficient use of other existing water supplies. The key principles of integrated water cycle management include:

- Considering all water sources, including wastewater, stormwater and groundwater.
- Integrating water and land use planning.
- Allocating and using water sustainably and equitably.
- Integrating water use with natural water processes.
- Adopting a whole of catchment integration of natural resource use and management.

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

- Potable water consumption
- Flood mitigation
- Stormwater quality management
- Groundwater management.

The first step in applying integrated water cycle management in urban catchments is to establish agreed environmental values for receiving environments. The existing environmental context of the site has been discussed in **Section 3** of this document. Guidance regarding environmental values and criteria is provided by a number of federal and state government policies and guidelines, and site specific studies that are detailed in **Section 1.2** and **Section 1.3**.

The design criteria discussed in the following sections are based on the assessment of the existing environment within the GCMP development area, and with the aim of achieving the integrated water cycle outcomes discussed above.

4.2 Water conservation

The water conservation design criteria proposed are consistent with the guidelines presented in *Better Urban Water Management* (WAPC 2008) and *Developing a Local Water Management Strategy* (DoW 2008). This LWMS proposes the following water conservation criteria:

Criteria WC1	Reduce potable water consumption within future development lots by 25% on the Green Star Design and As Built Water Calculator.
Criteria WC2	Zero potable scheme water use for irrigation purposes.
Criteria WC3	All lot irrigation requirements will be met by fit for purpose approaches using non-potable water.

Criteria WC4 Use of groundwater for irrigation of open space and public spaces will be reduced over time.

Criteria WC5 Water metering will be installed for all individually developed lots, with all major water users to be sub-metered, as applicable.

The manner in which this objective will be achieved is further detailed in **Section 5**.

4.3 Stormwater management

The principle behind stormwater management for the site is to mimic the existing hydrological conditions, as described in **Section 3.5**. This principle and the guidance documents discussed in **Section 1.2** and **Section 1.3** have guided the stormwater management criteria which include:

Criteria SW1 Manage (retain and/or detain) stormwater runoff from impervious areas generated by the first 15 mm of rainfall within development lots at source.

Criteria SW2 Convey all flows above the first 15 mm rain event and up to the 1% AEP event to the living stream and swale network via appropriately sized stormwater infrastructure.

Criteria SW3 Detained stormwater (first flush) should be fully infiltrated within 12 hours.

Criteria SW4 Appropriate pre-treatment of hydrocarbons, gross pollutants and sediment is required from new carparks and any other point source development areas.

Criteria SW5 Non-structural controls are to be implemented to improve water quality.

Criteria SW6 Habitable floor levels for new developments shall be at least 300 mm above the 1% AEP flooding levels.

Criteria SW7 The piped drainage network shall be designed to accommodate runoff generated during the 20% AEP event.

Criteria SW8 Stormwater runoff up to the 1% AEP from internal GCMP catchments will be detained and/or retained within the GCMP area.

Criteria SW9 Stormwater runoff flow rates for the 1% AEP to existing Water Corporation infrastructure will be maintained within current or approved levels.

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

4.4 Groundwater management

The principle behind the groundwater management strategy is to maintain the existing groundwater hydrology. This LWMS proposes the following groundwater management criteria:

Criteria GW1	Finished floor levels of habitable buildings should have a minimum 500 mm clearance from MGL.
Criteria GW2	Inverts of flood detention and retention structures to be set at or above MGL.
Criteria GW3	Groundwater quality leaving the GCMP development area (downstream) shall be maintained at similar levels to the quality of groundwater entering the GCMP development area (upstream).

The manner in which these objectives will be achieved is further detailed in **Section 8**.

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 supply

Greater Curtin is serviced by the WC Integrated Water Supply Scheme (IWSS) which supplies scheme water for potable and some limited non-potable uses.

The campus is located within the Kewdale-South Perth Water Supply Scheme, which is well served by large trunk and distribution mains nearby. There is a large 610 mm distribution main running along Manning Road, and a 460 mm off-take main extends north up Hillview Terrace. Curtin currently draws potable water from the IWSS via three supply connections. A summary of the three existing connections to the IWSS connections is provided in **Table 5**.

Table 5: *Existing potable water connections and capacities*

Potable water supply connection location	Water meter diameter (mm)	WC allowable maximum flow rate (L/min)
Manning Road, corner of Conlon Street.	150	2,000
Kent Street, corner of Beazley Avenue.	100	750
Brand Drive, opposite Adie Court	100	750

Currently, a Service Headworks Agreement exists between Curtin University and WC, which states that the WC shall provide a guaranteed total flow rate of 2,750 L/min to the Bentley campus.

The WC has advised that in the future the existing mains are likely to have the capacity to serve long term demands, however smaller reticulated mains to and through the site may need to be individually assessed at each development stage (or mains extension stage) to the capacity to provide compliant services (Brett Coombes 2018, *pers. comm*. 18 September).

Scheme water will continue to service Greater Curtin, and will be used for in-lot uses excluding irrigation.

5.1.1.1 Campus reticulation

To service the future needs of the campus during the Greater Curtin planning horizon and beyond, the development requires upgrades to two of the existing connections to the IWSS to 150 mm diameter capable of 2,000 L/min potentially prior to the commencement of Stage 2. The expected flow rate, demand and consumption allowances and calculations, across the future GCMP planning horizon have been assessed (Lucid 2018). The assessment indicates that demand management will need to be implemented in future stages, and the measures proposed to achieve this are summarised in the following sections.

5.1.1.2 Demand reduction strategy

In order to maintain potable water flow and pressure characteristics and service reliability compliant with Australian Standards and the WC requirements, campus wide demand management will be implemented to reduce the expected probable simultaneous demand (PSD) and mitigate associated pressure drop and water velocity impacts upon hydraulic infrastructure.

The strategy proposed to support demand reduction aligns with Curtin's commitment to reduce potable water usage by 25-30 % as per Green Star requirements, and involves:

- Provision of new water reticulation and refurbishment / replacement of existing hydraulic networks where required.
- Specification of water efficient fixtures, fittings and equipment.
- Potable water consumption monitoring through campus wide sub-metering and fault signalling.
- Scheme water will not be used for irrigation within the GCMP development area.
- Maintenance and recommissioning of campus mechanical systems and cooling towers
- Rainwater harvesting for non-potable usage (within new developments).

In addition to the measures outlined above for reducing potable water consumption, it is proposed to manage infrastructure issues associated with exceeding PSD limits, and achieve targets by undertaking the following (Lucid 2018):

- Restricting maximum flow to each development lot to 1 L/s through the use of:
    - Flow limiting valves
    - Approved meters with flow restriction
- Implementation of break tank and pumping assemblages – this would be on a per lot development basis for all future GCMP stages, and in existing buildings which currently experience low pressure or where refurbishment is planned.

The above measures will ensure that supply flow and pressure is maintained.

Lot development for all future stages will require demonstrated compliance with the above demand management strategies for reducing probable simultaneous demand (PSD), within relevant planning and design documentation.

5.1.2 Groundwater supply

The proponent currently holds a groundwater licence (GWL45914(6)) which grants an annual allocation of 587,290 kL from the superficial aquifer. This allocation is for:

- Irrigation of 19.0 ha recreation areas
- Irrigation of 46.0 ha turf and gardens
- Irrigation of 1.28 ha synthetic turf
- Pool and lake water level maintenance
- Horticultural purposes.

A portion of the allocated groundwater will be used for irrigation of verges, gardens and landscaped areas across the Greater Curtin development area (excluding irrigated areas within development lots).

Groundwater will not be provided to individually developed lots. Individual lots may implement rainwater harvesting systems to satisfy non-potable water requirements (see **Section 5.1.3**).

5.1.3 Rainwater harvesting

Individual development lots may elect to implement a rainwater harvesting system to supply water for the irrigation of lot scale gardens and other non-potable uses. This will enable a reduction in the use of potable water where drinking quality water is not required.

The design of any rainwater harvesting and storage system will acknowledge and consider the long term trend of declining rainfall being experienced in Perth and the long periods of minimal rainfall experienced during summer. If this strategy is used, landscaped areas to be irrigated with rainwater will be designed so that the expected demand for rainwater does not exceed availability.

This approach has been implemented within the recent lots developed in Stage 1, which utilises Rocla Plastream storage systems to provide 700 kL of storage, and ultimately supplies 13,100 kL/yr for irrigation, laundry and toilet flushing. This demonstrates that this proposed demand management and water conservation measure can and will be adopted.

5.2 Water conservation measures

5.2.1 Groundwater conservation

Curtin is committed to ensuring that use of groundwater use complies with the allocated volume in GWL45914(6). The use of groundwater will be minimised in the longer term across the GCMP development area by adopting the approaches described in the following sections.

5.2.1.1 Dispersed drawdown

The irrigation system currently employed across the GCMP area is automated and centrally managed. Groundwater for irrigation is sourced from eight bores spread across the Greater Curtin area. The use of a bore field spreads out water demand (and impacts of drawdown) across a larger area.

5.2.1.2 Soil wetting agents

Soil wetting agents are added to the groundwater extraction system at source (bore). The use of wetting agents increases the adsorption of water into hydrophobic soils and therefore reduces the overall irrigation demand.

5.2.1.3 Weather Station

A weather station is incorporated into the irrigation system so that irrigation rates are automatically reduced in response to rainfall, a function which was historically performed manually. This reduces the amount of water applied following rainfall, thereby reducing water use.

5.2.1.4 Soil moisture measurement

Soil moisture probes are used beneath playing surfaces across Curtin. These determine the actual amount of water required and irrigation rates are adjusted accordingly.

5.2.1.5 Water wise gardens

Water use can be reduced on a development scape within landscaped areas by employing water wise gardening (WWG) measures and minimising soft landscaping treatments. Some of the following water efficiency measures are utilised within the GCMP area, and they will be adopted within all new development in the GCMP:

- Improve soil with conditioner certified to Australian Standard AS4454 to a minimum depth of 150 mm where turf is proposed and a minimum depth of 300 mm for garden beds.
- Design and install the irrigation system according to best water efficiency practices.
  - Control systems should have capacity to irrigate different zones with different irrigation rates.
  - Emitters should disperse coarse droplets or be subterranean.
- Minimise the amount of turfed areas.
- Mulch garden beds to 75 mm thickness with a product certified to Australian Standard AS4454.
- Minimise the use of fertiliser and, where required, use type appropriate slow release fertilisers.

5.2.1.6 Smart water scheduling and application

Water application to open spaces is modified on a daily basis, dependant on the inputs provided from the weather station and soil moisture probes. This results in water application being limited to that which is required.

5.2.2 Future irrigation water demand

A water use schedule for the GCMP development demonstrates that many public areas will either not be irrigated in the longer term or will have a reduced irrigation rate, and therefore irrigation demand from groundwater will be reduced within the site in the future. The predicted ultimate irrigation demand (i.e. following implementation of Stage 4) has been determined by spatially allocating land use types within the GCMP and assigning each a realistic irrigation rate. These rates and the potential future irrigation demand is shown in **Table 6**. Note that these provide estimated absolute irrigation rates for different land uses, and in reality the average irrigation rate for open spaces is 7,500 kL/ha/yr.

***Table 6**: land use type irrigation rates and potential future demand*

Irrigation land use	Area	rate	irrigation volume kL/ha/yr
Road verges	4.6	7,500	34,200
Sporting ground, high use	12.2	10,000	122,000
Other open space	14.0	6,750	94,567
Living stream open spaces	3.5	6,750	23,760

Irrigation land use	Area	rate	irrigation volume kL/ha/yr
Plaza	1.4	6,750	9,720
Courtyards of buildings	20.5	6,750	138,375
Roads	8.4	0	0
Paths	2.9	0	0
Lakes	1.3	0	0
Water management features	0.8	6,750	5,467
Development lots	41.2	0	0
Total	110.8		428,090

In addition to the areas identified in **Table 6**, an additional 54,500 kL/yr is used for irrigation of areas beyond the GCMP area (Vickery House, Guild House, Erica Underwood and Technology Park), plus a further 36,100 kL/yr for horticultural, pool and ornamental pond maintenance purposes, Assuming that this use is maintained, the total future irrigation demand will be 518,690 kL/ha/yr, which shows an overall reduction over time may be possible, thereby achieving **Criteria WC4**.

It is noted that achieving the irrigation demand reduction discussed above (and thereby reducing reliance on groundwater) will be reliant on full implementation of the GCMP, and therefore the predicted use should be considered a preliminary estimate that Curtin will aim to work towards. In reality irrigation water use should be monitored annually, and if necessary the demand target should be updated to reflect the most up to date approach to implementing the GCMP.

5.2.3 Potable water conservation

Curtin University has committed to water conservation measures that will be implemented across Greater Curtin across future development. These are discussed here to demonstrate the plan to reduce ongoing water use. Curtin has agreed with the WC that the following conservation measures will be implemented to reduce potable water usage:

- Monitoring of building water consumption through a dedicated database.
- Development of an overall strategy that will assess current total demand and predict future demand over Greater Curtin.
- Installation of WELS star rated water saving devices in new development areas.
- Regular maintenance and monitoring of measurement systems to identify and manage leaks.
- Provision of additional sub-meters (e.g. at construction sites) to assist in more accurate consumption monitoring.
- Maintenance of cooling towers to ensure they are balanced and not expelling potable water to sewer unnecessarily.
- Replacement of faulty sections of site potable water supply network.

The Water Efficiency Management Plan (WEMP) is a plan monitored by WC which outlines Curtin University's water usage objectives as agreed with the WC. The WEMP proposes a target across Greater Curtin for 2018 of 7.4 kL/student and staff for 2018. In order to assist in achieving the broader target for Greater Curtin, **Criteria WC1** is proposed. All developments within the Greater

Curtin development will be required to commit to and deliver a 25% reduction in water use based on the Green Star Design and As Built Potable Water Calculator at a precinct level.

5.2.3.1 Water efficient fixtures

The use of water efficient fixtures will be mandated to reduce overall potable water consumption. For the implementation of this strategy, the following restrictions will be considered:

- Taps - 5 star rating under the water efficiency labelling and standards (WELS)
- Toilets - 4 star WELS rating
- Bath and showers - 3 star WELS rating
- Washing machines and dishwashers - 4 stars WELS rating.

An initial water balance for the development lots within Stage 1 using the Green Star Potable Water calculator indicated that the use of the above fittings will be important to achieving the required reduction in potable water use, demonstrating that compliance is possible. Future lot development across the GCMP will be required to demonstrate compliance with **Criteria WC1** within the relevant future UWMP.

5.2.3.2 Potable water not to be used for irrigation purposes

All Curtin managed landscaped areas within the GCMP development area will be irrigated using groundwater. This does not include landscaped areas within individual development lots. No potable water will be utilised for irrigation of any open spaces or landscaped areas within the site. The minor exception to this is water used for productive food gardens and water features where primary contact is possible.

5.2.3.3 Campus wide monitoring and fault signaling

Curtin University is currently in the process of implementing ‘iEnergy’, an automated database to capture and record potable water usage data as well as the installation of sub-metering and monitoring for all buildings on campus where required.

The implementation of campus wide monitoring will allow:

- Validation of the billing information collected by the WC.
- Monitoring of potable water usage for each building on campus.
- Identification of over-use and potential leaks via fault signals (alerts) generated by the automated water monitoring database.

The current strategy for implementing this system includes the following:

- Update the existing Hydraulic Services Specification to include the minimum requirements for the installation of sub-meters and their connection to the University communications network.
- Update developer specifications document to include minimum requirements for the implementation of a sub-meter connected to the University communications network.
- Extension of Curtin University communications infrastructure to allow for campus wide coverage.

5.3 Compliance summary

A summary of the proposed water conservation design criteria and how they will be addressed within Stage 1 is provided in **Table 7**.

Table 7: *Water conservation compliance summary*

Criteria number	Criteria description	Manner in which compliance will be achieved
WC1	Reduce potable water consumption within development lots by 25% on the Green Star Design and As Built Water Calculator	Use of water efficient fixtures.
		No potable scheme water to be used for irrigation within development areas.
		Implementation of fault/ water leak detection.
WC2	Zero scheme water use for irrigation purposes	Scheme water will not be used for irrigation purposes.
WC3	All lot irrigation requirements will be met by fit for purpose approaches using non-potable water	Individual lots can elect to implement a rainwater harvesting system to supply water for irrigation purposes.
WC4	Use of groundwater for irrigation of open space and public spaces within Stage 1 will be reduced over time	Land areas requiring irrigation will be reduced with implementation of the GCMP.
		Future development lots will not irrigate with groundwater.
		The use of soil moisture probes will determine the actual amount of water required. Irrigation rates will be adjusted accordingly.
		Use of a weather station linked to the irrigation system to prevent the use of water during and following rain events.
		Use of soil wetting agents to increase the adsorption of water into hydrophobic soils and therefore reduce the overall irrigation demand.
		Use of WWG principles in all landscaped areas.
		Irrigation rates will be reduced following establishment period.
WC5	Water metering will be installed for all individually developed lots, with all major water users to be sub-metered, as applicable	Installation of lot scale water meters, with sub-meters where required for major water users.

6 Wastewater Infrastructure

6.1 Wastewater planning

Curtin University is located within the Collier Sewer District, and the WC has undertaken long term wastewater planning for this District. This planning over the whole Bentley Campus was further developed by Pritchard Francis during work to support development within Stage 1. The wastewater master planning within the site that has been approved by WC is contained in **Appendix F**.

6.2 Internal sewer drainage network

There are multiple sewer drainage catchments within Greater Curtin. Each catchment is serviced by gravity fed pipework and a sewer ejecting pumping station (SEPS). The SEPS within each catchment pumps the collected wastewater into one of four WC sewer drainage easements which exist within Greater Curtin. The piped networks within each of these easements convey wastewater from the various sewer catchments within Greater Curtin to the Manning Road West pumping station, located in the south eastern corner of George Burnett Park, west of Greater Curtin. WC has advised that this pumping station has a capacity of up to 130 L/s (F Kroll 2013, *pers. comm*., 29 August).

The Greater Curtin Stage 1 LWMS (Emerge Associates) outlined the proposed sewer drainage strategy for Stage 1. An assessment of the existing and estimated sewer discharge volumes and flow rates has determined that some upgrade of the pump station system may be required to support development of future stages of the GCMP. This may require a capacity upgrade to the existing WC reticulated sewer network with the construction of a new WC pump station (near the corner of Kent Street and Manning Road)

6.3 Water Corporation requirements

The existing sewer drainage network using the existing gravity fed WC sewer drainage utility mains (i.e. business as usual) may not be able to accommodate the development beyond Stage 2 (as discussed in **Section 6.2**).

The WC has suggested that for future stages the Manning Road West pumping station is not able to be upgraded to increase its capacity. The option currently under consideration is an on-site sewer pumping station with a rising main from Greater Curtin to the DN600 Beaton Street gravity sewer. Any modification to this system which may be required will therefore be addressed in further detail (in future) when the system is approaching servicing limitations. In addition to the pump station, a 2 km pressure main discharging eastwards to an existing DN600 gravity sewer (on corner of Beaton and Eureka Streets) may also be required.

7 Stormwater Management Strategy

Within the GCMP area, stormwater management systems comprise of soakwells, recharge wells, rain gardens, pit and pipe drainage network, infiltration basins and a proposed living stream to convey runoff from major rain events to the Jack Finney Lake.

The proposed stormwater management system has been guided by a broader Living Knowledge Stream ideology, which integrates the local indigenous and environmental heritage associated with Greater Curtin. This knowledge has been used to guide the landscape design of the GCMP and create a sense of place which acknowledges the heritage and history of the area. A component of this will include the construction of a living stream and its use in the management of stormwater. The living stream will be designed in accordance with the relevant DWER guidelines.

The stormwater management strategy for the site has been developed in accordance with the guidance documents detailed in **Section 1.2**, in consideration of the existing environment (see **Section 3**) and proposed land uses (see **Section 2**). The overarching stormwater management principle is to retain and treat the small event runoff (first 15 mm) as close to source as possible, with the 1% AEP event being retained within the GCMP areas in major event basins or Jack Finney Lake. Each component of the stormwater management network has been designed to achieve the objectives and criteria stated in **Section 4.3**.

A number of structural measures are provided across the site in order to achieve the objectives detailed above. These include:

- Lot scale storage
- Rain gardens
- Permeable road drainage collection pits
- Surface/sheet flow to permeable road verges
- Swales located within green corridors
- Subsurface infiltration cells
- Living Stream
- FSA/CBs.

These measures are described in the following sections. The locations of the above features (where known) is shown in **Figure 6**.

7.1 Lot scale storage and drainage

The existing academic hub and built form currently uses a variety of measures to achieve infiltration at source (soakwells, shallow groundwater infiltration wells, subsurface infiltration cells, informal surface soakage, groundwater recharge wells). This existing approach will be maintained in the future where these buildings are retained.

Future development lots will retain the first 15 mm of rainfall on lot, which will be achieved with the use of soakwells/onsite soakage. Stormwater runoff from development lots in excess of the first 15 mm will be discharged to the road pavement via overland flow, or in some cases to the piped drainage network via direct lot connections.

Some development lots may choose to implement a rainwater harvesting and storage system (see **Section 5.1.3**). In these cases, the volume of stormwater retained on lot would potentially be greater than the first 15 mm. However, as the implementation of rainwater harvesting will not be mandated, the stormwater drainage network design has assumed that lots will retain the first 15 mm of rainfall only. The retention of the first 15 mm of rainfall on lot will achieve **Criteria SW1**.

Depending on specific location and surrounds, future development lots may need to be provisioned with stormwater discharge connections to the piped drainage network.

7.2 Rain gardens

Surface runoff within road reserves may be conveyed to roadside rain gardens via measures such as slotted kerbing (as has been implemented within Stage 1). Where utilised, rain gardens should aim to accommodate the first 15 mm of runoff generated within road reserves, where sufficient verge space allows this approach. This will provide a volumetric treatment efficiency of 99.5% (Engineers Australia 2006).

Once the rain gardens are at capacity (i.e. in excess of 15 mm rainfall), stormwater will typically enter the piped drainage network via side entry pits. The rain gardens will ideally be ‘offline’ from the remainder of the drainage network to provide maximum stormwater treatment.

Rain gardens will be (and have thus far been) designed and implemented with a maximum depth of 300 mm. Rain gardens should 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).

7.3 Road drainage

Road drainage will be achieved by a combination of surface sheet flow (on road pavement), localised sheet flow from road pavement areas (e.g. via flush kerbing to localised permeable surfaces) and by a pipe network.

Runoff from the first 15 mm of rainfall will either be infiltrated directly at source (within soakwells or directed via sheet flow to adjacent permeable verge spaces), or will be directed to more formalised treatment structures such as rain gardens located in road reserve (as has been implemented in Stage 1). In events up to the 20% AEP, runoff will either be surface sheet flow, or will be directed to side entry pits and conveyed by the piped drainage network to the downstream treatment areas. In excess of the 20% AEP event, the road network has been graded such that it will convey stormwater runoff to the living stream or relevant downstream FSA.

7.4 Swales within green corridors

Swales will be used to convey runoff within green corridors where grades allow. The intention is that these will link to the living stream or to flood storage in open space areas. They would nominally be shallow turfed structures 4-6 m wide and up to 0.5 m deep, however the actual design and the ability to implement the swales will be dependant on localised constraints and the need to integrate with retained infrastructure. These details will need to be confirmed in future at a time close to individual stage development which includes the relevant green corridor.

7.5 Living stream

The GCMP proposes the use of a living stream to provide treatment and storage of stormwater runoff, as well as the conveyance of runoff to Jack Finney Lake and to link the two WC CBs during larger storm events. Note that the living stream would be constructed within the areas identified by the Living Knowledge Stream, however it is not intended that the entire living Knowledge Stream areas will be required for hydraulic conveyance of stormwater. While the living stream will be a constructed waterway, its design will reflect the functions of a natural stream as far as practicable within the context of its urban setting.

The living stream will be designed to ensure that minor roads remain passable during the 20% AEP event, and that arterial roads (Main Street and bus routes) are passable during the critical duration 1% AEP event.

The proposed alignment of the living stream is shown in **Figure 6**, with conceptual landscape designs provided in **Appendix G** and a summary of the modelling assumptions relevant to the design of the living stream provided in **Appendix H**.

7.6 Flood storage areas

7.6.1 Kent Street Compensating Basin (Water Corporation)

The future design of the Kent Street CB will be consistent with that which is currently modelled (and approved in principle) by the WC. The contributing catchment (22.4 ha) has been determined based on the GCMP development parcels and WC catchments combined. The future design incorporates the catchments for the existing and the temporary Kent Street CBs, and utilises the area proposed to remain between future development cells. The conceptual future design will have a top water level area of 6,742 m^2 and a depth of up to 1.5 m. This design will maintain the previously assumed basin volume of 8,170m^3.

7.6.2 Curtin University Compensating Basin (Water Corporation)

The existing Curtin University CB, located on the northern end of the site adjacent to Hayman Road will be retained in its current form. When the GCMP is fully implemented, the basin will have a total catchment area of 10.7 ha. It will have a design top water level surface area of 6,856 m^2 and a depth of up to 3.8 m.

7.6.3 Jack Finney Lake

Jack Finney Lake is located centrally within the site and is proposed to receive runoff from the GCMP development via the existing piped drainage network, and the proposed living stream and interconnected swales. This lake also receives runoff from pre-existing connected areas of Greater Curtin, which has been accounted for in the conceptual designs. The Jack Finney Lake has a potential top water level area of 26,288 m^2 and a depth up to 2.2 m.

No modification is required to the shape or volume of the lake in order to accommodate future development, other than to facilitate the interface with the living stream.

7.6.4 Northwestern basin

A minor basin will be required to be constructed on the northeast corner of the campus to service a smaller (2.7 ha) catchment. The FSA will need to be 1,125 m^2 and have a design depth of 1.2 m.

7.6.5 Busport basin (east)

The existing busport basin will need to be modified to accommodate proposed road alignments of the GCMP. The location of this will be generally consistent with the existing however the alignment and shape will likely need to change. The Busport basin will have a design top water level area of 515 m^2 and a design depth of up to 2.8 m.

7.6.6 Southern Oval storage

The main southern sports fields and surrounding future development parcels will require some form of runoff management. The future topography will result in a trapped low for the sports grounds, and therefore the storage area will be required to fully retain the major runoff event. The catchment for this flood storage area is 6.6 ha however much of this is permeable playing surfaces and adjacent runoff areas, and therefore the runoff volume required to be retained is comparatively low. The Southern Oval flood storage area will have a top water level area of 6,520 m^2 however the design depth is only 0.11 m. The design approach utilises the area between the ovals to negate the need for a deeper FSA.

7.6.7 Academic Core basin

The central catchment which contains the majority of the existing academic core is 23 ha and runoff from major events currently accumulates in an existing carpark area. The runoff is then mechanically pumped to Jack Finney Lake. In order to avoid the need to mechanically pump out in the future, a basin/storage area will be located at the current low point and this will be gravity drained via combination of culvert (beneath road pavement) and a portion of living stream to the Jack Finney Lake. The storage area will need to provide 1,775 m^3 of storage, and could be accommodated within either a 1 m deep 2,500 m^2 basin with 1:6 side slopes or within subsurface storage cells (depending on functionality required of the area.

7.6.8 Former Barblett Oval

Runoff from Stage 1 in excess of the capacity of rain gardens will discharge into a storage swale located adjacent to the former Barblett Oval. This swale has sufficient capacity to accommodate the 10% AEP event. In events up to the 1% AEP, stormwater will overflow into the former Barblett Oval.

The 1% AEP storage area has a base level of 8.00 m AHD, top water level of 8.15 m AHD, and an additional storage volume of 370 m^3. The current storage area will need to be augmented in the future to accommodate additional runoff from the 3 ha catchment north of University Boulevard. This will result in a storage area of 2,085 m^2 with 1.2 m depth.

7.7 Non-structural stormwater management measures

The structural measures proposed within GCMP development area provide both a storage and treatment function to stormwater runoff, as detailed previously. 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).

A number of non-structural measures will also be implemented within the site to help reduce nutrient loads within stormwater runoff. These measures include:

- Maintenance of WSUD features.
- Minimising fertiliser use to establish and maintain vegetation within landscaped areas.
- Drought tolerant plant species that require minimal water and nutrients will be used.

7.8 Stormwater criteria compliance summary

The proposed stormwater design criteria and how these are addressed are summarised in **Table 8**.

Table 8: *Stormwater management compliance summary*

Criteria number	Criteria description	Manner in which compliance will be achieved
SW1	Manage (retain and/or detain) stormwater runoff from impervious areas generated by the first 15 mm of rainfall within development lots at source.	At a minimum, individual development lots will retain the first 15 mm of rainfall. Some lots may elect to retain more than this as part of a rainwater harvesting system to provide non-potable water for irrigation purposes.
SW2	Convey all flows above the first 15 mm rain event and up to the 1% AEP event to the living stream and swale network via appropriately sized stormwater infrastructure.	Rain gardens and informal verge/swale areas will retain the first 15 mm from road pavement where appropriate. Runoff in excess of this from road pavement will be diverted to downstream FSAs (e.g. Jack Finney Lake) via the living stream or piped drainage network.
		The piped drainage network will be designed to accommodate the 20% AEP event, and the living stream has been designed to accommodate the 1% AEP event.
SW3	Detained stormwater (first flush) should be fully infiltrated within 12 hours.	Rain gardens have been designed with a maximum depth of 300 mm. Based on the sandy conditions (see **Section 3.2.2**), stormwater in rain gardens will fully infiltrate within 12 hours once rainfall stops.
SW4	Appropriate pre-treatment of hydrocarbons, gross pollutants and sediment is required from carparks and any other point source development areas.	The retention of the first 15 mm in rain gardens and other treatment areas provides a volumetric treatment efficiency of 99.5%.
SW5	Non-structural controls are to be implemented at all scales of the development area.	Non-structural measures proposed include the maintenance of WSUD features, minimised use of fertilisers in landscaped areas and the use of drought resistant plant species.
SW6	Habitable floor levels for new developments shall be at least 300 mm above the 1% AEP flooding levels.	Detailed designs for the individual development lots will demonstrate a 300 mm clearance between habitable floor levels and 1% AEP top water levels within FSAs. This will be documented in future UWMPs.
SW7	The piped drainage network shall be designed to accommodate runoff generated during the 20% AEP event.	The piped drainage network has been (and will be for future areas) designed to accommodate the 20% AEP event.
SW8	Stormwater runoff up to the 1% AEP will be detained and/or retained within GCMP area	The stormwater network, including the living stream, Jack Finney Lake and minor (non-WC) storage basins have been designed to fully retain the 1% AEP event.
SW9	Stormwater runoff flow rates for the 1% AEP to existing Water Corporation infrastructure will be maintained within current or approved levels.	Runoff modelling of the catchments that will contribute to the WC basins demonstrates that the basins will be able to accommodate the required volumes.

8 Groundwater Management Strategy

The groundwater management criteria provided in **Section 4.4** can be achieved through the methods described below.

8.1 Groundwater level management

Final habitable floor levels within each development lot will be determined during the detailed design stage and will be presented in future UWMPs, and will achieve the minimum 0.5 m clearance above MGL as required for **Criteria GW1**.

All stormwater retention features will be designed to achieve a minimum clearance of 0.5 m between the basin invert and MGL, achieving **Criteria GW2**. An indicative landscape concept plan for the living stream, Jack Finney Lake and the main flood storage areas which show how they may be implemented is provided in **Appendix G**.

8.2 Groundwater quality management

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

The reduction of nutrient loads to groundwater will be achieved through the following measures:

- Direct stormwater to rain gardens designed to retain and treat the small event (15 mm) runoff, consistent with best management practices (see **Section 7.2**).
- Minimising fertiliser use to establish and maintain vegetation landscaped areas.
- Utilising water wise plant species that require minimal water and nutrients.
- Turf areas will be minimised and used for functional / amenity requirements only in order to reduce nutrient usage during establishment and maintenance.
- Retain trees and existing vegetation where possible.

The above measures will assist in maintaining the quality of water prior to infiltration into the underlying groundwater and will assist in achieving **Criteria GW3**.

8.3 Groundwater criteria compliance summary

A summary of the proposed groundwater design criteria and how these are addressed is given in **Table 9**.

Table 9: *Groundwater management compliance summary*

Criteria number	Criteria description	Manner in which compliance will be achieved
GW1	Finished floor levels of habitable buildings should have a minimum 500 mm clearance from MGL.	Detailed designs for the individual development lots will demonstrate a 500 mm clearance between habitable floor levels and MGL. This will be documented in future UWMPs.
GW2	Inverts of flood detention and retention structures to be set at or above MGL.	The least clearance to MGL across the WC basins is the Kent Street CB which is ~ 0.4m above MGL. The least clearance at any of the university controlled FSAs is 1.3 m, at Jack Finney Lake.
GW3	Groundwater quality leaving the GCMP development area (downstream) shall be maintained at similar levels to the quality of groundwater entering the GCMP development area (upstream).	The retention of the first 15 mm in rain gardens and on lot will provide a volumetric treatment efficiency of 99.5% (Engineers Australia 2006).
		Rain gardens, the living stream and Jack Finney Lake will be planted with nutrient stripping plant species to provide additional treatment to stormwater prior to infiltrating to groundwater.
		Non-structural measures such as the maintenance of WSUD features and minimised use of fertilisers in landscaped areas will further reduce the pollutant load to stormwater.

9 Matters to be addressed at future development stages

While strategies have been provided within this LWMS that address planning for water management within the GCMP development area, it is a logical progression that the design of buildings and facilities within the individual development lots and their supportive UWMPs will clarify details not provided within the LWMS. The main areas that will require further clarification within future UWMPs include:

- Lot drainage approach
- Design and implementation of lot scale water conservation strategies
- Non-structural water quality improvement measures
- Construction period management strategy
- Design integration with WC drainage assets
- Wastewater infrastructure upgrades and timing
- Groundwater use reduction measures.

These are further detailed in the following sections.

9.1 Lot drainage

As described in **Section 7.1**, the stormwater management strategy requires each development lot to retain the first 15 mm on lot. Lot drainage information must include any proposed systems, such as rainwater harvesting (see **Section 5.1.3**). The detailed design which demonstrates lot retention will be confirmed in future UWMP documentation.

9.2 Design and implementation of water conservation strategies

Several water conservation measures have been proposed in this LWMS (see **Section 5**). These water conservation strategies will be incorporated into the design and maintenance of landscaped areas and each development lot. Measures to be implemented within each development lot will be detailed within future UWMP documentation.

9.3 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). The non-structural water quality improvement measures proposed in this LWMS (see **Section 7.7**) are intended to be easily implemented within the design and maintenance of public and landscaped areas. Future UWMP documentation will provide reference to these measures as appropriate.

9.4 Construction period management strategy

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

9.5 Design integration with Water Corporation drainage assets

The two main WC assets (Kent Street CB and Curtin University CB) will be retained in location and functionality. As indicated, the hydraulic design of the Curtin University CB will be retained as is, and the Kent Street CB will be upgraded to incorporate the temporary basin immediately adjacent. This will be done in accordance with the conceptual approach approved by WC unless negotiated otherwise in the future. It is expected that as development progresses in proximity of these the form of the surrounds and the manner in which they tie in to them will need to be further explored and detailed in future UWMPs or development approvals (Das) for the relevant areas.

9.6 Wastewater infrastructure upgrades and timing

As indicated, the full implementation of the GCMP will likely require some measure of upgrading both internal and external wastewater infrastructure. The need for this should be revised in the future to align with any changes to the proposed staging and consequent service demands. Such revision may necessitate resubmission of the overall servicing proposal to WC. Future water planning documentation (UWMPs, DAs) should provide an update of any such changes.

9.7 Groundwater use reduction measures

As indicated in **Section 5.2.2** the future demand for groundwater to meet irrigation needs could potentially be reduced from current use rates. This is largely based on changes in land use and the exclusion of irrigation by groundwater from development lots, but also by the waterwise approach that will be adopted in future landscaping. The irrigation demand should be continually revised on an annual basis, and Curtin is aware that they will need to work closely with DWER to not just ensure compliance with licence conditions, but also to work at reducing irrigation demand over time. The latest position with regard to irrigation demand should be provided in future UWMPs, and this will assist Curtin to continue with proactive planning for water use across the GCMP area.

10 Monitoring Program

The aim of this section is make recommendations regarding future post-development monitoring. It will be necessary to confirm that the structural and non-structural management measures that are implemented are able to fulfil their intended management purpose. This proposed monitoring program will be further detailed at the UWMP stage but are summarised in the following sections.

10.1 Surface water monitoring

Post-development surface water monitoring should be undertaken within key flood detention/retention structures. The aim of the water monitoring will be to guide management of the open space areas around, and which discharge into Jack Finney Lake, the Kent Street CB and Curtin University CB.

Monitoring will measure physio-chemical parameters and nutrients, and will need to be episodic, in response to rainfall. Parameters to be measured will include:

- Temperature
- pH
- Electrical conductivity (EC)
- Dissolved oxygen (DO)
- Oxidation-reduction potential (ORP)
- TN
- Total kjeldahl nitrogen (TKN)
- Ammonia (NH_4)
- Oxides of nitrogen (NO_x)
- Reactive phosphorous
- TP.

10.2 Groundwater monitoring

Post-development groundwater monitoring aims to provide a site specific understanding of impacts to the water table. Given the variability of the observed water quality data (see **Section 3.6.2**), it is proposed that post-development groundwater monitoring will reference both a derived water quality target and an upstream/downstream comparison of water quality within the site. These could either be new bores or may include the existing monitoring bore network across Greater Curtin.

Groundwater quality monitoring should be conducted on a quarterly basis for a period of two years, commencing on completion of construction works at all development lots. Parameters to be monitored will be consistent with those measured for surface water.

10.3 Contingency action plan

10.3.1 Trigger criteria

Groundwater quality trigger values for the site have been derived from the NWQMS (ANZECC 2000) trigger values, described in **Table 10**.

Table 10: *Post development triggers values*

Trigger Values	pH	EC (mS/cm)	TP (mg/L)	TN (mg/L)	NO_x (mg/L)	NH_3 (mg/L)
Average	6.8 - 8.0	0.3	0.065	1.2	0.15	0.08

Given there is no surface water quality data from within the site, the initial monitoring of surface water will provide the first baseline measurement, and the interpretation of (and response to) data will be based on an analysis of trends and comparison to nearby groundwater quality data.

10.3.2 Contingency actions

If the results from the first monitoring occasion indicate that nutrient concentrations exceed the nominated trigger values, a number of contingency actions may be deployed. The first action is to repeat the monitoring to remove the potential for sampling error. If the repeat sampling event still shows results which breach the trigger values, the next action will be to compare upstream and downstream concentrations for groundwater, and by comparison to surface water quality. This will have the aim of determining whether the source of the exceedance is from surface runoff, the nearby open space management or whether it is indicative of background levels. If the downstream concentrations or surface versus groundwater concentrations are >20% higher than the upstream concentrations, the following actions may be undertaken:

- Review nutrient application practices to identify source if possible.
- Conduct surveillance of development area to determine other potential and obvious nutrient inputs.
- Remove source if possible (e.g. fertiliser applications)
- Remove sediment bound nutrients by cleaning accumulated sediments from rain gardens, living stream or other treatment areas.
- Harvesting/pruning of plants in rain gardens to encourage further growth and nutrient removal.

If the downstream nutrient concentrations are found to be generally consistent with the upstream concentrations, the next action will be to conduct a comparison with background data collected prior to development. There is some amount of variability in nutrient concentrations experienced across Greater Curtin 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 the DWER to determine if the trigger values should be revised.

Following the implementation of the above contingency measures the groundwater quality will be re-sampled. If the results of the analysis still show water quality characteristics which breach the trigger values, DWER will be informed of the results, and Curtin University will seek to work with

DWER to determine if the results are representative of a broader catchment management issue, and whether any additional contingency actions need to be implemented.

10.4 Reporting

An ongoing water quality monitoring report will be prepared by Curtin to assist in internal review of onsite management practices. This reporting would tie in with existing WEMP reporting and annual reporting DWER. The water quality monitoring will be made available to the ToVP and DWER on request. Where interim results are available, these will be provided to the ToVP and DWER upon request during the monitoring program.

11 Implementation Plan

This LWMS is a key supportive document for the GCMP development. The provision of this LWMS provides 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 site and to guide the development of future UWMPs.

11.1 Roles and Responsibility

This LWMS provides a framework that Curtin University can utilise to assist in establishing stormwater management methods that have been based upon site specific environmental characteristics and are consistent with relevant Stage Government policies. The responsibility for working within the framework established within this LWMS rests with Curtin University, although it is anticipated that future UWMPs will be developed in consultation with the ToVP as the ultimate approval agency.

The proponents of development within each of the individual development lots will be responsible for the preparation of the detailed designs and supportive UWMPs. It is also their responsibility to demonstrate that the proposed development within the individual development lots and the supportive UWMPs comply with the objectives and management approaches provided in this LWMS.

11.2 Funding

Funding for the strategies as described in this LWMS will be managed through parties to the project. Funding for works related within individual development lots will be subject to negotiation between Curtin University and the proponent for each lot.

11.3 Review

It is not anticipated that this LWMS will be reviewed unless the proposed development layout undergoes significant change post-lodgement. If the GCMP is substantially modified this LWMS could be revised and criteria reviewed to ensure that all are still appropriate. While this is possible, it is most likely that such changes could be addressed within successive planning stages and could be documented in a future UWMP.

12 References

12.1 General references

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Figures

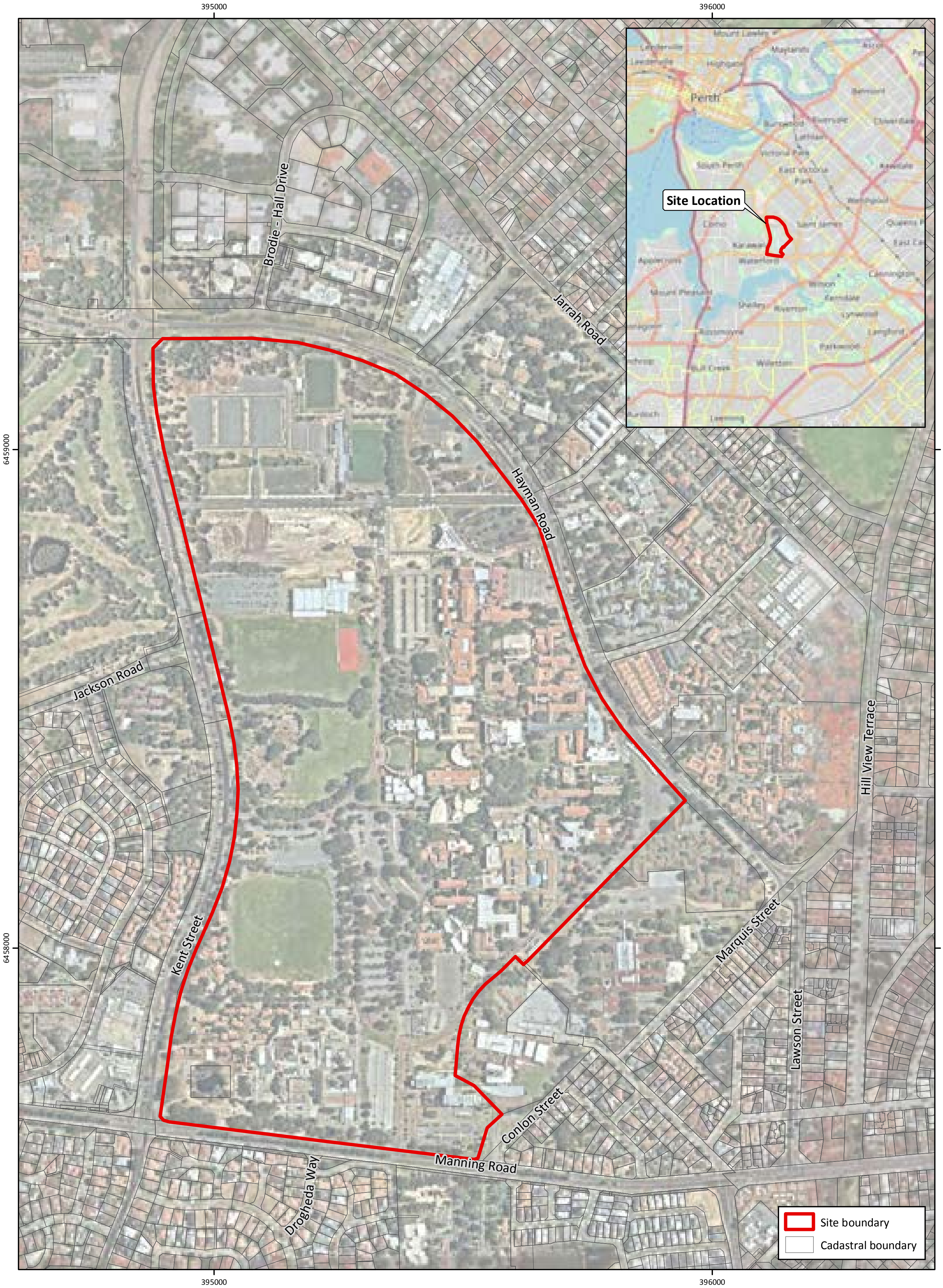

Figure 1: **Site Location**

Project: Local Water Management Strategy
Curtin University

Client: Curtin

Plan Number:
EP18-089(01)--F02

Drawn:	KNM
Date:	28/11/2018
Checked:	JRT
Approved:	DPC
Date:	28/11/2018

N

0 100 200
Metres

Scale: 1:210,000@A4

GDA 1994 MGA Zone 50

emerge
ASSOCIATES

While Emerge Associates makes every attempt to ensure the accuracy and completeness of data, Emerge accepts no responsibility for externally sourced data used

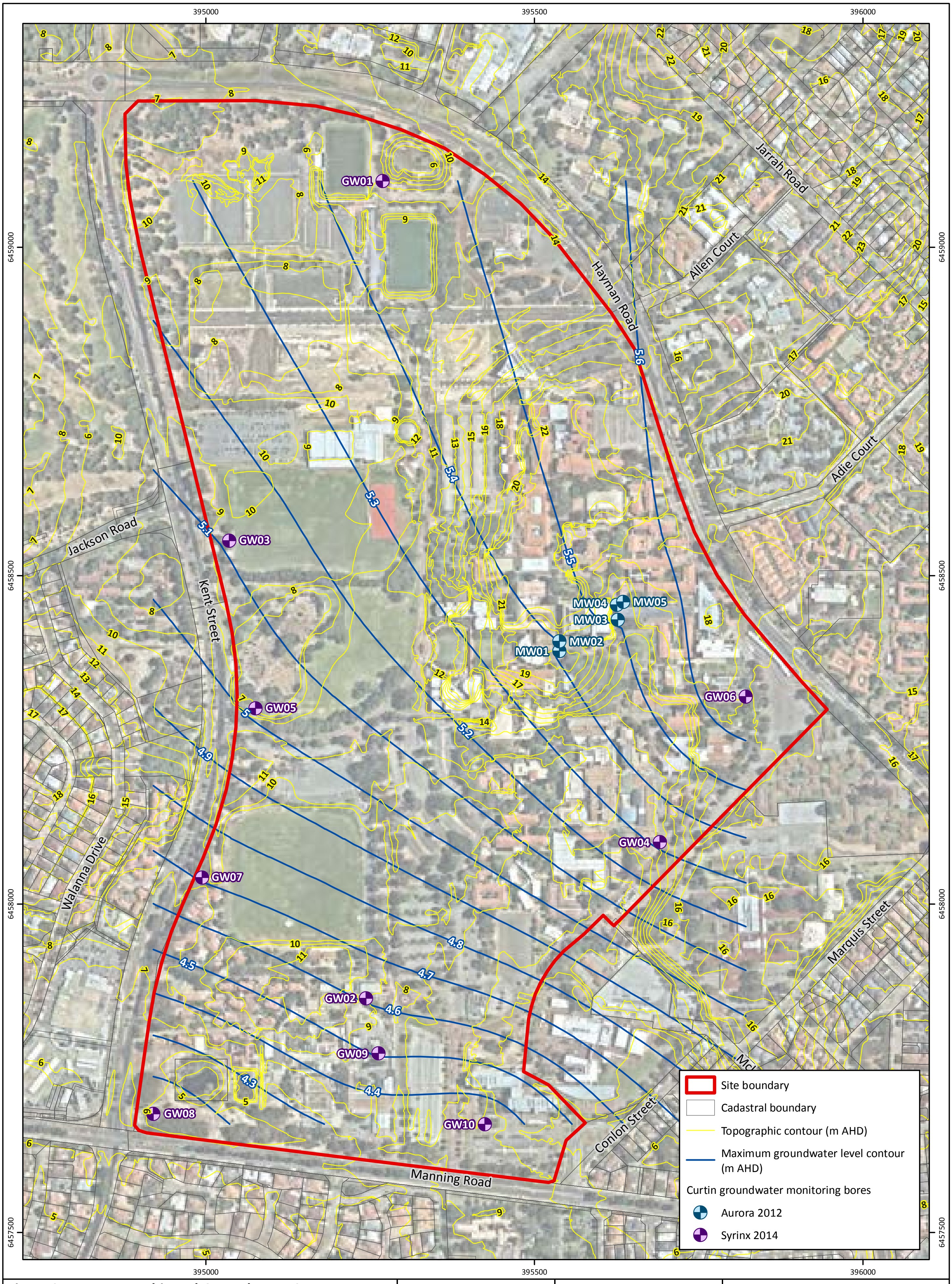

Figure 2: **Topographic and Groundwater Contours**

Project: Local Water Management Strategy
Curtin University

Client: Curtin

Plan Number:
EP18-089(01)--F03
Drawn: KNM
Date: 28/11/2018
Checked: JRT
Approved: DPC
Date: 28/11/2018

N

Scale: 1:7,500@A4
GDA 1994 MGA Zone 50

emerge
ASSOCIATES

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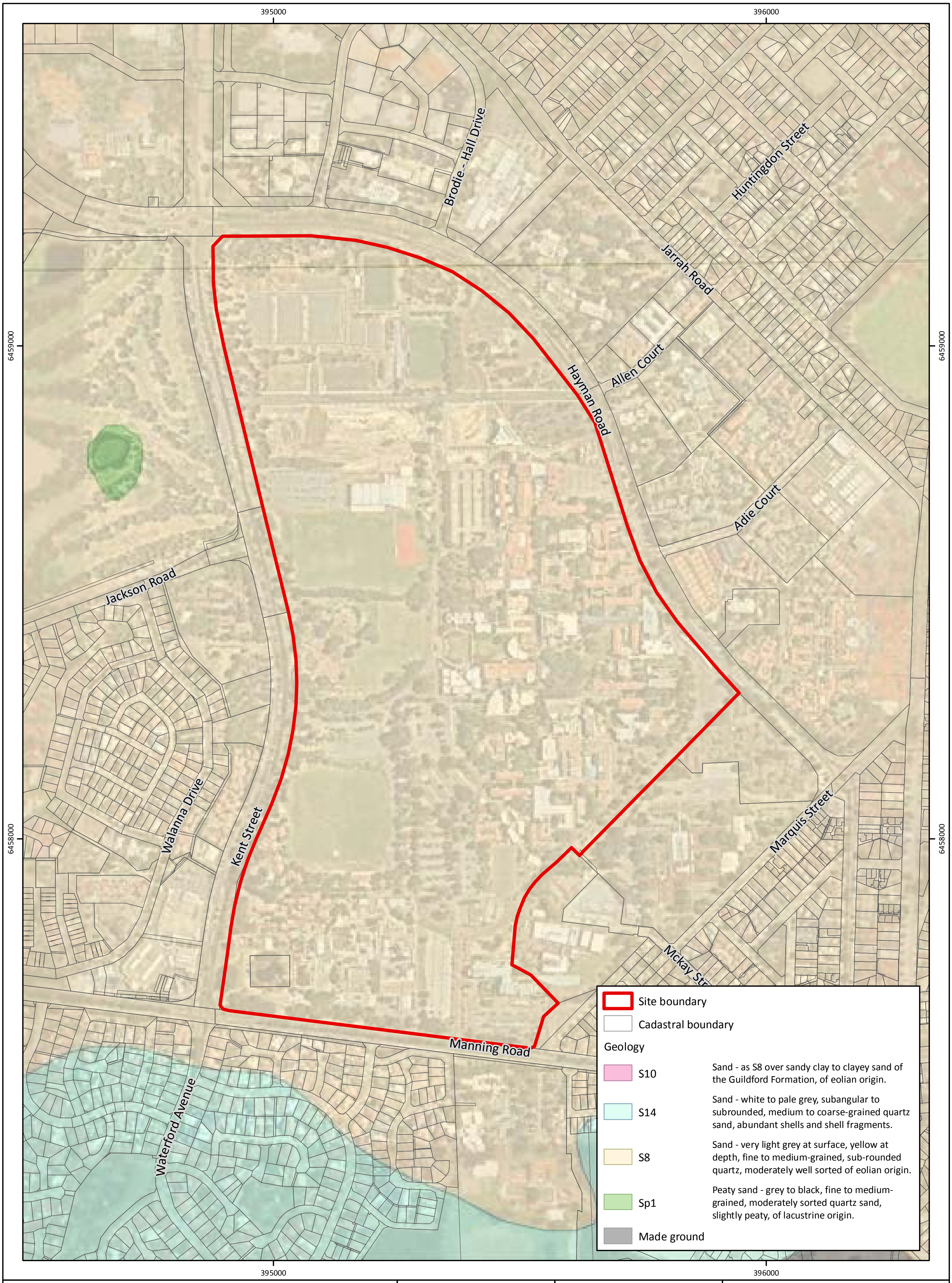


Figure 3: **Regional Geological Mapping**

Project: Local Water Management Strategy
Curtin University

Client: Curtin

Plan Number:
EP18-089(01)--F04

Drawn:	KNM
Date:	28/11/2018
Checked:	JRT
Approved:	DPC
Date:	28/11/2018

N

0 100 200
Metres
Scale: 1:10,000@A4
GDA 1994 MGA Zone 50

emerge ASSOCIATES

While Emerge Associates makes every attempt to ensure the accuracy and completeness of data, Emerge accepts no responsibility for externally sourced data used

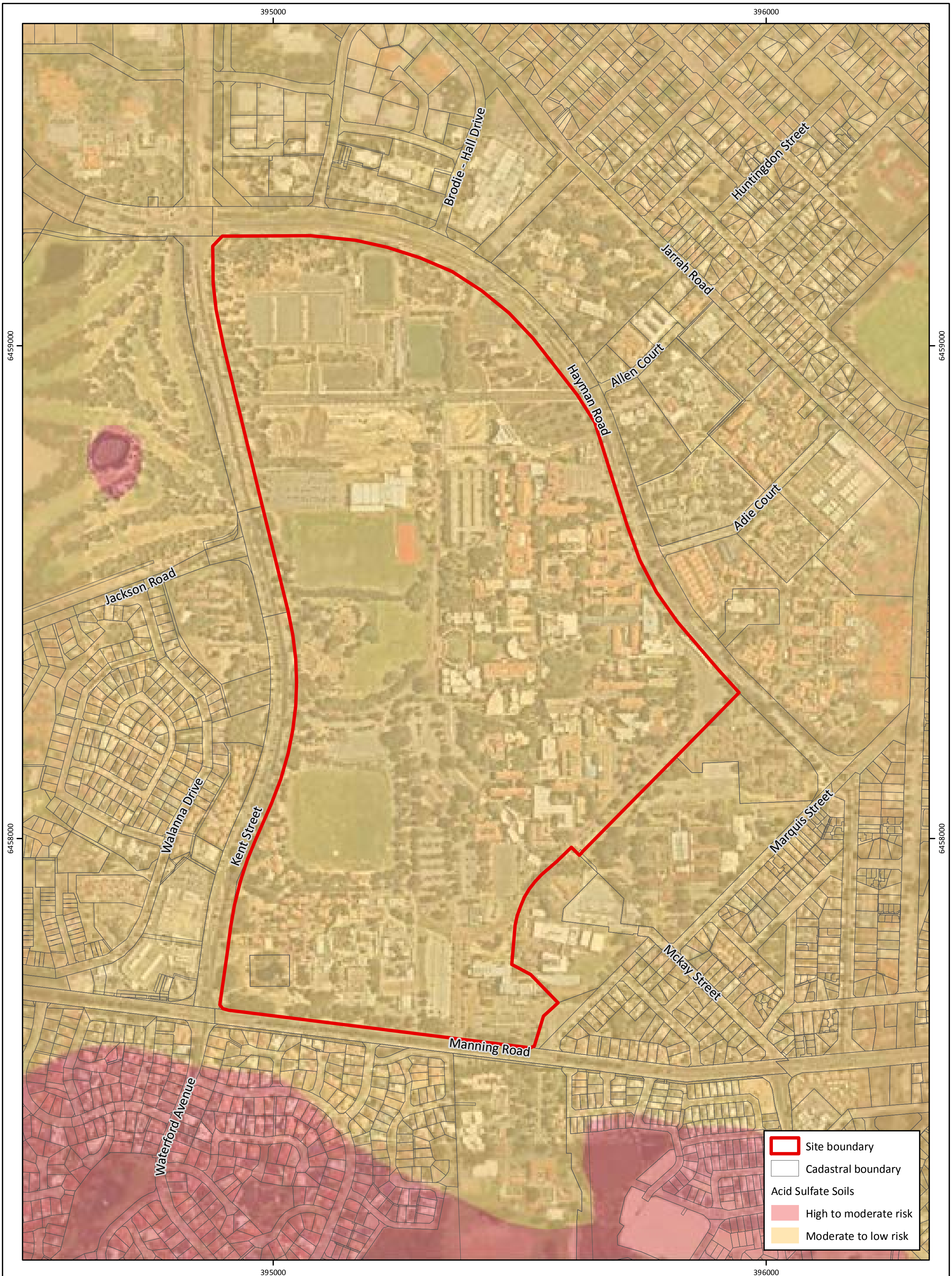


Figure 4: **Acid Sulfate Soil Risk Mapping**

Project: Local Water Management Strategy
Curtin University
Client: Curtin

Plan Number:
EP18-089(01)--F05
Drawn: KNM
Date: 28/11/2018
Checked: JRT
Approved: DPC
Date: 28/11/2018

N

0 100 200
Metres
Scale: 1:10,000@A4
GDA 1994 MGA Zone 50

emerge ASSOCIATES

While Emerge Associates makes every attempt to ensure the accuracy and completeness of data, Emerge accepts no responsibility for externally sourced data used

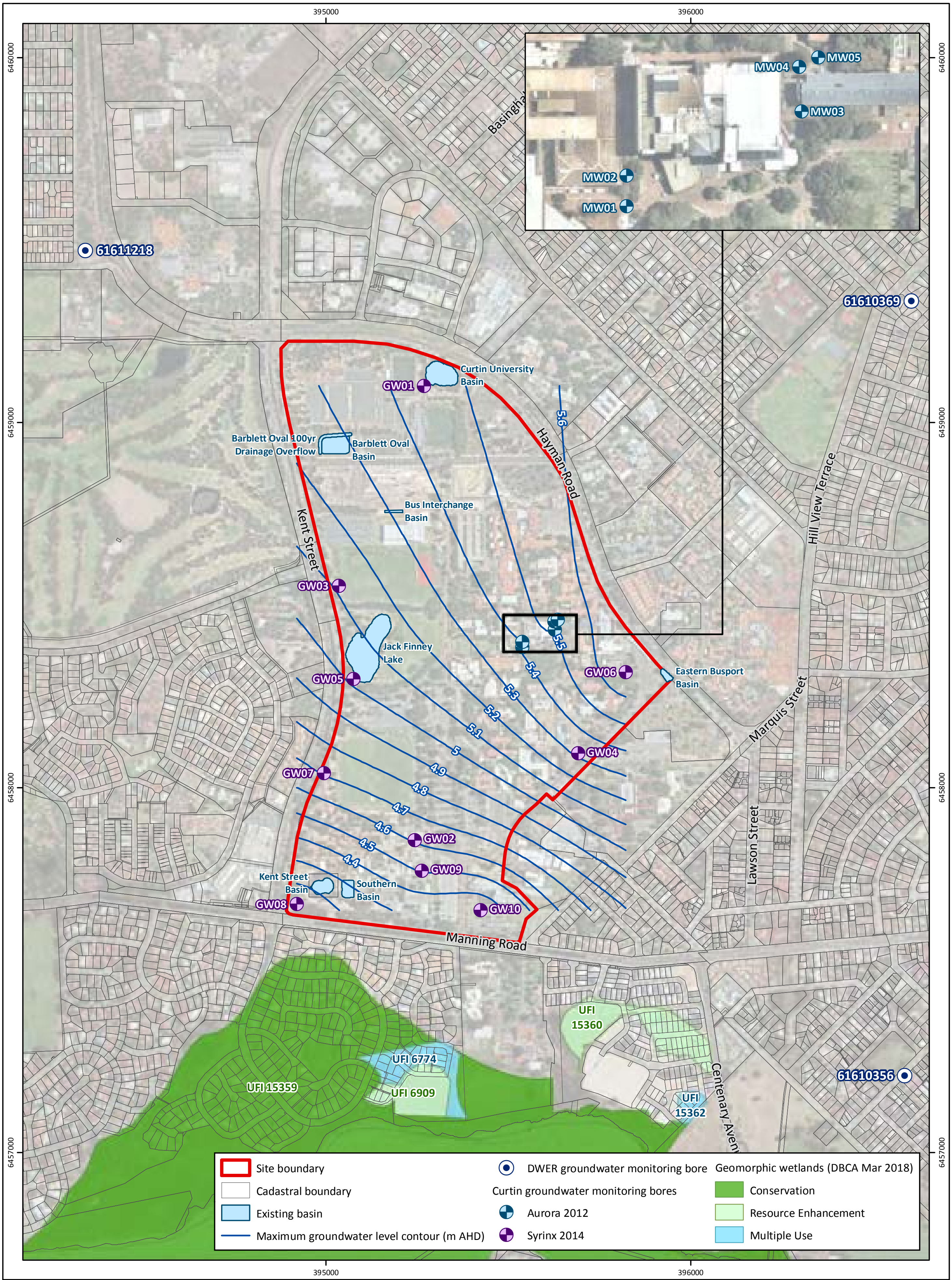


Figure 5: Wetlands and Hydrological Features

Project: Local Water Management Strategy
Curtin University

Client: Curtin

Plan Number:
EP18-089(01)--F06

Drawn:	KNM
Date:	28/11/2018
Checked:	JRT
Approved:	DPC
Date:	28/11/2018

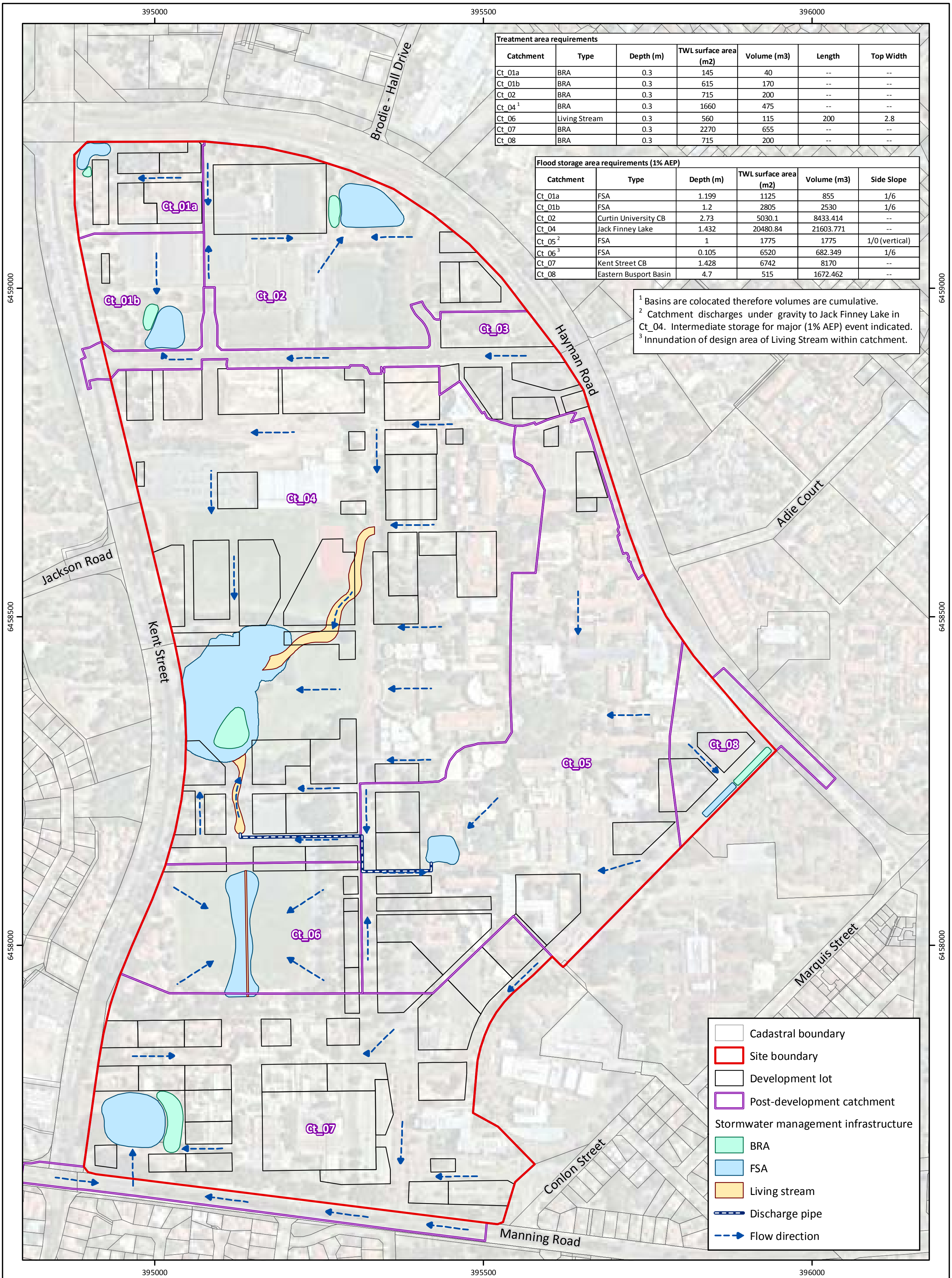
N

0 100 200 300 400
Metres

Scale: 1:13,500@A4
GDA 1994 MGA Zone 50

emerge
ASSOCIATES

While Emerge Associates makes every attempt to ensure the accuracy and completeness of data, Emerge accepts no responsibility for externally sourced data used



Treatment area requirements

Catchment	Type	Depth (m)	TWL surface area (m2)	Volume (m3)	Length	Top Width
Ct_01a	BRA	0.3	145	40	--	--
Ct_01b	BRA	0.3	615	170	--	--
Ct_02	BRA	0.3	715	200	--	--
Ct_04[1]	BRA	0.3	1660	475	--	--
Ct_06	Living Stream	0.3	560	115	200	2.8
Ct_07	BRA	0.3	2270	655	--	--
Ct_08	BRA	0.3	715	200	--	--

Flood storage area requirements (1% AEP)

Catchment	Type	Depth (m)	TWL surface area (m2)	Volume (m3)	Side Slope
Ct_01a	FSA	1.199	1125	855	1/6
Ct_01b	FSA	1.2	2805	2530	1/6
Ct_02	Curtin University CB	2.73	5030.1	8433.414	--
Ct_04	Jack Finney Lake	1.432	20480.84	21603.771	--
Ct_05[2]	FSA	1	1775	1775	1/0 (vertical)
Ct_06[3]	FSA	0.105	6520	682.349	1/6
Ct_07	Kent Street CB	1.428	6742	8170	--
Ct_08	Eastern Busport Basin	4.7	515	1672.462	--

[1] Basins are colocated therefore volumes are cumulative.

[2] Catchment discharges under gravity to Jack Finney Lake in Ct_04. Intermediate storage for major (1% AEP) event indicated.

[3] Innundation of design area of Living Stream within catchment.

Figure 6: Stormwater Management Plan

Project: Local Water Management Strategy
Curtin University

Client: Curtin

Plan Number:
EP18-089(01)--F07
Drawn: KNM
Date: 28/11/2018
Checked: JRT
Approved: DPC
Date: 28/11/2018

N

0 100 200
Metres
Scale: 1:7,500@A4
GDA 1994 MGA Zone 50

emerge ASSOCIATES

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Appendix A

Greater Curtin Master Plan

THE ILLUSTRATIVE MASTER PLAN

An illustrative plan has been produced to visually explore and communicate the full potential of what can be delivered, through the application of the plans and strategies which define the physical translation of the Greater Curtin vision.

It provides an indicative view of the structure of the built form, infrastructure and landscape character that will result from the application of the master plan design direction and planning principles, and in particular it seeks to demonstrate the place making and experiential outcomes that are sought.

1	Gateway development
2	Urban student residential
3	The Greens
4	Perth Hockey Stadium – elite hockey hub
5	Light rail alignment
6	Hayman Road light rail stop
7	Northern light rail stop, bus interchange and retail hub
8	Health research and practice
9	Indoor Sport and recreation centre
10	Urban plaza and Curtin Dome
11	Living Stream providing stormwater management and urban amenity
12	Main Street urban boulevard
13	Corso
14	Jack Finney Lake
15	Central Park
16	Mixed Residential
17	Facilities management hub
18	Academic core
19	Dolphin dreaming trail
20	Southern light rail stop, urban plaza and retail hub
21	Existing trees
22	New arts hub – education and community
23	Improved connectivity to Canning College
24	Research Laboratories
25	Light rail stabling facility


BENTLEY TECHNOLOGY PARK
POLYTECHNIC WEST TAFE
HAYMAN ROAD
KENT STREET
WATERFORD PLAZA
CANNING COLLEGE
MANNING ROAD
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25

Appendix B

Greater Curtin Masterplan development stages

DELIVERY

The following staging plans identify the proposed sequencing for the delivery of development across the site in four stages: 0-5 years, 6-10 years, 11-15 years and 16-20 years.

The proposed delivery sequencing builds around a series of early catalyst opportunities that will ‘kick start’ development around the northern and southern transport nodes.

STAGE 1
0-5 YEARS

STAGE 2
6-10 YEARS

STAGE 3
11-15 YEARS

STAGE 4
16-20 YEARS

Land Use

- 🟪 AC. Academic
- *GF 🟩 CO. Community Space
- 🟦 RA. Residential Apartment
- 🟨 RC. Residential Academic
- ☐ RE. Retail (ground floor only)
- ⬜ RH. Residential Hotel
- 🟥 RO. Residential Short Stay
- ⬛ RS. Residential Students
- 🟧 RT. Residential Townhouse
- 🟦 OF. Office/Commercial
- ▨ TC. Transport Car Park
- ▨ TI. Transit Interchange
- ▨ TS. Transit Stabling
- ⬚ Parcel Boundary

* Denotes Ground Floor land use for certain community use buildings

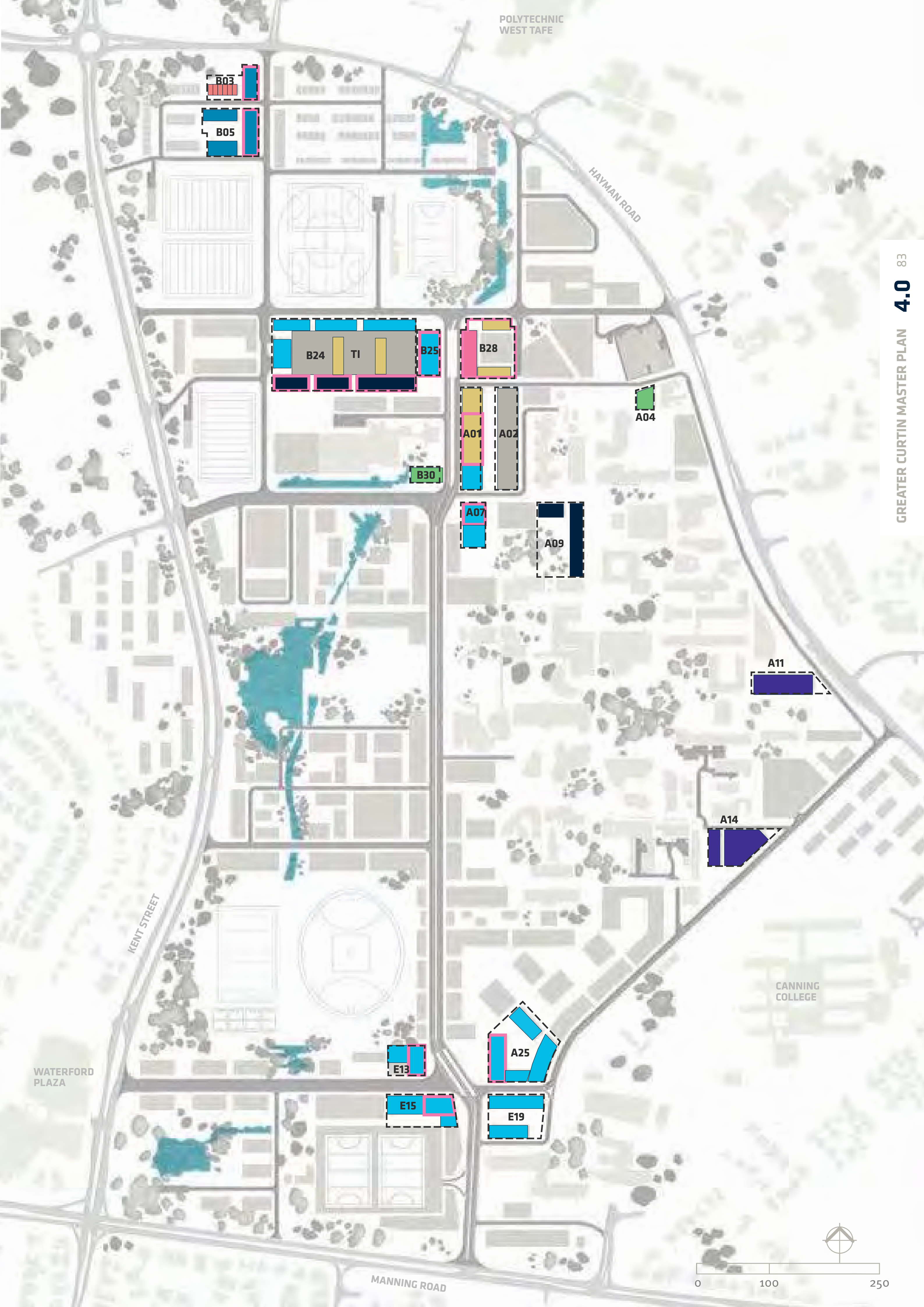
STAGE 1: 0-5 YEARS

Stage 1 delivers key public transport infrastructure that creates northern and southern transit hubs, establishing strong arrival points and encouraging development to grow.

In Greater Curtin North, a new bus interchange establishes a northern gateway, framing Main Street and catalysing large and small format retail and office space. Significant student residential is also established, consolidating activity in Greater Curtin North and further supporting retail development.

In Greater Curtin South, significant academic activities and commercial offices establish around a transit-enabled square, harnessing and enhancing synergies between research and industry.

Parcel Number	**Parcel Area (m²)**
A01	3,822
A02	3,822
A04	618
A07	1,898
A09	6,061
A11	2,506
A14	3,390
A25	7,264
B03	2,455
B05	4,458
B24	18,682
B25	1,703
B28	5,348
B30	752
E13	2,042
E15	3,847
E19	4,181
TOTAL	**72,849**


POLYTECHNIC
WEST TAFE
B03
B05
HAYMAN ROAD
B24
TI
B25
B28
A01
A02
A04
B30
A07
A09
A11
A14
KENT STREET
CANNING
COLLEGE
WATERFORD
PLAZA
A25
E13
E15
E19
MANNING ROAD
0
100
250

Land Use

- 🟪 AC. Academic
- *GF 🟩 CO. Community Space
- 🟦 RA. Residential Apartment
- 🟨 RC. Residential Academic
- □ RE. Retail (ground floor only)
- ⬜ RH. Residential Hotel
- 🟥 RO. Residential Short Stay
- ⬛ RS. Residential Students
- 🟥 RT. Residential Townhouse
- 🟦 OF. Office/Commercial
- ▨ TC. Transport Car Park
- ▨ TI. Transit Interchange
- ▨ TS. Transit Stabling
- ⛶ Parcel Boundary

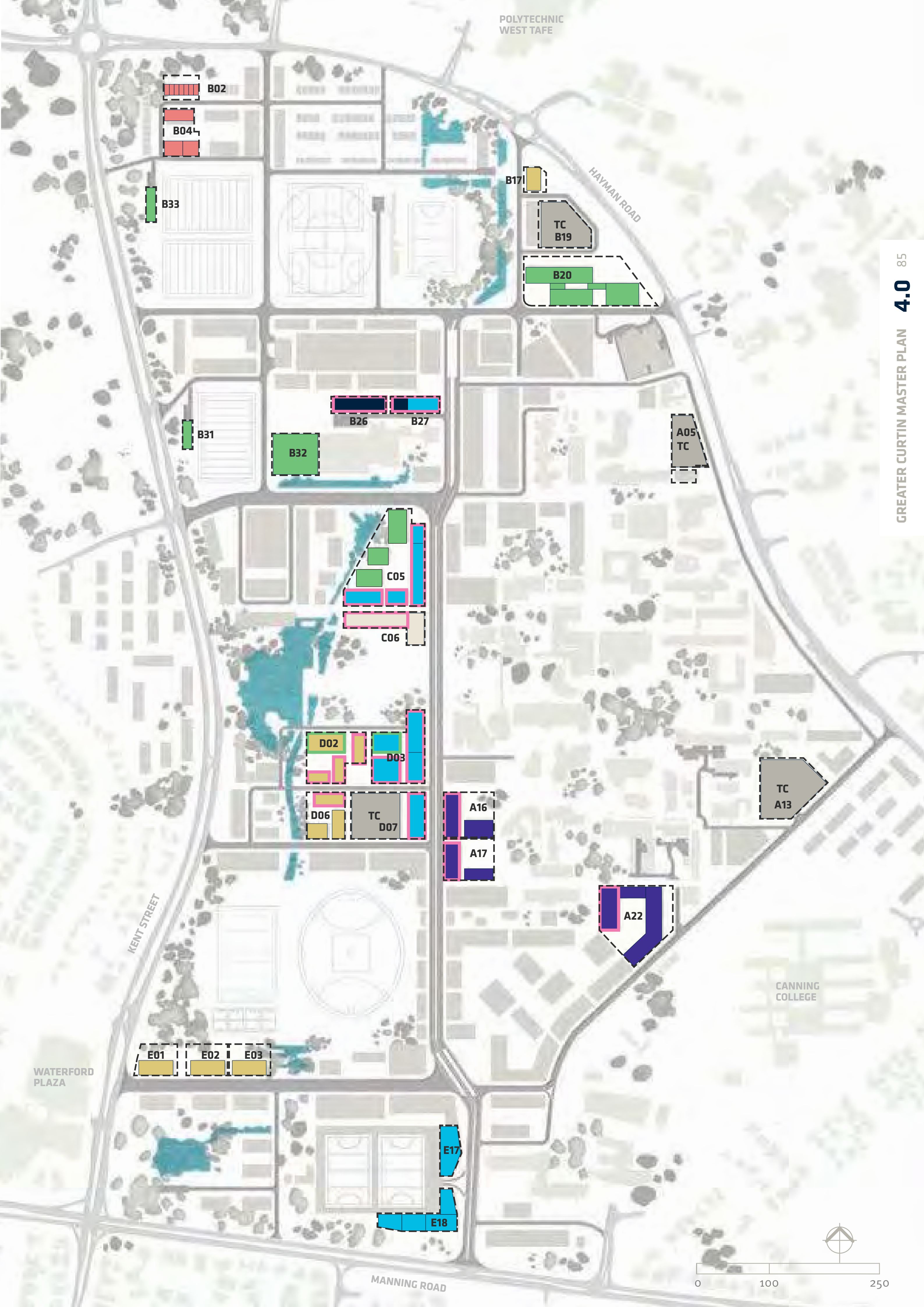
* Denotes Ground Floor land use for certain community use buildings

STAGE 2: 6-10 YEARS

Stage 2 strengthens and diversifies the core of Greater Curtin; further defining Main Street as a central spine framed by commercial and community development. Key east-west bands of development are established, extending the traditional academic core, blurring the boundary between city and university and framing key parkland and strengthening the ceremonial heart.

Increased residential development diversifies Greater Curtin's population and supports the expansion of the indoor sporting centre. Key parking structures are delivered; further unlocking redevelopment potential and supporting a movement hierarchy that prioritises people over cars.

Parcel Number	Parcel Area (m²)
A05	2,608
A13	5,547
A16	4,072
A17	3,749
A22	8,211
B02	1,448
B04	2,690
B17	1,059
B19	5,679
B20	10,019
B26	1,830
B27	1,999
B31	439
B32	3,390
B33	530
C05	10,501
C06	2,698
D02	4,550
D03	5,458
D06	3,098
D07	6,041
E01	2,147
E02	2,309
E03	2,309
E17	1,550
E18	2,895
TOTAL	**96,826**


POLYTECHNIC WEST TAFE
B02
B04
B17
B33
HAYMAN ROAD
TC B19
B20
B26
B27
A05 TC
B31
B32
C05
C06
D02
D03
D06
TC D07
A16
A17
TC A13
A22
KENT STREET
CANNING COLLEGE
WATERFORD PLAZA
E01
E02
E03
E17
E18
MANNING ROAD
0
100
250

Land Use

🟪 AC. Academic
*GF 🟩 CO. Community Space
🟦 RA. Residential Apartment
🟨 RC. Residential Academic
□ RE. Retail (ground floor only)
⬜ RH. Residential Hotel
🟥 RO. Residential Short Stay
⬛ RS. Residential Students
🟥 RT. Residential Townhouse
🟦 OF. Office/Commercial
⬜ TC. Transport Car Park
⬜ TI. Transit Interchange
⬜ TS. Transit Stabling
⬚ Parcel Boundary

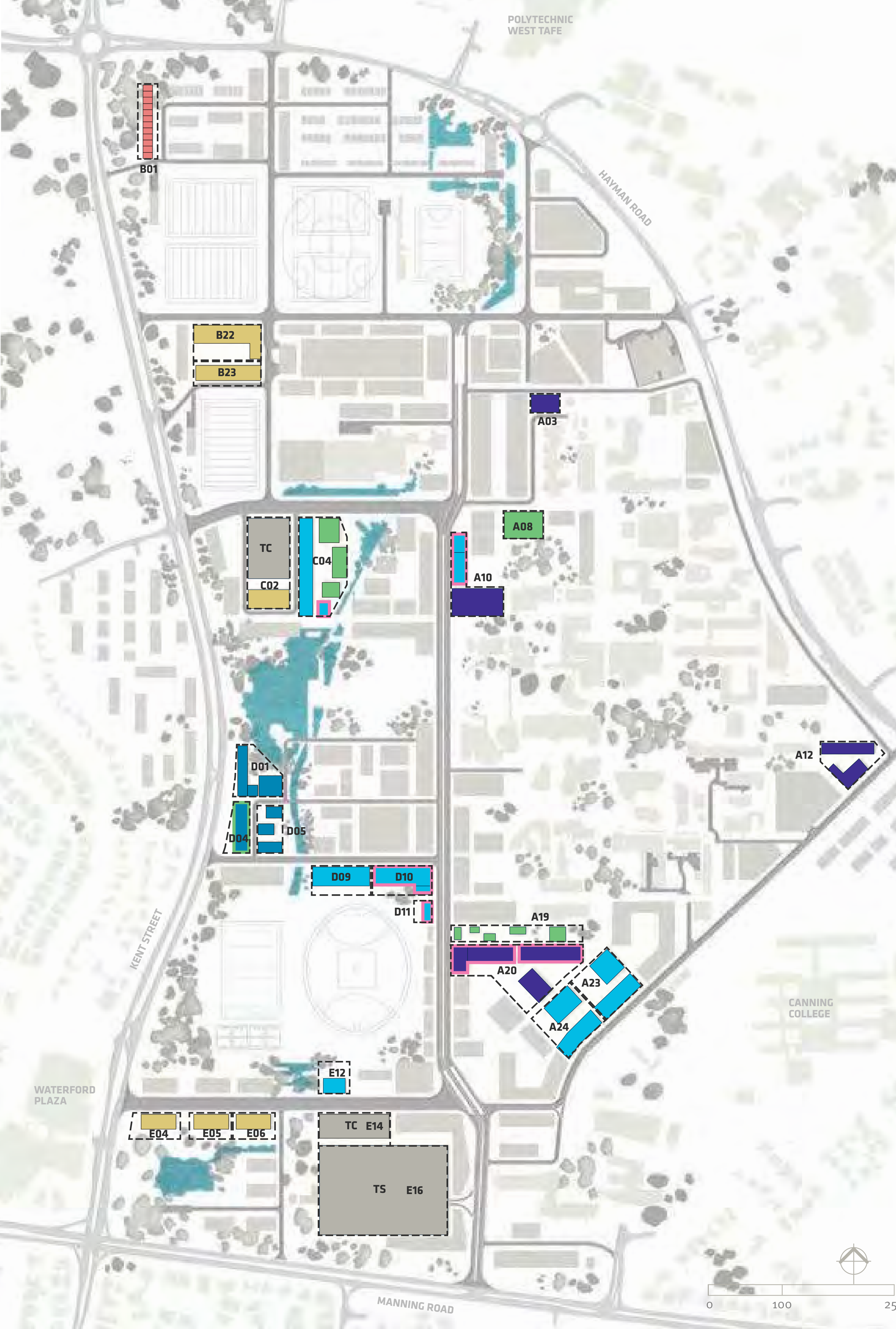
* Denotes Ground Floor land use for certain community use buildings

STAGE 3: 11-15 YEARS

Stage 3 further extends east-west bands of development, framing key streets and parkland. In Greater Curtin South, the southern transit node is augmented with the establishment of a strong arts and research presence.

The delivery of additional parking structures liberates further land for redevelopment and community enjoyment. In Greater Curtin South, a light rail stabling facility provides the opportunity to further establish partnerships in research and industry.

Parcel Number	Parcel Area (m²)
A03	879
A08	1,807
A10	3,880
A12	3,372
A19	3,486
A20	9,607
A23	4,485
A24	4,944
B01	2,391
B22	4,010
B23	2,656
C02	6,619
C04	7,876
D01	3,379
D04	1,704
D05	1,965
D09	2,819
D10	2,819
D11	592
E04	2,449
E05	2,145
E06	2,145
E12	1,609
E14	3,936
E16	20,700
TOTAL	**102,274**


POLYTECHNIC
WEST TAFE
HAYMAN ROAD
B01
B22
B23
A03
A08
TC
C02
C04
A10
A12
D01
D04
D05
D09
D10
D11
A19
A20
A23
A24
KENT STREET
CANNING COLLEGE
E12
WATERFORD PLAZA
E04
E05
E06
TC E14
TS E16
MANNING ROAD
0
100
250

Land Use

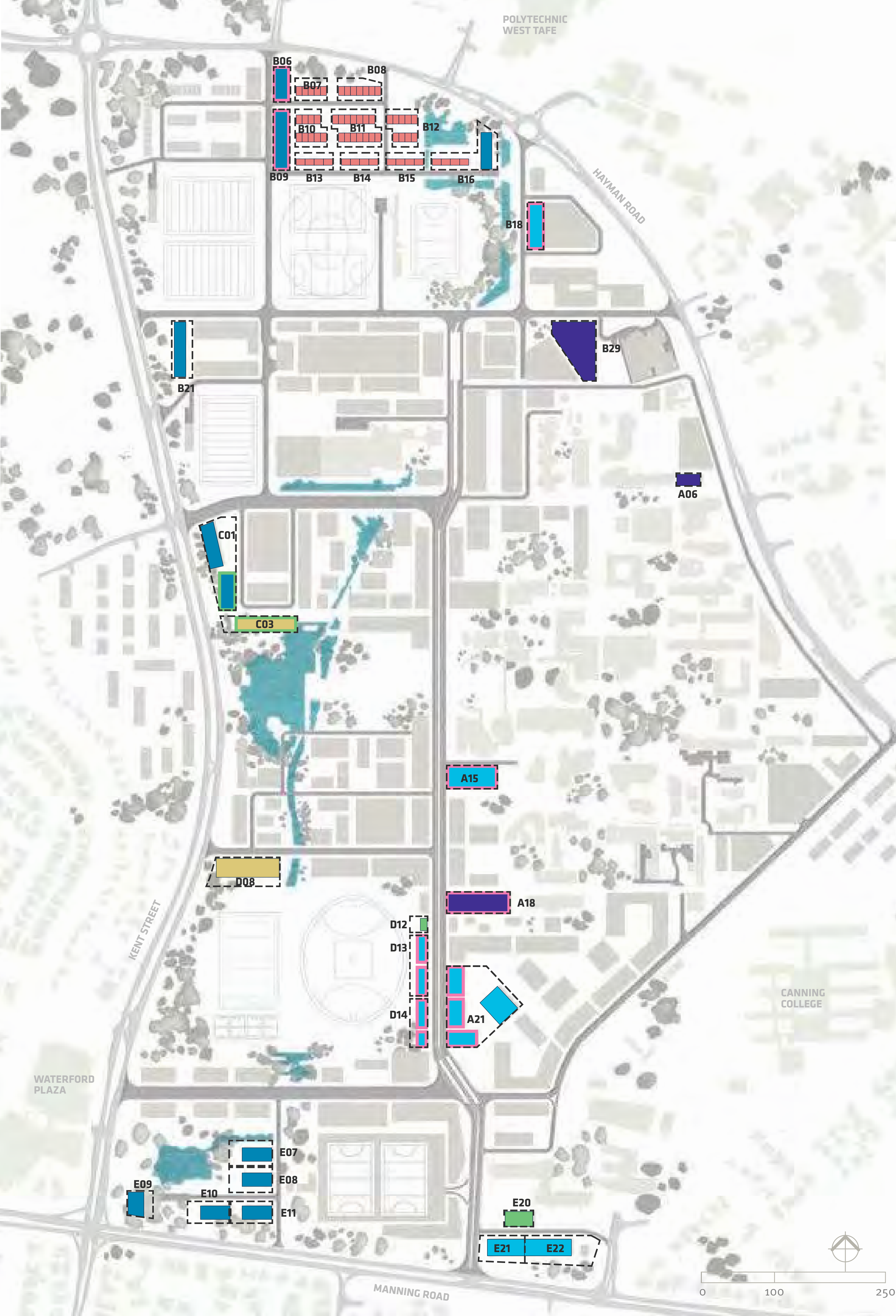
🟪 AC. Academic
*GF 🟩 CO. Community Space
🟦 RA. Residential Apartment
🟨 RC. Residential Academic
□ RE. Retail (ground floor only)
⬜ RH. Residential Hotel
🟥 RO. Residential Short Stay
⬛ RS. Residential Students
🟧 RT. Residential Townhouse
🟦 OF. Office/Commercial
▩ TC. Transport Car Park
▩ TI. Transit Interchange
▩ TS. Transit Stabling
⛶ Parcel Boundary

* Denotes Ground Floor land use for certain community use buildings

STAGE 4: 16-20 YEARS

Stage 4 augments the diversification of Greater Curtin's residential population, with the establishment of a variety of living options throughout the city. Additional office commercial and retail development strengthens Main Street and a community hub is created around the resources and chemistry research hub.

Parcel Number	**Parcel Area (m²)**
A06	469
A15	1,961
A18	2,258
A21	7,813
B06	907
B07	1,149
B08	1,535
B09	1,596
B10	1,793
B11	2,789
B12	1,793
B13	1,043
B14	1,043
B15	1,043
B16	2,201
B18	1,293
B21	1,957
B29	3,268
C01	4,237
C03	1,992
D08	3,338
D12	440
D13	1,753
D14	1,395
E07	1,931
E08	1,931
E09	1,089
E10	1,559
E11	1,559
E20	752
E21	2,028
E22	3,532
TOTAL	**63,447**


POLYTECHNIC
WEST TAFE
B06
B08
B07
B10
B11
B12
B09
B13
B14
B15
B16
HAYMAN ROAD
B18
B29
B21
A06
C01
C03
A15
D08
A18
KENT STREET
D12
D13
D14
A21
CANNING
COLLEGE
WATERFORD
PLAZA
E07
E08
E09
E10
E11
E20
E21
E22
MANNING ROAD
0
100
250

Appendix C

Groundwater monitoring bore logs

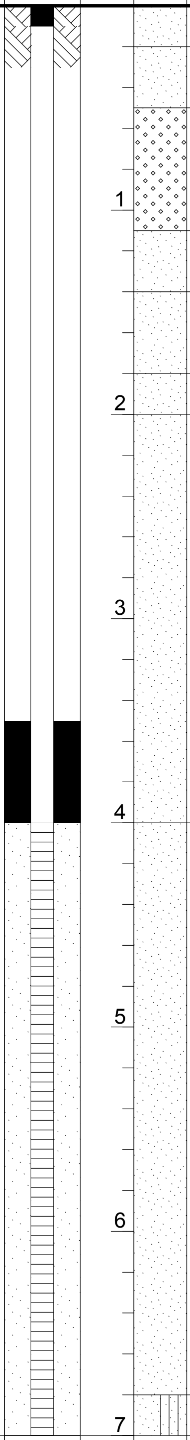
Syrinx Environmental

BOREHOLE NUMBER GW01

PAGE 1 OF 1

CLIENT Curtin University
PROJECT NAME Groundwater and Soil Investigations
PROJECT NUMBER 1320
PROJECT LOCATION Curtin University

DATE STARTED 27/9/13
COMPLETED 1/10/13
R.L. SURFACE (m) 8.092
DATUM m AHD
DRILLING CONTRACTOR National Geotech
NORTHING (m) 6459101.168
CO-ORDINATE SYSTEM MGA95 Zone 50
EQUIPMENT Direct Push
EASTING (m) 395268.761
HOLE LOCATION
HOLE SIZE (mm) 48
LOGGED BY NR
CHECKED BY PZ
NOTES



Method	Water	RL (m)	Depth (m)	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
HA		8		SAND, medium to coarse, brown-grey, organic matter.			
				SAND, medium, pale brown-grey, organic matter.		0.0	
		7	1	SAND, medium, well graded, grey-white.		0.0	
				SAND, medium, pale yellow-grey.			
				SAND, medium, yellow-grey, slightly moist.		0.0	
			2	SAND, medium, brown-grey.			
Direct Push		6		SAND, medium to coarse, poorly graded, sub-rounded, pale yellow-orange, moist.		0.0	
						0.0	
		5	3			0.0	
						0.0	
		4	4	SAND, medium to coarse, rounded, grey, moist to wet.		0.0	
	▼					0.0	
		3	5			0.0	
						0.0	
		2	6			0.0	
						0.0	
			7	SAND WITH SILT, medium to coarse, grey, wet.		0.0	
		1		Borehole GW01 terminated at 7m			

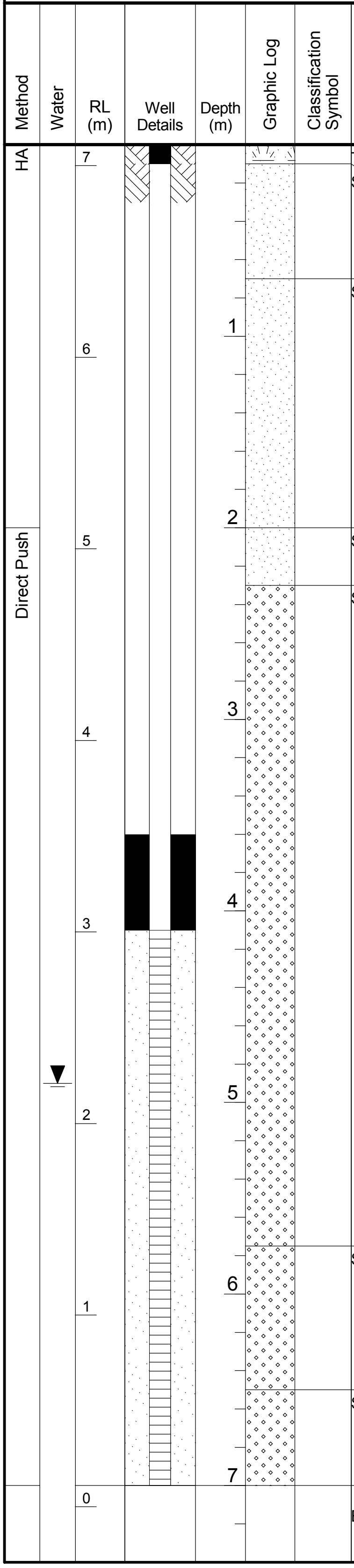
Syrinx Environmental

BOREHOLE NUMBER GW02

PAGE 1 OF 1

CLIENT Curtin University
PROJECT NAME Groundwater and Soil Investigations
PROJECT NUMBER 1320
PROJECT LOCATION Curtin University

DATE STARTED 2/10/13 **COMPLETED** 2/10/13
R.L. SURFACE (m) 7.110 **DATUM** m AHD
DRILLING CONTRACTOR National Geotech
NORTHING (m) 6457856.429 **CO-ORDINATE SYSTEM** MGA95 Zone 50
EQUIPMENT Direct Push
EASTING (m) 395243.667 **HOLE LOCATION**
HOLE SIZE (mm) 48
LOGGED BY NR **CHECKED BY** PZ
NOTES



Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
TOPSOIL, fine to medium, poorly graded, sub-rounded, dark brown, dry, organic matter.			
SAND, medium, poorly graded, sub-rounded, dark grey, dry.		0.0	
SAND, medium, poorly graded, sub-rounded, pale grey, dry.		0.0 0.0	
SAND, medium to coarse, pale brown-grey, dry.		0.0	
SAND, fine to medium, well graded, white-grey, wet.		0.0 0.0 0.0 0.0 0.0 0.0 0.0	
SAND, fine to medium, well graded, pale brown-grey, wet.		0.0	
SAND, medium to coarse, well graded, sub-rounded, brown, wet.		0.0 0.0	
Borehole GW02 terminated at 7m			

BOREHOLE NUMBER GW03

PAGE 1 OF 1

Syrinx Environmental

CLIENT Curtin University

PROJECT NUMBER 1320

PROJECT NAME Groundwater and Soil Investigations

PROJECT LOCATION Curtin University

DATE STARTED 1/10/13 **COMPLETED** 1/10/13

DRILLING CONTRACTOR National Geotech

EQUIPMENT Direct Push

HOLE SIZE (mm) 48

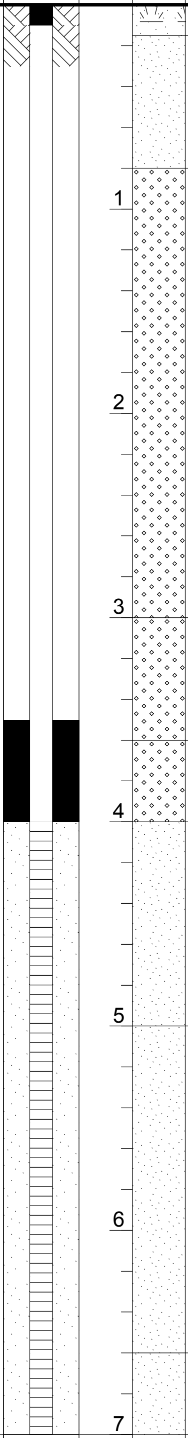
NOTES

R.L. SURFACE (m) 9.764 **DATUM** m AHD

NORTHING (m) 6458553.077 **CO-ORDINATE SYSTEM** MGA95 Zone 50

EASTING (m) 395035.29 **HOLE LOCATION**

LOGGED BY NR **CHECKED BY** PZ



Method	Water	RL (m)	Well Details	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
HA							TOPSOIL, fine to medium, well graded, dark brown-pale grey, dry, organic matter.			
		9					SAND, medium, poorly graded, dark grey-brown, dry, organic matter.		0.0	
Direct Push		8 7		1 2 3			SAND, medium to coarse, well graded, sub-rounded, pale grey-white, dry.		0.0 0.0 0.0 0.0	
							SAND, fine to medium, well graded, pale brown-red, dry to moist.		0.0 0.0	
		6		4			SAND, fine to medium, well graded, pale yellow-brown, moist, gravel pieces.			
	▼	5		5			SAND, medium to coarse, grey, moist to wet.		0.0 0.0	
		4		6			SAND, coarse, poorly graded, sub-angular, grey, wet.		0.0 0.0 0.0 0.0	
		3		7			SAND, coarse, poorly graded, sub-angular, grey, wet.		0.0	
							Borehole GW03 terminated at 7m			

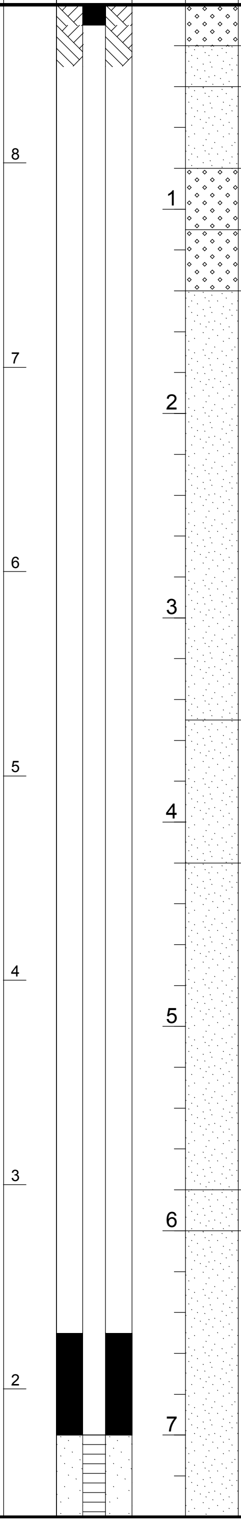
Syrinx Environmental

BOREHOLE NUMBER GW04

PAGE 1 OF 2

CLIENT Curtin University
PROJECT NAME Groundwater and Soil Investigations
PROJECT NUMBER 1320
PROJECT LOCATION Curtin University

DATE STARTED 27/9/13
COMPLETED 2/10/13
R.L. SURFACE (m) 8.774
DATUM m AHD
DRILLING CONTRACTOR National Geotech
NORTHING (m) 6458094.205
CO-ORDINATE SYSTEM MGA95 Zone 50
EQUIPMENT Direct Push
EASTING (m) 395691.314
HOLE LOCATION
HOLE SIZE (mm) 48
LOGGED BY NR
CHECKED BY PZ
NOTES



Method	Water	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
HA			SAND, medium, well graded, brown-grey.			
			SAND, medium, yellow-grey, organic matter.			
			SAND, medium, grey, slightly moist.		0.0	
			SAND, coarse, well graded, grey, slightly moist.		0.0	
			SAND, coarse, well graded, pale grey, slightly moist.			
Direct Push			SAND, coarse, grey, slightly moist.		0.0 0.0 0.0 0.0 0.0	
			SAND, medium, poorly graded, pale yellow-brown, moist.		0.0	
			SAND, medium, poorly graded, brown, moist, gravel pieces.		0.0 0.0 0.0	
			SAND, medium, poorly graded, pale yellow, moist.			
			SAND, medium, poorly graded, white-grey, moist.		0.0 0.0 0.0	

Syrinx Environmental

BOREHOLE NUMBER GW04

CLIENT Curtin University
PROJECT NAME Groundwater and Soil Investigations
PROJECT NUMBER 1320
PROJECT LOCATION Curtin University

DATE STARTED 27/9/13
COMPLETED 2/10/13
R.L. SURFACE (m) 8.774
DATUM m AHD
DRILLING CONTRACTOR National Geotech
NORTHING (m) 6458094.205
CO-ORDINATE SYSTEM MGA95 Zone 50
EQUIPMENT Direct Push
EASTING (m) 395691.314
HOLE LOCATION
HOLE SIZE (mm) 48
LOGGED BY NR
CHECKED BY PZ
NOTES

Method	Water	RL (m)	Well Details	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
Direct Push	▼	1 0		8 9			SAND, medium to coarse, poorly graded, grey-white, wet.		0.0 0.0 0.0 0.0 0.0	
		-1 -2 -3 -4 -5 -6		10 11 12 13 14			Borehole GW04 terminated at 9.5m			

Syrinx Environmental

BOREHOLE NUMBER GW05

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CLIENT Curtin University
PROJECT NAME Groundwater and Soil Investigations
PROJECT NUMBER 1320
PROJECT LOCATION Curtin University

DATE STARTED 1/10/13
COMPLETED 1/10/13
R.L. SURFACE (m) 12.410
DATUM m AHD
DRILLING CONTRACTOR National Geotech
NORTHING (m) 6458298.376
CO-ORDINATE SYSTEM MGA95 Zone 50
EQUIPMENT Direct Push
EASTING (m) 395075.416
HOLE LOCATION
HOLE SIZE (mm) 48
LOGGED BY NR
CHECKED BY PZ
NOTES

TOPSOIL, fine to medium, well graded, brown, dry, gravel pieces, organic matter.

SAND, coarse, poorly graded, dark grey-pale grey, dry.

SAND, medium to coarse, poorly graded, sub-angular, pale grey, moist to wet.

Borehole GW05 terminated at 4.5m

Syrinx Environmental

BOREHOLE NUMBER GW06

PAGE 1 OF 2

CLIENT Curtin University
PROJECT NAME Groundwater and Soil Investigations
PROJECT NUMBER 1320
PROJECT LOCATION Curtin University

DATE STARTED 27/9/13 **COMPLETED** 27/9/13
R.L. SURFACE (m) 8.789 **DATUM** m AHD
DRILLING CONTRACTOR National Geotech
NORTHING (m) 6458316.204 **CO-ORDINATE SYSTEM** MGA95 Zone 50
EQUIPMENT Direct Push
EASTING (m) 395821.859 **HOLE LOCATION**
HOLE SIZE (mm) 48
LOGGED BY NR **CHECKED BY** PZ
NOTES

Method	Water	RL (m)	Well Details	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
HA							TOPSOIL, medium to coarse, well graded, sub-angular, pale brown-dark brown, dry, organic matter.			
							SAND, medium to coarse, well graded, sub-angular, pale brown-pale grey, dry, organic matter.			
							SAND, coarse, poorly graded, grey-pale grey, dry.		0.0	
		8					SAND, coarse, poorly graded, yellow-pale yellow, dry.			
				1					0.0	
							SAND, coarse, poorly graded, sub-angular, yellow-black, dry to moist.		0.0	
		7								
				2					0.0	
Direct Push							SAND, medium to coarse, poorly graded, yellow-brown, dry.		0.0	
		6								
				3					0.0	
							SAND, medium to coarse, poorly graded, yellow, dry.		0.0	
		5								
				4					0.0	
							SAND, medium to coarse, poorly graded, pale yellow, dry.		0.0	
		4								
				5					0.0	
									0.0	
		3								
				6					0.0	
									0.0	
		2								
				7					0.0	

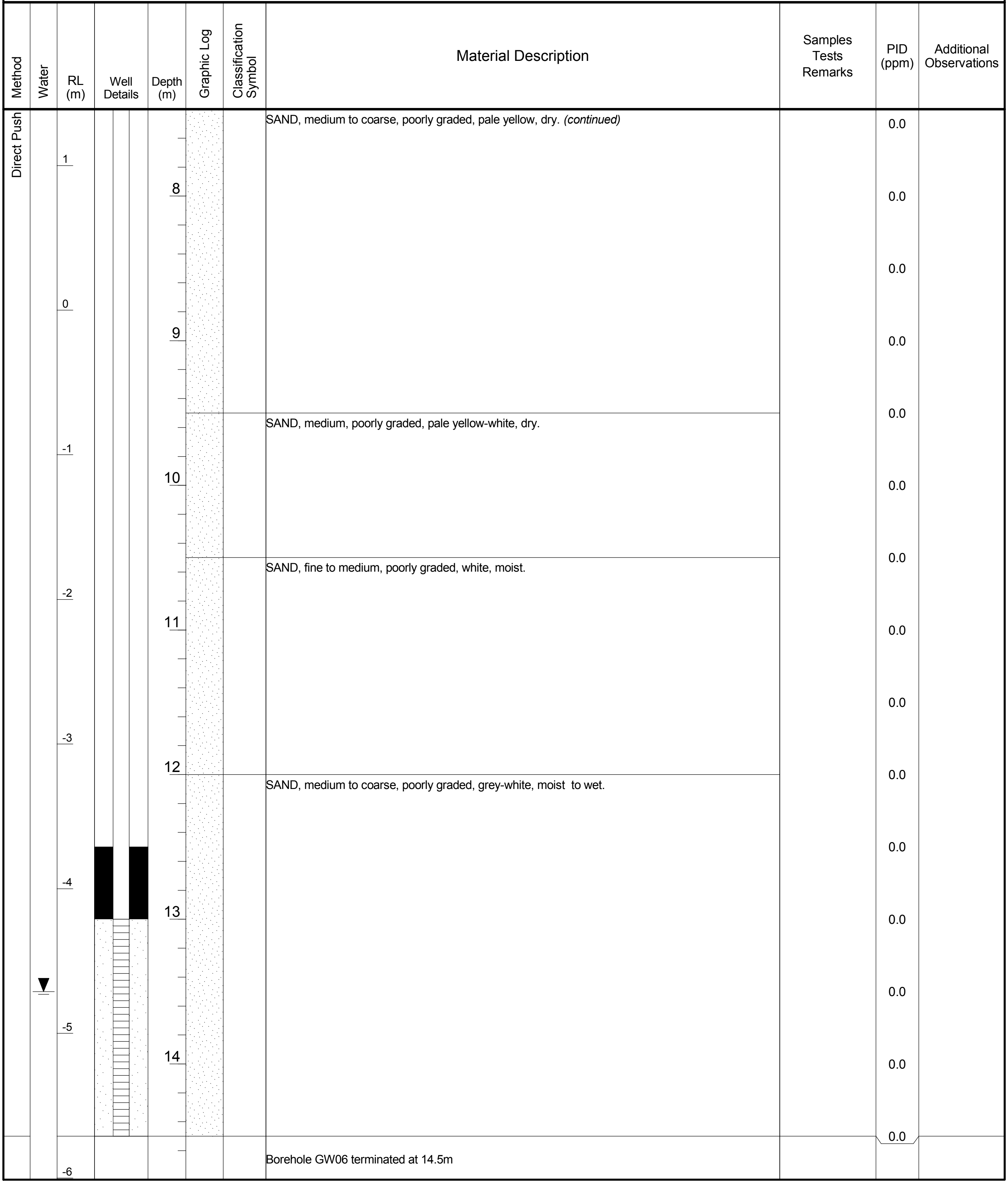
Syrinx Environmental

BOREHOLE NUMBER GW06

PAGE 2 OF 2

CLIENT Curtin University
PROJECT NAME Groundwater and Soil Investigations
PROJECT NUMBER 1320
PROJECT LOCATION Curtin University

DATE STARTED 27/9/13
COMPLETED 27/9/13
R.L. SURFACE (m) 8.789
DATUM m AHD
DRILLING CONTRACTOR National Geotech
NORTHING (m) 6458316.204
CO-ORDINATE SYSTEM MGA95 Zone 50
EQUIPMENT Direct Push
EASTING (m) 395821.859
HOLE LOCATION
HOLE SIZE (mm) 48
LOGGED BY NR
CHECKED BY PZ
NOTES



Material Description

SAND, medium to coarse, poorly graded, pale yellow, dry. *(continued)*

SAND, medium, poorly graded, pale yellow-white, dry.

SAND, fine to medium, poorly graded, white, moist.

SAND, medium to coarse, poorly graded, grey-white, moist to wet.

Borehole GW06 terminated at 14.5m

Samples Tests Remarks

PID (ppm)
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0

Additional Observations

BOREHOLE NUMBER GW07

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Syrinx Environmental

CLIENT Curtin University

PROJECT NAME Groundwater and Soil Investigations

PROJECT NUMBER 1320

PROJECT LOCATION Curtin University

DATE STARTED 1/10/13 **COMPLETED** 1/10/13

R.L. SURFACE (m) 9.200 **DATUM** m AHD

DRILLING CONTRACTOR National Geotech

NORTHING (m) 6458040.227 **CO-ORDINATE SYSTEM** MGA95 Zone 50

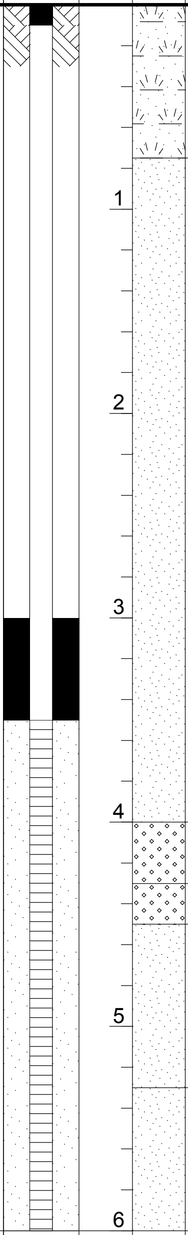
EQUIPMENT Direct Push

EASTING (m) 394993.892 **HOLE LOCATION**

HOLE SIZE (mm) 48

LOGGED BY NR **CHECKED BY** PZ

NOTES



Method	Water	RL (m)	Well Details	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
HA		9					TOPSOIL, fine to medium, poorly graded, sub-angular, pale brown-grey, dry, gravel, organic matter.		0.0	
HA Direct Push	▼	8 7 6		1 2 3 4			SAND, medium, poorly graded, sub-rounded, pale grey-white, dry to moist, moist to wet with depth.		0.0 0.0 0.0 0.0 0.0 0.0 0.0	
		5					SAND, medium to coarse, well graded, dark grey-brown, wet, no odour.		0.0	
							SAND, medium to coarse, well graded, brown, wet.			
		4		5			SAND, coarse, poorly graded, angular, pale brown-yellow, wet.		0.0 0.0	
				6			SAND, coarse, angular, pale yellow-grey, wet, gravel fragments.		0.0 0.0	
		3 2		7			Borehole GW07 terminated at 6m			

Syrinx Environmental

BOREHOLE NUMBER GW08

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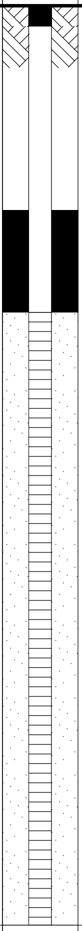
CLIENT Curtin University
PROJECT NAME Groundwater and Soil Investigations
PROJECT NUMBER 1320
PROJECT LOCATION Curtin University

DATE STARTED 1/10/13
COMPLETED 1/10/13
R.L. SURFACE (m) 9.888
DATUM m AHD
DRILLING CONTRACTOR National Geotech
NORTHING (m) 6457680.569
CO-ORDINATE SYSTEM MGA95 Zone 50
EQUIPMENT Direct Push
EASTING (m) 394920.046
HOLE LOCATION
HOLE SIZE (mm) 48
LOGGED BY NR
CHECKED BY PZ
NOTES



Method	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
HA	SAND, medium, poorly graded, pale grey-grey, dry, organic matter.			
	SAND, medium to coarse, well graded, sub-rounded, grey-black, dry.		0.0	
	SAND, medium to coarse, well graded, pale grey, dry to wet.		0.0 0.0 0.0	
Direct Push	SAND, fine to medium, black, wet.			
	SAND, medium to coarse, well graded, dark brown-red, wet.		0.0 0.0 0.0	
	SAND, coarse, poorly graded, grey-pale brown, wet.		0.0 0.0	
	Borehole GW08 terminated at 4.5m			

RL (m): 9, 8, 7, 6, 5, 4, 3
Depth (m): 1, 2, 3, 4, 5, 6, 7

Syrinx Environmental

BOREHOLE NUMBER GW09

CLIENT Curtin University
PROJECT NAME Groundwater and Soil Investigations
PROJECT NUMBER 1320
PROJECT LOCATION Curtin University

DATE STARTED 2/10/13
COMPLETED 2/10/13
R.L. SURFACE (m) 17.991
DATUM m AHD
DRILLING CONTRACTOR National Geotech
NORTHING (m) 6457772.338
CO-ORDINATE SYSTEM MGA95 Zone 50
EQUIPMENT Direct Push
EASTING (m) 395262.335
HOLE LOCATION
HOLE SIZE (mm) 48
LOGGED BY NR
CHECKED BY PZ
NOTES

Method	Water	RL (m)	Well Details	Depth (m)	Graphic Log	Classification Symbol	Material Description	Samples Tests Remarks	PID (ppm)	Additional Observations
HA							SAND, fine to medium, well graded, sub-rounded, grey-brown, dry, slight organic odour.			
							SAND, fine to medium, poorly graded, sub-rounded, grey-yellow, dry, no odour.		0.0	
		17		1					0.0	
							SAND, fine to medium, poorly graded, sub-rounded, yellow-grey, dry, no odour.		0.0	
							SAND, fine to medium, well graded, orange-pale brown, dry.			
Direct Push		16		2			SAND, medium, well graded, sub-angular, grey-dark grey, dry, some gravel.		0.0	
							SAND, medium, poorly graded, orange-pale yellow, moist.		0.0	
		15		3			SAND, medium to coarse, well graded, yellow, moist.		0.0	
									0.0	
		14		4			SAND, medium to coarse, poorly graded, sub-rounded, grey-white, moist to wet.		0.0	
	▼								0.0	
		13		5					0.0	
									0.0	
							SAND, medium, well graded, sub-angular, yellow-grey, wet.			
		12		6			SAND, fine to medium, well graded, grey-white, wet.		0.0	
							SAND, coarse, well graded, grey-white, wet.		0.0	
							Borehole GW09 terminated at 6.5m			
		11		7						

Syrinx Environmental

BOREHOLE NUMBER GW10

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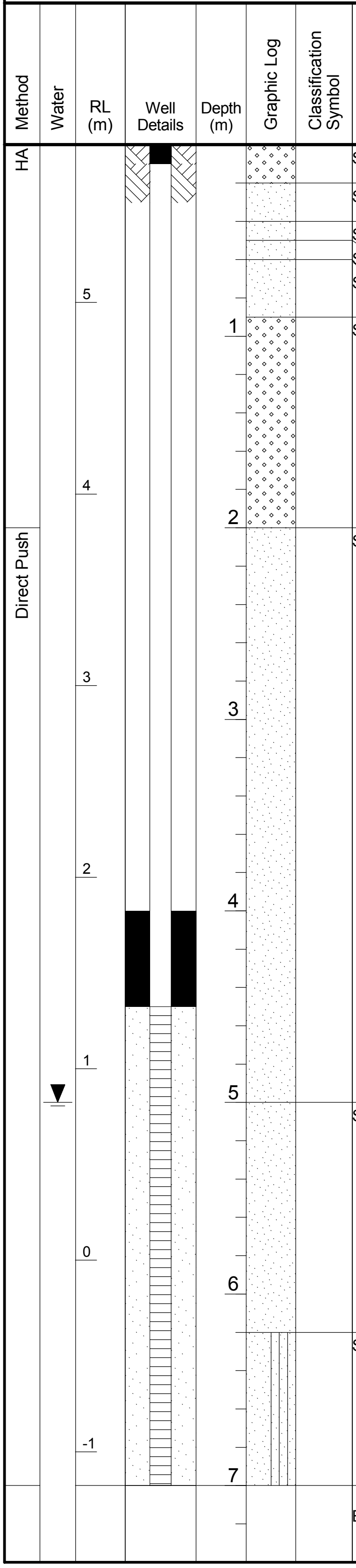
CLIENT Curtin University
PROJECT NAME Groundwater and Soil Investigations
PROJECT NUMBER 1320
PROJECT LOCATION Curtin University

DATE STARTED 27/9/13
COMPLETED 2/10/13
R.L. SURFACE (m) 5.824
DATUM m AHD
DRILLING CONTRACTOR National Geotech
NORTHING (m) 6457664.417
CO-ORDINATE SYSTEM MGA95 Zone 50
EQUIPMENT Direct Push
EASTING (m) 395424.265
HOLE LOCATION
HOLE SIZE (mm) 48
LOGGED BY NR
CHECKED BY PZ
NOTES



Material Description

SAND, coarse, well graded, pale brown, slightly moist, organic matter.

SAND, coarse, brown-grey, organic matter, limestone fragments.

SAND, coarse, brown-grey, limestone fragments.

SAND, medium, brown-grey, organic matter.

SAND, coarse, pale grey-brown, organic matter.

SAND, coarse, well graded, grey, slightly moist.

SAND, medium, poorly graded, sub-rounded, white-grey, dry to moist, wet with depth.

SAND, medium to coarse, poorly graded, brown, wet.

SAND WITH SILT, medium to coarse, poorly graded, sub-rounded, pale brown, with silt.

Borehole GW10 terminated at 7m

Samples Tests Remarks

PID (ppm)

0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0
0.0

Additional Observations

BOREHOLE / TEST PIT 1320 CURTIN.GPJ SYRINX AUSTRALIAN STANDARD.GDT 4/12/13

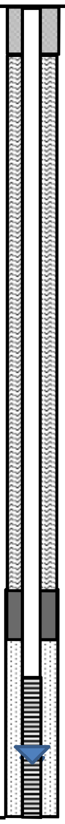
Groundwater Monitoring Well Log

Monitoring Well No:
MW1

CLIENT:	Curtin University of Technology	**DATE COMMENCED:**	31/05/2012
PROJECT:	DSI	**DATE COMPLETED:**	31/05/2012
LOCATION:	Bentley	**LOGGED BY:**	N. Buckingham
JOB NUMBER:	CUT2012-001	**CHECKED BY:**	B. Dermody

Drilling Co:	Eco Probe	**Drilling Method:**	Hollow stem auger	**Surface RL:**	NA	**Easting:**	395537.828
Driller:	Mitch Skender	**Weather:**	Cloudy / Sunny	**Datum:**	m AHD	**Northing:**	6458384.841
50mm Class 18 PVC		**Total Depth of Hole:**	17.1 m bgl	**Top of Casing RL:**			20.265
Bore diameter:	50mm	**Static Water Level:**	16 m bgl	**Water Strike:**		16 m bgl	

Depth (m bgl)	GRAPHICAL LOG		LITHOGICAL DESCRIPTION	Depth (m bgl)	Sample ID	WELL CONSTRUCTION
						Flush finish in gatic
0.0		0.0 to 0.5 mbgl	**BRICK PAVERS**			
0.5			**FILL:** Gravelly sand with limestone gravels (1 to 5cm in size), yellow (light/creamy), dry.			Concrete (0.0 - 0.5 mbgl)
1.0		1.0 to 18.0 mbgl				
1.5						
2.0						
2.5			**SAND:** Orange/yellow, fine to medium grained, well sorted, quartz, moist, cemented sand nodules			
3.0						
3.5						
l						Soil cuttings (0.5 - 12.2 mbg;)
4.5						
5.0						
5.5			Sand becoming paler gradually with depth			
6.0						
6.5						
7.0						
7.5						
8.0						
8.5						
9.0						
9.5						
10.0						
10.5						
11.0						
11.5						
12.0						Bentonite (12.2 - 13.1 mbgl)
12.5						
13.0						
13.5						
14.0						Gravel pack (13.1 - 17.1 mbgl)
14.5						
15.0						
15.5						Slotted screen (14 - 17.0 mbgl)
16.0						
16.5			Sand grey / white in colour at the base of hole			
17.0						
17.5						
			EOH = 17.1 mbgl			

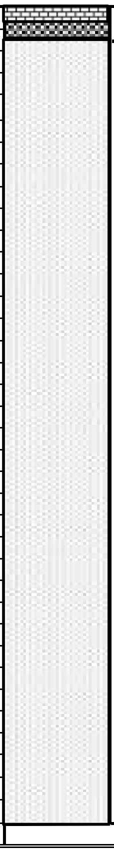


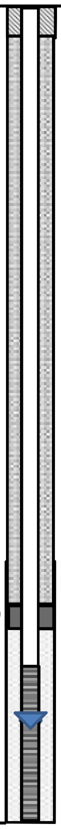
Groundwater Monitoring Well Log

Monitoring Well No:
MW2

CLIENT:	Curtin University of Technology	**DATE COMMENCED:**	1/06/2012
PROJECT:	DSI	**DATE COMPLETED:**	1/06/2012
LOCATION:	Bentley	**LOGGED BY:**	N. Buckingham
JOB NUMBER:	CUT2012-001	**CHECKED BY:**	B. Dermody

Drilling Co:	Eco Probe	**Drilling Method:**	Hollow stem auger	**Surface RL:**	NA	**Easting:**	395537.839
Driller:	Mitch Skender	**Weather:**	Overrcast	**Datum:**	m AHD	**Northing:**	6458400.135
50mm Class 18 PVC		**Total Depth of Hole:**	18.0 m bgl	**Top of Casing RL:**			20.319
Bore diameter:	50mm	**Static Water Level:**	16.0 m bgl	**Water Strike:**		16.0 m bgl	





Depth (m bgl)	GRAPHICAL LOG		LITHOLOGICAL DESCRIPTION	Depth (m bgl)	Sample ID	WELL CONSTRUCTION
						Flush finish in gatic
0.0		0.0 to 0.3 mbgl	**BRICK PAVERS**	0.0		
0.5			**FILL:** Gravelly sand, creamy yellow, fine to medium grained limestone gravel, compact, moist, paving sub base	0.5		Concrete (0.0 - 0.3 mbgl)
1.0				1.0		
1.5				1.5		
2.0				2.0		
2.5				2.5		
3.0			**SAND:** Yellow / orange, fine to medium grained, well sorted, sub angular quartz and feldspar, moist, occasional cemented gravels of sand.	3.0		
3.5				3.5		
I				I		
4.5				4.5		Native fill (0.5 - 12.2 mbg;)
5.0				5.0		
5.5				5.5		
6.0				6.0		
6.5				6.5		
7.0				7.0		
7.5				7.5		
8.0			Grading to light creamy yellow at approximately 8 mbgl	8.0		
8.5		0.3 to 18.0 mbgl		8.5		
9.0				9.0		
9.5				9.5		
10.0				10.0		
10.5				10.5		
11.0				11.0		
11.5				11.5		
12.0				12.0		
12.5				12.5		
13.0				13.0		
13.5				13.5		Bentonite (13.2 - 14.0 mbgl)
14.0				14.0		Gravel pack (14.0 - 18.0 mbgl)
14.5				14.5		
15.0				15.0		
15.5				15.5		Slotted screen (15.0 - 18.0 mbgl)
16.0				16.0		
16.5				16.5		
17.0				17.0		
17.5			EOH = 18.0 mbgl	17.5		
18.0				18.0		

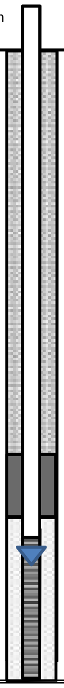
Groundwater Monitoring Well Log

Monitoring Well No:
MW3

CLIENT:	Curtin University of Technology	**DATE COMMENCED:**	31/05/2012
PROJECT:	DSI	**DATE COMPLETED:**	31/05/2012
LOCATION:	Bentley	**LOGGED BY:**	B. Dermody
JOB NUMBER:	CUT2012-001	**CHECKED BY:**	N. Buckingham

Drilling Co:	Eco Probe	**Drilling Method:**	Hollow stem auger	**Surface RL:**	NA	**Easting:**	395626.749
Driller:	Mitch Skender	**Weather:** Overcast		**Datum:**	m AHD	**Northing:**	6458432.818
50mm Class 18 PVC		**Total Depth of Hole:**	13.4 mbgl	**Top of Casing RL:**	15.887		
Bore diameter:	50mm	**Static Water Level:**	11.0 mbgl	**Water Strike:**	11 m bgl		

Depth (m bgl)	GRAPHICAL LOG		LITHOGICAL DESCRIPTION	Depth (m bgl)	Sample ID	WELL CONSTRUCTION
						Steel riser 0.5m
0.0		0.0 - 3.0 mbgl	**SAND:** Grey, fine to medium grained, moderately sorted, disturbed with limestone concrete and brick gravel and boulders, assorted small construction / demolition waste, moist, no odours	0.0		Native fill (0.0 - 9.0 mbg;)
0.5				0.5		
1.0				1.0		
1.5				1.5		
2.0				2.0		
2.5				2.5		
3.0		3.0 - 13.4 mbgl	**SAND:** Creamy yellow, fine to medium grained, well sorted, sub angular quartz and feldspar, moist, no odours	3.0	V26	
3.5				3.5		
4.0				4.0		
4.5				4.5		
5.0				5.0		
5.5				5.5		
6.0				6.0		
6.5				6.5		
7.0				7.0		
7.5			Grading to light cream at 7.5 mbgl	7.5		
8.0				8.0		
8.5				8.5		
9.0			Light grey	9.0		Bentonite (9.0 - 10.0 mbgl)
9.5				9.5		
10.0				10.0		Gravel pack (10.0 - 13.4 mbgl)
10.5				10.5		Slotted screen (10.4 - 13.4 mbgl)
11.0				11.0		
11.5				11.5		
12.0				12.0		
12.5				12.5		
13.0			EOH = 13.4 mbgl	13.0		
13.4				13.4		



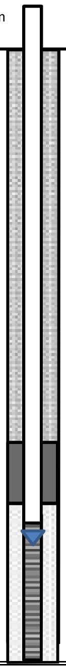
Groundwater Monitoring Well Log

Monitoring Well No:
MW4

CLIENT:	Curtin University of Technology	**DATE COMMENCED:**	31/05/2012
PROJECT:	DSI	**DATE COMPLETED:**	31/05/2012
LOCATION:	Bentley	**LOGGED BY:**	B. Dermody
JOB NUMBER:	CUT2012-001	**CHECKED BY:**	N. Buckingham

Drilling Co:	Eco Probe	**Drilling Method:**	Hollow stem auger	**Surface RL:**	NA	**Easting:**	395625.522
Driller:	Mitch Skender	**Weather:**	Overcast	**Datum:**	m AHD	**Northing:**	6458455.471
50mm Class 18 PVC		**Total Depth of Hole:**	13.5 mbgl	**Top of Casing RL:**			16.467
Bore diameter:	50mm	**Static Water Level:**	10.9 mbgl	**Water Strike:**		10.9 m bgl	

Depth (m bgl)	GRAPHICAL LOG		LITHOLOGICAL DESCRIPTION	Depth (m bgl)	Sample ID	WELL CONSTRUCTION
						Steel riser 0.820 m
0.0				0.0		
0.5			**SAND:** Grey, fine to medium grained, moderately sorted, moist, sub angular quartz, limestone gravel, PVC offsets, disturbed natural soil, no odours	0.5		
1.0		0.0 - 2.5 mbgl		1.0		
1.5				1.5		
2.0				2.0		
2.5				2.5		
3.0			**SAND:** Light grey/cream, fine to medium grained, well sorted, sub angular quartz, moist	3.0	V21	
3.5				3.5		
4.0				4.0		Native fill (0.0 - 8.5 mbg;)
4.5			Grading to creamy yellow at approximately 4.5 mbgl	4.5		
5.0				5.0		
5.5			Grading to brown at approximately 5.5 mbgl	5.5		
6.0				6.0		
6.5				6.5		
7.0				7.0		
7.5		3.0 - 13.4 mbgl		7.5		
8.0			Grading to light cream at approximately 8.0 mbgl	8.0		
8.5				8.5		
9.0				9.0		Bentonite (8.5 - 9.5 mbgl)
9.5				9.5		
10.0				10.0		
10.5				10.5		Gravel pack (9.5 - 13.5 mbgl)
11.0				11.0		
11.5				11.5		
12.0				12.0		Slotted screen (10.5 - 13.5 mbgl)
12.5				12.5		
13.0			EOH = 13.5 mbgl	13.0		
13.5				13.5		

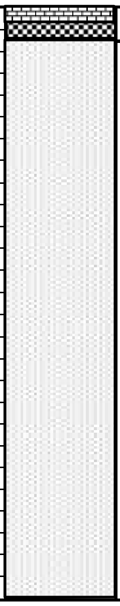
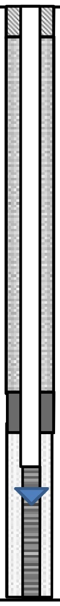


Groundwater Monitoring Well Log

Monitoring Well No:
MW5

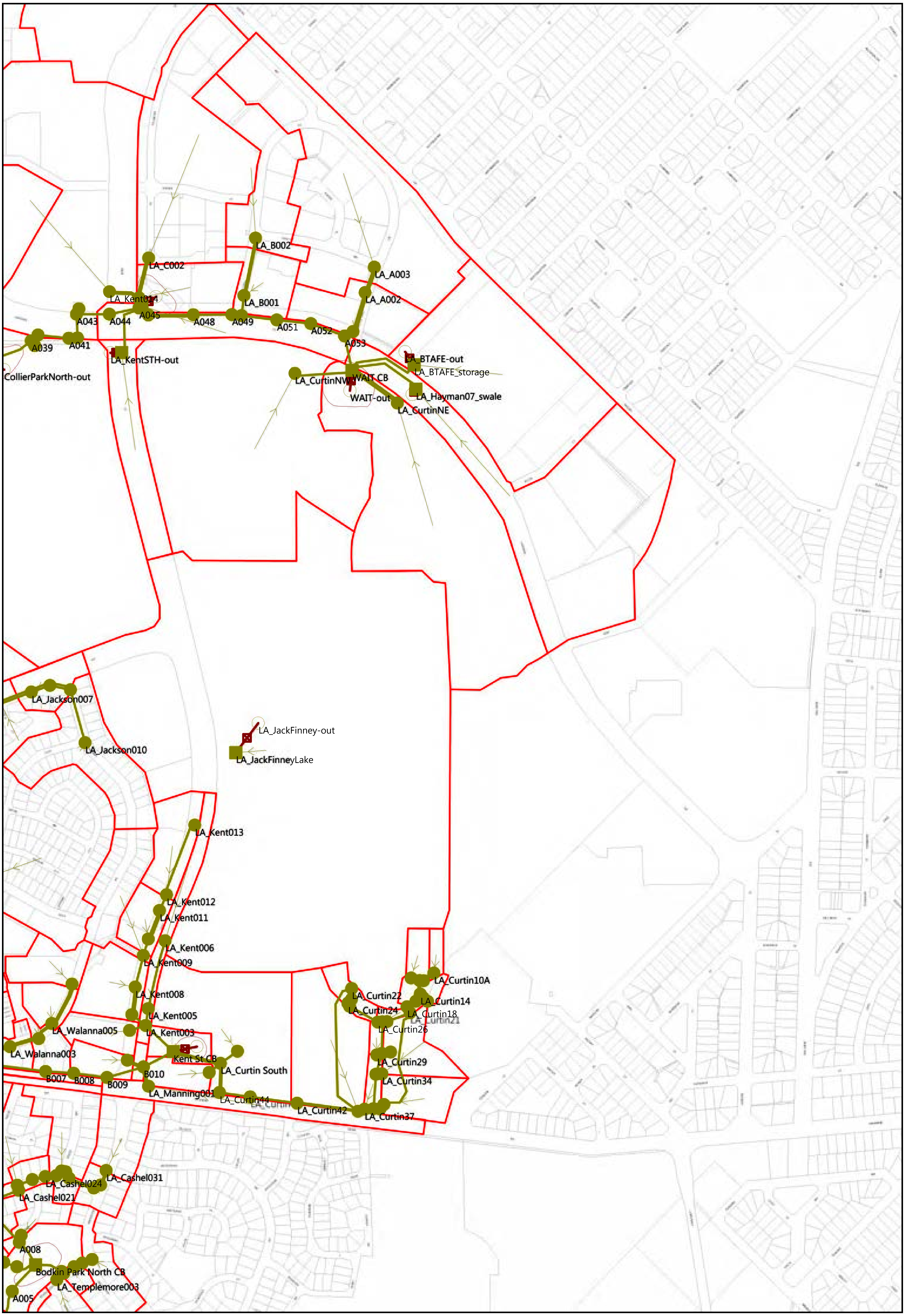
CLIENT:	Curtin University of Technology	**DATE COMMENCED:**	1/06/2012
PROJECT:	DSI	**DATE COMPLETED:**	1/06/2012
LOCATION:	Bentley	**LOGGED BY:**	B. Dermody
JOB NUMBER:	CUT2012-001	**CHECKED BY:**	

Drilling Co:	Eco Probe	**Drilling Method:**	Hollow stem auger	**Surface RL:**	NA	**Easting:**	395635.261
Driller:	Mitch Skender	**Weather:** Overcast		**Datum:**	m AHD	**Northing:**	6458460.249
50mm Class 18 PVC		**Total Depth of Hole:**	13.0 m bgl	**Top of Casing RL:**	15.291		
Bore diameter:	50mm	**Static Water Level:**	10.9 m bgl	**Water Strike:**	10.9 m bgl		

Depth (m bgl)	GRAPHICAL LOG		LITHOLOGICAL DESCRIPTION	Depth (m bgl)	Sample ID	WELL CONSTRUCTION
						Flush finish in gatic
0.0		0.0 to 0.3 mbgl	**BRICK PAVERS**	0.0		Concrete (0.0 - 0.3 mbgl) 
0.5			**FILL:** Gravelly sand, creamy yellow, fine to medium grained limestone gravel, compact, moist, paving sub base	0.5		
1.0				1.0		
1.5				1.5		
2.0				2.0		
2.5				2.5		
3.0			**SAND:** Yellow / orange, fine to medium grained, well sorted, sub angular quartz and feldspar, moist, occasional cemented gravels of sand.	3.0		
3.5				3.5		
I				I		Native fill (0.3 - 8.4 mbg;)
4.5				4.5		
5.0				5.0		
5.5				5.5		
6.0				6.0		
6.5		0.3 to 18.0 mbgl		6.5		
7.0				7.0		
7.5				7.5		
8.0			Grading to light creamy yellow at approximately 8 mbgl	8.0		
8.5				8.5		Bentonite (8.4 - 9.2 mbgl)
9.0				9.0		
9.5				9.5		
10.0				10.0		Gravel pack (9.2 - 13.0 mbgl)
10.5				10.5		
11.0				11.0		Slotted screen (10.0 - 13.0 mbgl)
11.5				11.5		
12.0				12.0		
12.5				12.5		
13.0			EOH = 13.0 mbgl	13.0		

Appendix D

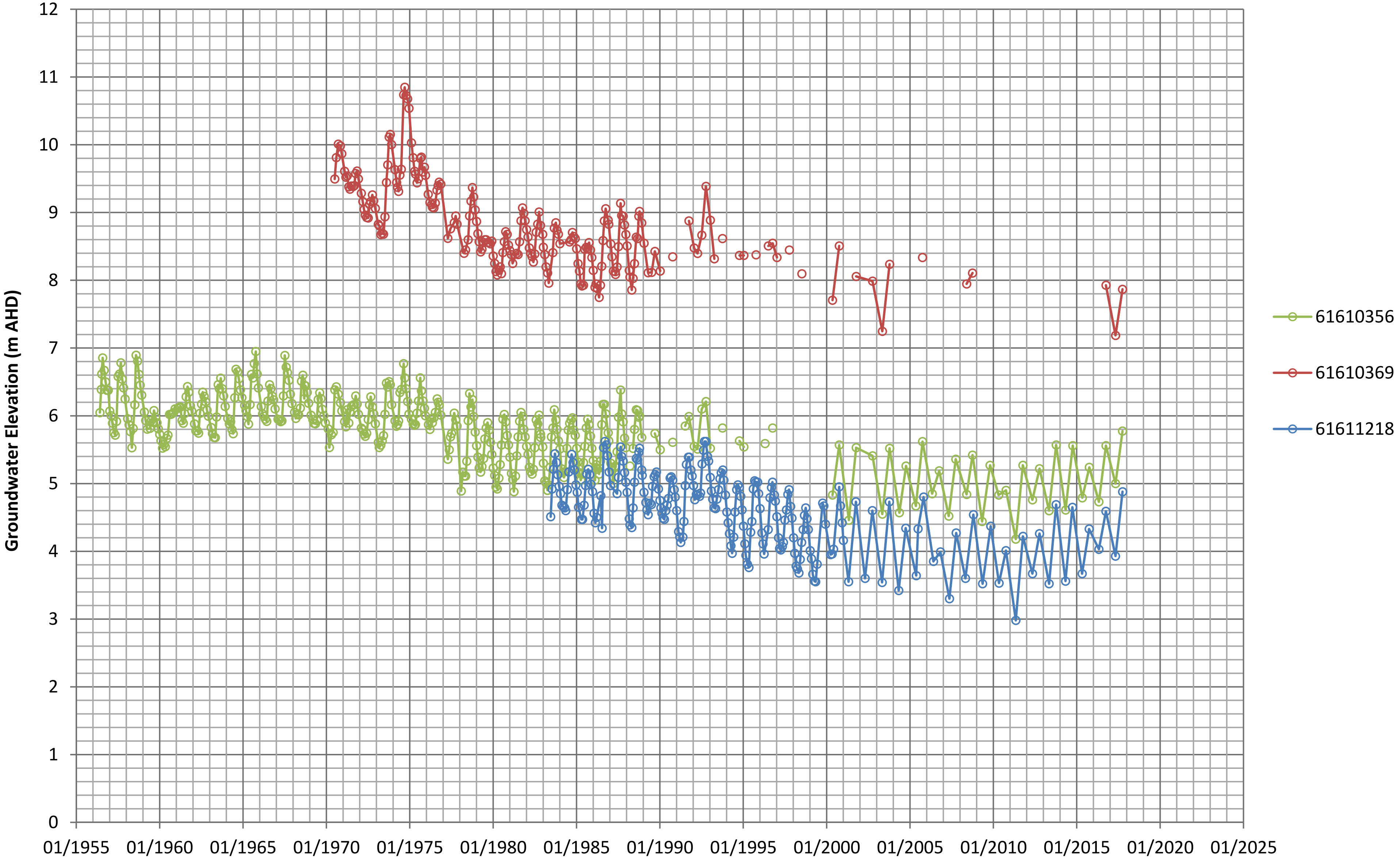
Water Corporation link-node runoff model diagram


LA_B002
LA_C002
LA_A003
LA_B001
LA_A002
LA_Kent014
A043
A044
A045
A048
A049
A051
A052
A053
A039
A041
LA_KentSTH-out
CollierParkNorth-out
LA_BTAFE-out
LA_BTAFE_storage
LA_CurtinNW
WAIT CB
WAIT-out
LA_Hayman07_swale
LA_CurtinNE
LA_Jackson007
LA_JackFinney-out
LA_Jackson010
LA_JackFinneyLake
LA_Kent013
LA_Kent012
LA_Kent011
LA_Kent006
LA_Kent009
LA_Kent008
LA_Kent005
LA_Walanna005
LA_Kent003
LA_Walanna003
Kent St CB
LA_Curtin South
B007
B008
B009
B010
LA_Manning001
LA_Curtin44
LA_Curtin10A
LA_Curtin22
LA_Curtin14
LA_Curtin24
LA_Curtin18
LA_Curtin21
LA_Curtin26
LA_Curtin29
LA_Curtin34
LA_Curtin42
LA_Curtin37
LA_Cashel031
LA_Cashel024
LA_Cashel021
A008
Bodkin Park North CB
LA_Templemore003
A005

Appendix E

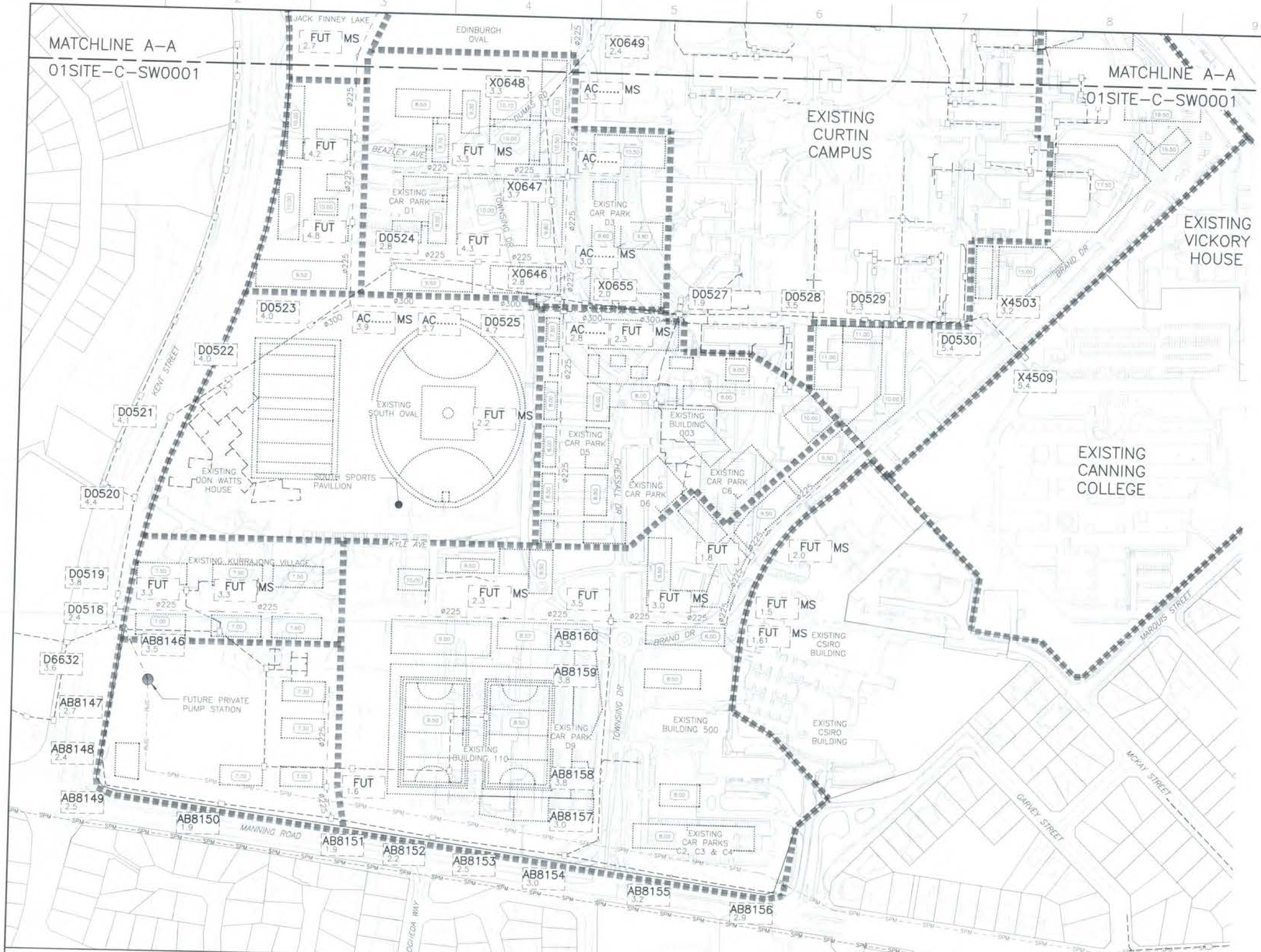
DWER monitoring bore hydrographs

Nearby Groundwater Level Data (DWER 2018)



Appendix F

Approved wastewater planning



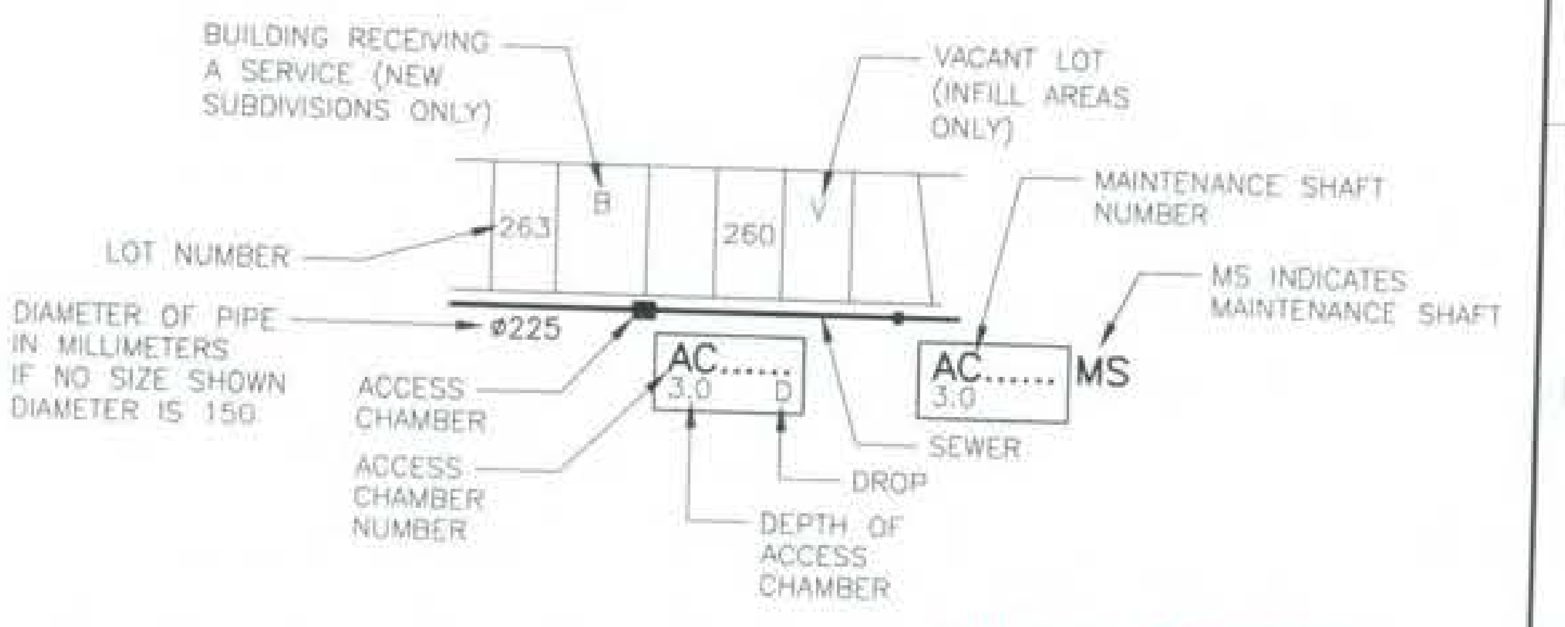
LEGEND

■ ■ ■ ■ ■ ■ ■ ■	INDICATIVE SEWER CATCHMENT BOUNDARIES (BASED ON GREATER CURTIN MASTER PLAN)
▬ ▬ ▬ ▬	STAGE 1 SEWER RETICULATION BOUNDARY
—WC—■—WC—	PROPOSED WATER CORPORATION GRAVITY SEWER AND ASSOCIATED CHAMBERS
—SW—■—SW—	PROPOSED CURTIN STAGE 1 GRAVITY SEWER AND ASSOCIATED CHAMBERS
– – – □ – – –	EXISTING GRAVITY SEWER AND ASSOCIATED CHAMBERS
– · – □ – · –	FUTURE GRAVITY SEWER AND ASSOCIATED CHAMBERS
— SPM — SPM —	FUTURE SEWER PRESSURE MAIN
— SPM — SPM —	EXISTING SEWER PRESSURE MAIN
········	FUTURE BUILDING ENVELOPES
	SURVEY DATA
AC...... MS 0.0 D	W.C. ACCESS CHAMBER NUMBER CHAMBER DEPTH AND DROP NOTATION MS – INDICATES MAINTENANCE SHAFT
CU000 MS 0.0 D	CURTIN STAGE 1 ACCESS CHAMBER NUMBER CHAMBER DEPTH AND DROP NOTATION MS – INDICATES MAINTENANCE SHAFT
AC...... MS 0.0 D	FUTURE WATER CORPORATION ACCESS CHAMBER
FUT MS 0.0 D	FUTURE CURTIN UNI ACCESS CHAMBER
X0000 MS 0.0 D	EXISTING CHAMBER NUMBER
00.00	FUTURE BUILDING F.F.L.

SITE PLAN NOTES:

LOCAL AUTHORITY: = TOWN OF VICTORIA PARK
CITY OF SOUTH PERTH
ESTIMATED MAX. G.W.L. = 5.0
No. OF ACCESS CHAMBERS = 8
No. OF MAINTENANCE SHAFTS = 3
LENGTH OF SEWERS (m):
WATER CORPORATION 225 DIAMETER = 346.80m
CURTIN UNI STAGE 1 225 DIAMETER = 184.80m

NOTATION



ALL NEW CONNECTIONS TO EXISTING SEWERS BY WATER CORPORATION AT DEVELOPERS EXPENSE.

FINAL SUBMISSION

20m 0m 20m 40m
1:1000

SME 1503904

LX30-001-002-01A

THIS PLAN IS ACCEPTED AS COMPLYING WITH OVERALL SCHEME PLANNING. COMPLIANCE WITH RELEVANT MANUALS REMAINS THE RESPONSIBILITY OF THE CONSULTING ENGINEER.

NO WORKS ARE TO COMMENCE ON SITE UNTIL STARTUP ARRANGEMENTS HAVE BEEN MADE WITH THE RELEVANT WORK INSPECTOR. SEE DEVELOPERS MANUAL FOR CONTACT DETAILS.

FOR: MANAGER LAND SERVICING 18-06-2015 AARON OMARE

FILE No.: JT1 2015 03904 V01

RETICULATION AREA: ????????? ?????

FEATURE SURVEY – TRIMMED	01SITE–C–SY0001
PF DESIGN BASE FILE	01SITE–C–SP0100
REFERENCES	DRAWING

ISSUED FOR APPROVAL

REV	DATE	REVISION	DRN	CHK	PROJ APP
D	05/06/15	ISSUED FOR APPROVAL	DM	Tc	PO
C	20/05/15	ISSUED FOR 85% DESIGN REVIEW	TM		
B	16/06/14	50% DESIGN DEVELOPMENT RE-ISSUE	TM		
A	23/01/14	PRELIMINARY ISSUE TO WATER CORPORATION	TM		

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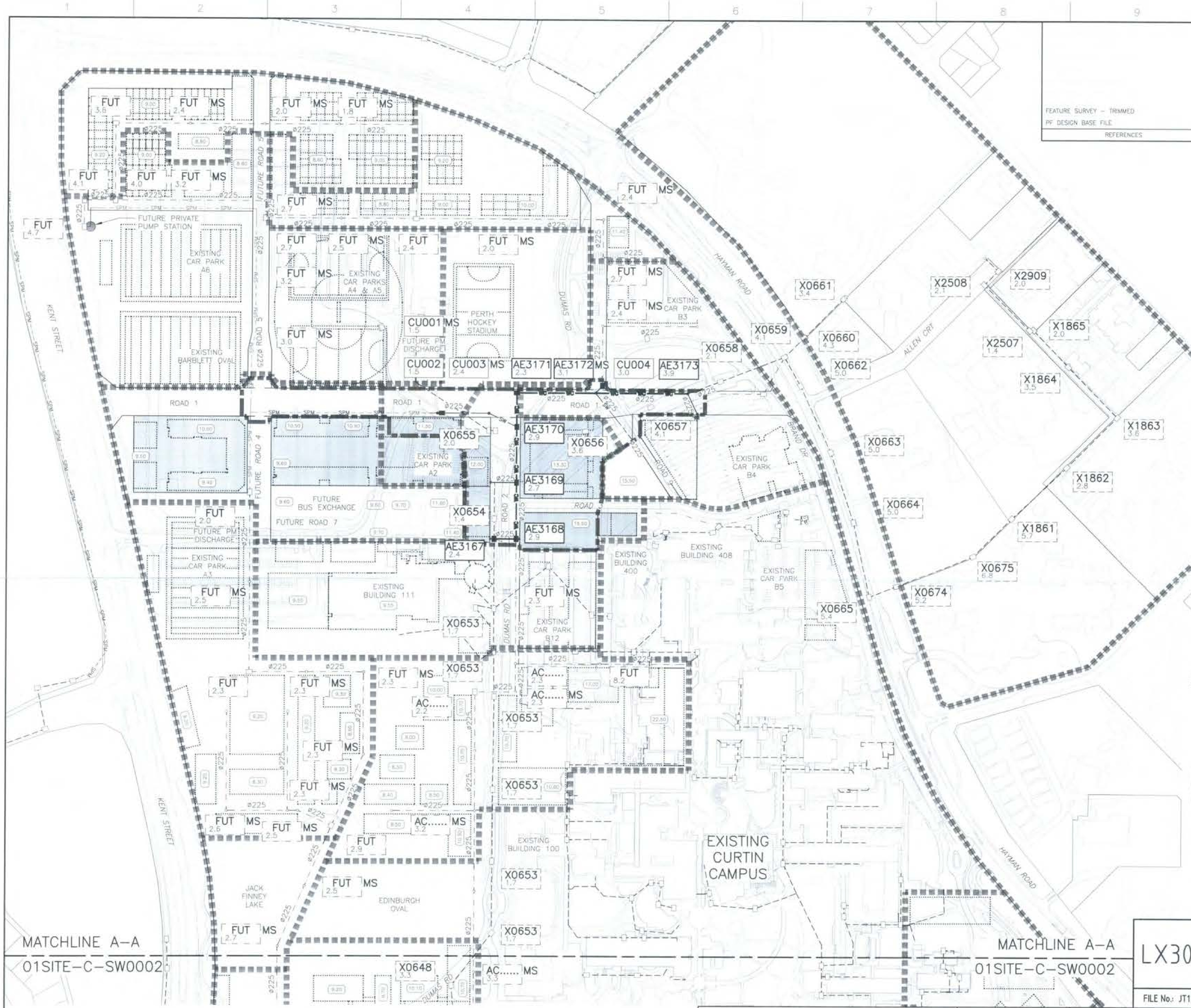
TEL 9266 9266 FAX 9266 3131

DRN BY	T. MCFARLANE
DATE	JAN 2014
DESIGNED	T. MCFARLANE
CHECKED	
PROJ APP	
CLIENT APP	

CURTIN UNIVERSITY, BENTLEY
MAINSTREET PROJECT
OVERALL SEWER SITE PLAN
STAGE 1 – SHEET 2

CURTIN PROJ No UPJ00146
SCALE: 1:1000
UNIT: m
DWG STATUS PRELIMINARY DESIGN
SHEET SIZE A1
DWG No 01SITE– C–SW0002
SHEET 02 OF 02
ISSUE D

REFERENCES	DRAWING
FEATURE SURVEY - TRIMMED	01SITE-C-SY0001
PF DESIGN BASE FILE	01SITE-C-SP0100



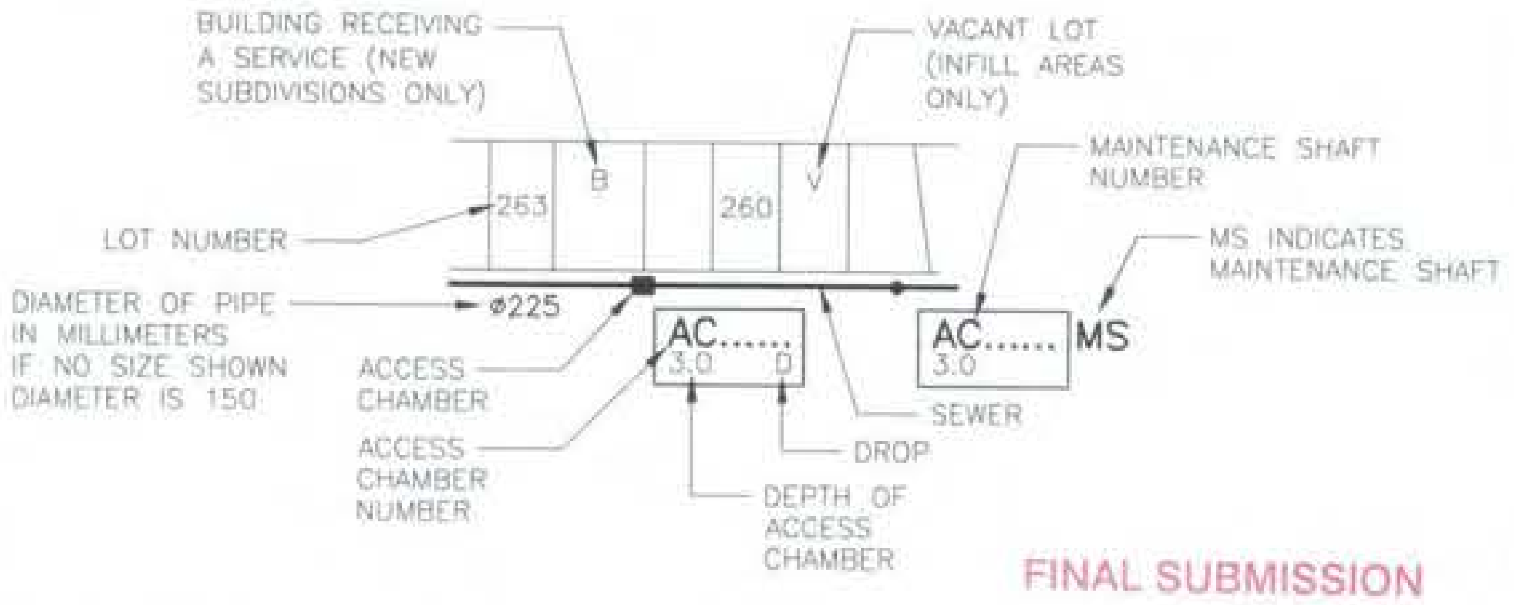
LEGEND

■■■■■■■■■	INDICATIVE SEWER CATCHMENT BOUNDARIES (BASED ON GREATER CURTIN MASTER PLAN)
▬ ▪ ▬ ▪ ▬	STAGE 1 SEWER RETICULATION BOUNDARY
▭	STAGE 1 DEVELOPMENT LOTS
●—WC—■—WC—●	PROPOSED WATER CORPORATION GRAVITY SEWER AND ASSOCIATED CHAMBERS
●—SW—■—SW—●	PROPOSED CURTIN STAGE 1 GRAVITY SEWER AND ASSOCIATED CHAMBERS
- - - -□- - - -	EXISTING GRAVITY SEWER AND ASSOCIATED CHAMBERS
○- - -□- - -○	FUTURE GRAVITY SEWER AND ASSOCIATED CHAMBERS
— SPM — SPM —	FUTURE SEWER PRESSURE MAIN
—— SPM —— SPM ——	EXISTING SEWER PRESSURE MAIN
········	FUTURE BUILDING ENVELOPES
	SURVEY DATA
AC...... MS 0.0 D	W.C. ACCESS CHAMBER NUMBER CHAMBER DEPTH AND DROP NOTATION MS – INDICATES MAINTENANCE SHAFT
CU000 MS 0.0 D	CURTIN STAGE 1 ACCESS CHAMBER NUMBER CHAMBER DEPTH AND DROP NOTATION MS – INDICATES MAINTENANCE SHAFT
AC...... MS 0.0 D	FUTURE WATER CORPORATION ACCESS CHAMBER
FUT MS 0.0 D	FUTURE CURTIN UNI ACCESS CHAMBER
X0000 MS 0.0 D	EXISTING CHAMBER NUMBER
00.00	FUTURE BUILDING F.F.L.

SITE PLAN NOTES:

LOCAL AUTHORITY: = TOWN OF VICTORIA PARK
CITY OF SOUTH PERTH
ESTIMATED MAX. G.W.L. = 5.0
No. OF ACCESS CHAMBERS = 8
No. OF MAINTENANCE SHAFTS = 3
LENGTH OF SEWERS (m):
WATER CORPORATION 225 DIAMETER = 346.80m
CURTIN UNI STAGE 1 225 DIAMETER = 184.80m

NOTATION



FINAL SUBMISSION

ALL NEW CONNECTIONS TO EXISTING SEWERS BY WATER CORPORATION AT DEVELOPERS EXPENSE.

20m 0m 20m 40m
1:1000

SME 1503904

LX30-001-001-01A

THIS PLAN IS ACCEPTED AS COMPLYING WITH OVERALL SCHEME PLANNING. COMPLIANCE WITH RELEVANT MANUALS REMAINS THE RESPONSIBILITY OF THE CONSULTING ENGINEER.

NO WORKS ARE TO COMMENCE ON SITE UNTIL STARTUP ARRANGEMENTS HAVE BEEN MADE WITH THE RELEVANT WORK INSPECTOR. SEE DEVELOPERS MANUAL FOR CONTACT DETAILS.

FOR: MANAGER LAND SERVICING 18.06.2015 AARON PITTARD

FILE No.: JT1 2015 03904 V01

RETICULATION AREA: ????????? ?????

DIAL BEFORE YOU DIG
www.1100.com.au
The Essential First Step.

ISSUED FOR APPROVAL

REV	DATE	REVISION	DRN	CHK	PROJ APP
D	05/06/15	ISSUED FOR APPROVAL	DM	TO	
C	20/05/15	ISSUED FOR 85% DESIGN REVIEW	TM		
B	16/06/14	50% DESIGN DEVELOPMENT RE-ISSUE	TM		
A	23/01/14	PRELIMINARY ISSUE TO WATER CORPORATION	TM		

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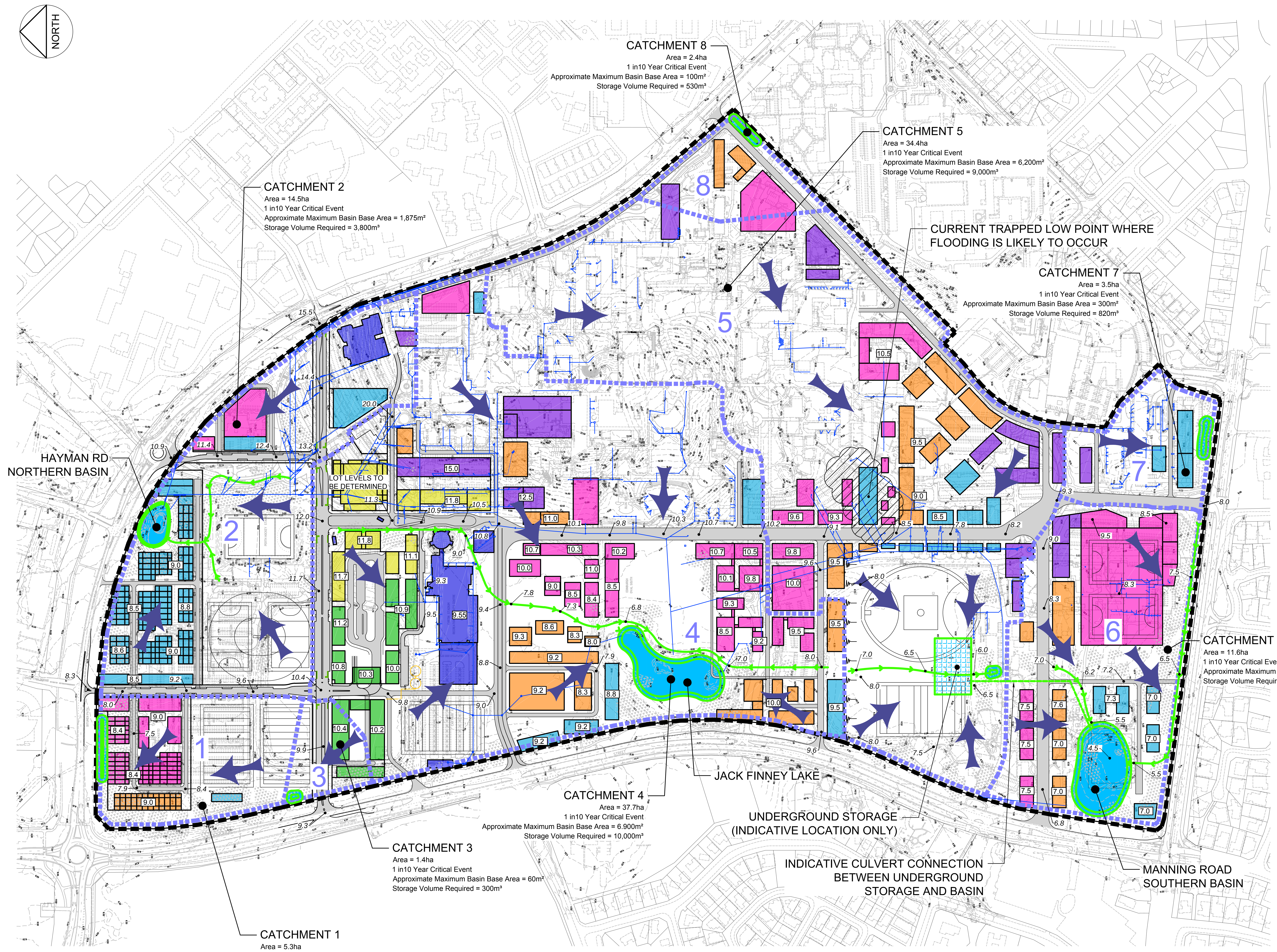
DRN BY T. MCFARLANE
DATE JAN 2014
DESIGNED T. MCFARLANE
CHECKED
PROJ APP
CLIENT APP

CURTIN UNIVERSITY, BENTLEY
MAINSTREET PROJECT
SEWER OVERALL SITE PLAN
STAGE 1 – SHEET 1

CURTIN PROJ No UPJ00146
SCALE: 1:1000
UNIT: m
DWG STATUS PRELIMINARY DESIGN
SHEET SIZE A1
DWG No 01SITE–C–SW0001
SHEET 01 OF 02
ISSUE D



CATCHMENT 8
Area = 2.4ha
1 in10 Year Critical Event
Approximate Maximum Basin Base Area = 100m²
Storage Volume Required = 530m³

CATCHMENT 5
Area = 34.4ha
1 in10 Year Critical Event
Approximate Maximum Basin Base Area = 6,200m²
Storage Volume Required = 9,000m³

CATCHMENT 2
Area = 14.5ha
1 in10 Year Critical Event
Approximate Maximum Basin Base Area = 1,875m²
Storage Volume Required = 3,800m³

CATCHMENT 7
Area = 3.5ha
1 in10 Year Critical Event
Approximate Maximum Basin Base Area = 300m²
Storage Volume Required = 820m³

CATCHMENT 6
Area = 11.6ha
1 in10 Year Critical Event
Approximate Maximum Basin Base Area = 1,800m²
Storage Volume Required = 3,000m³

CATCHMENT 4
Area = 37.7ha
1 in10 Year Critical Event
Approximate Maximum Basin Base Area = 6.900m²
Storage Volume Required = 10,000m³

CATCHMENT 3
Area = 1.4ha
1 in10 Year Critical Event
Approximate Maximum Basin Base Area = 60m²
Storage Volume Required = 300m³

CATCHMENT 1
Area = 5.3ha
1 in10 Year Critical Event
Approximate Maximum Basin Base Area = 255m²
Storage Volume Required = 1200m³

LEGEND

- - - -	SITE BOUNDARY
	EXISTING CONTOUR
	EXISTING ROAD & CAR PARK
	EXISTING DRAINAGE INFRASTRUCTURE
☐	EXISTING BUILDING FOOTPRINT
☐	NEW BUILDING FOOTPRINT BASED ON MASTERPLAN
▨	NEW ROAD LAYOUT BASED ON MASTERPLAN
	INDICATIVE DETENTION BASIN / WETLAND
➤	PROPOSED INDICATIVE OVERLAND FLOW DIRECTION
	INDICATIVE LIVING STREAM
■■■■■■	DRAINAGE CATCHMENT BOUNDARY
5	DRAINAGE CATCHMENT NUMBER
7.0	PRELIMINARY INDICATIVE BLOCK LEVEL
10.5	PRELIMINARY INDICATIVE PAVEMENT / GROUND LEVEL
10.5	PRELIMINARY INDICATIVE LIVING STREAM / BASIN INVERT LEVEL
	INDICATIVE BATTER
☐	EXISTING BUILDING FOOTPRINT
🟨	STAGE 1A – PROPOSED BUILDING AREAS FOR INITIAL DEVELOPMENT WITHIN STAGE 1
🟩	STAGE 1B – PROPOSED BUILDING AREAS FOR SECONDARY DEVELOPMENT WITHIN STAGE 1
🟪	STAGE 1C – PROPOSED BUILDING AREAS REMAINING WITH STAGE 1 OF THE MASTERPLAN
🟥	FUTURE BUILDING AREAS WITHIN STAGE 2 OF THE MASTERPLAN
🟧	FUTURE BUILDING AREAS WITHIN STAGE 3 OF THE MASTERPLAN
🟦	FUTURE BUILDING AREAS WITHIN STAGE 4 OF THE MASTERPLAN
🟦	NEW BUILDING FOOTPRINT BASED ON MASTERPLAN – UNDEFINED
△	EXISTING TREES TO REMAIN (SUBJECT TO FURTHER INVESTIGATION)

NOTES:

1. BASINS SHOWN REPRESENT APPROXIMATE MAXIMUM SIZES REQUIRED TO CONTAIN ALL STORMWATER RUNOFF WITHIN RESPECTIVE CATCHMENTS. IT EXCLUDES ANY STORAGE THAT MAY BE ACHIEVED IN UPSTREAM PIPE AND PIT INFRASTRUCTURE, ROAD SIDE BIO–RETENTION SWALES OR LIVING STREAMS, IF IMPLEMENTED.
2. AN AVERAGE RUNOFF COEFFICIENT OF 0.6 IS USED FOR STORMWATER VOLUME CALCULATIONS, APPROXIMATING FOR LARGE AREAS OF GREEN SPACE. THIS WILL NEED TO BE REFINED DURING SUBSEQUENT DESIGN DEVELOPMENT PHASES.

REV	DATE	REVISION	DRN	CHK	PROJ APP	REFERENCES	DRAWING
D	25/10/13	GAP ANALYSIS REPORT	TM				
C	16/10/13	RE–ISSUED FOR INFORMATION	TM				
B	03/09/13	RE–ISSUED FOR INFORMATION	BM				
A	16/08/143	ISSUED FOR INFORMATION	BM			–	

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DRN BY	–
DATE	AUG 2013
DESIGNED	–
CHECKED	–
PROJ APP	–
CLIENT APP	–

CHECK SITE DIMENSIONS
AND VERIFY DRAWINGS
PRIOR TO CONSTRUCTION

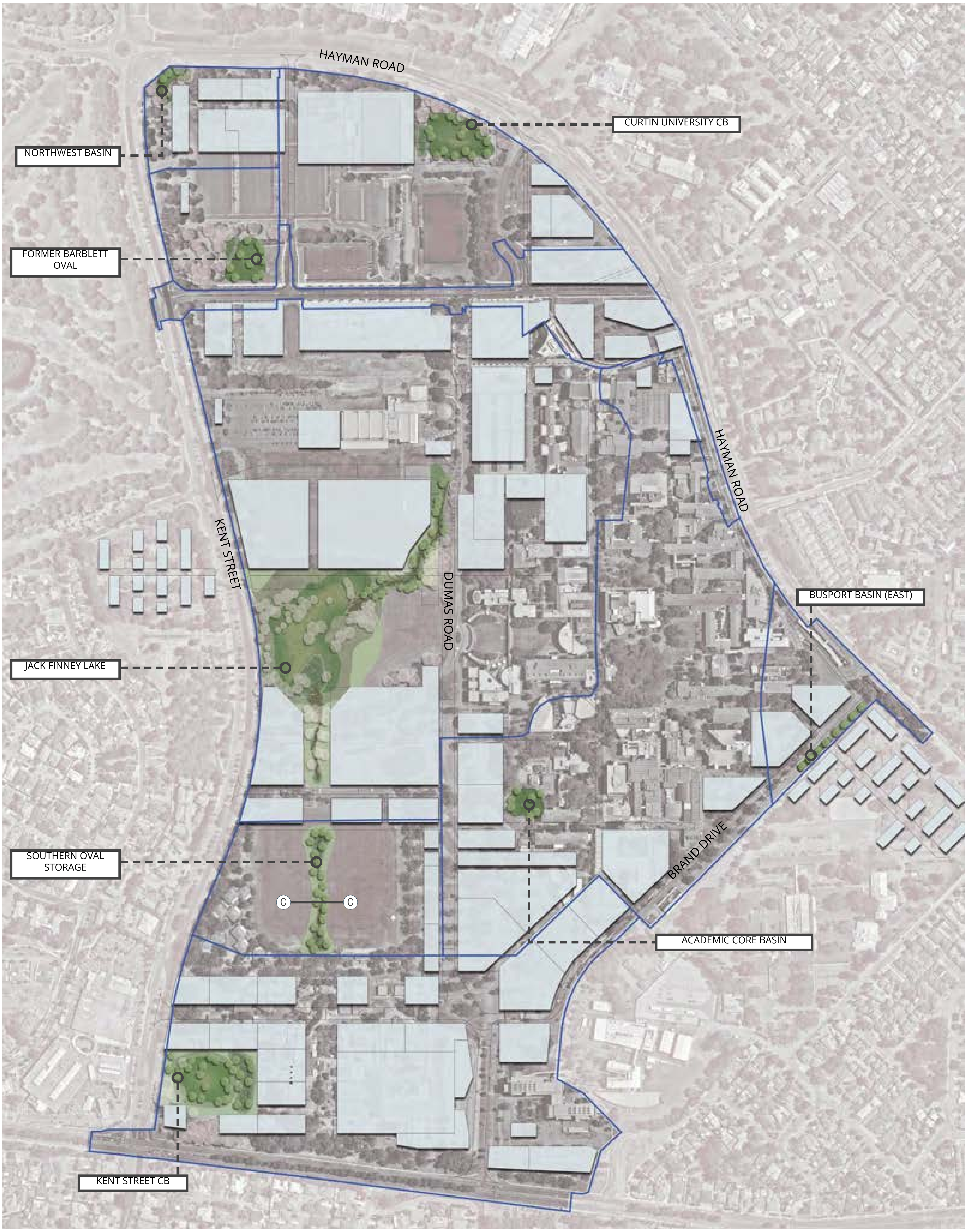
CURTIN UNIVERSITY MASTERPLAN GAP ANALYSIS PRELIMINARY LEVELS, CATCHMENT & OVERLAND FLOW PATH PLAN

CURTIN PROJ No: MASTER
SCALE: 1:3000
UNIT: mm
DWG STATUS: FOR INFORMATION ONLY
SHEET SIZE: A1
DWG No: 01SITE–G–SK1
SHEET: 01
OF: 01
ISSUE: D

E:\Working\2012\12–211 Curtin Uni Mainstreet\Civil\SS\130924 Data Prior to Detailed Design\SK1 – Drainage Catchment.dwg – Fri Oct 25 2013 – 2:08pm Todd

Appendix G

Landscape masterplan and concepts



GREATER CURTIN LWMS

MASTERPLAN CONCEPT

DWG DES
REV A
DATE 28-11-2018

0 25 50 75 100 125 m

SCALE 1 : 5000 @ A3

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LOCATION PLAN: NTS

Basin Flood Storage Top of Water Levels and Volumes

Bio-retention	**Base**	6.4m	– – – – –
20% AEP -	**TWL**	7.20m	– – – – –
	Depth	0.8m	
	Area	17,065m2	
	Volume	10,283 cu.m	
1% AEP -	**TWL**	7.80m	– – – – –
	Depth	1.4m	
	Area	20,481m2	
	Volume	21,604 cu.m	

Legend

▨	**Proposed Living Stream**
●	**Proposed Trees**
●	**Existing Trees**
🟩	**Plant Palette - Melaleuca Woodland**
🟩	**Plant Palette - Marri Sheoak Forest**
🟩	**Plant Palette - Banksia Woodland**

Note: Refer 'Living Knowledge Stream Design Guide' by Syrinx for further details on Plant Palettes.

GREATER CURTIN LWMS - JACK FINNEY LAKE
LANDSCAPE CONCEPT

DWG DES
REV B
DATE 28-11-2018

0 7.5 15 22.5 30 37.5 m
SCALE 1 : 1500 @ A3

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ASSOCIATES
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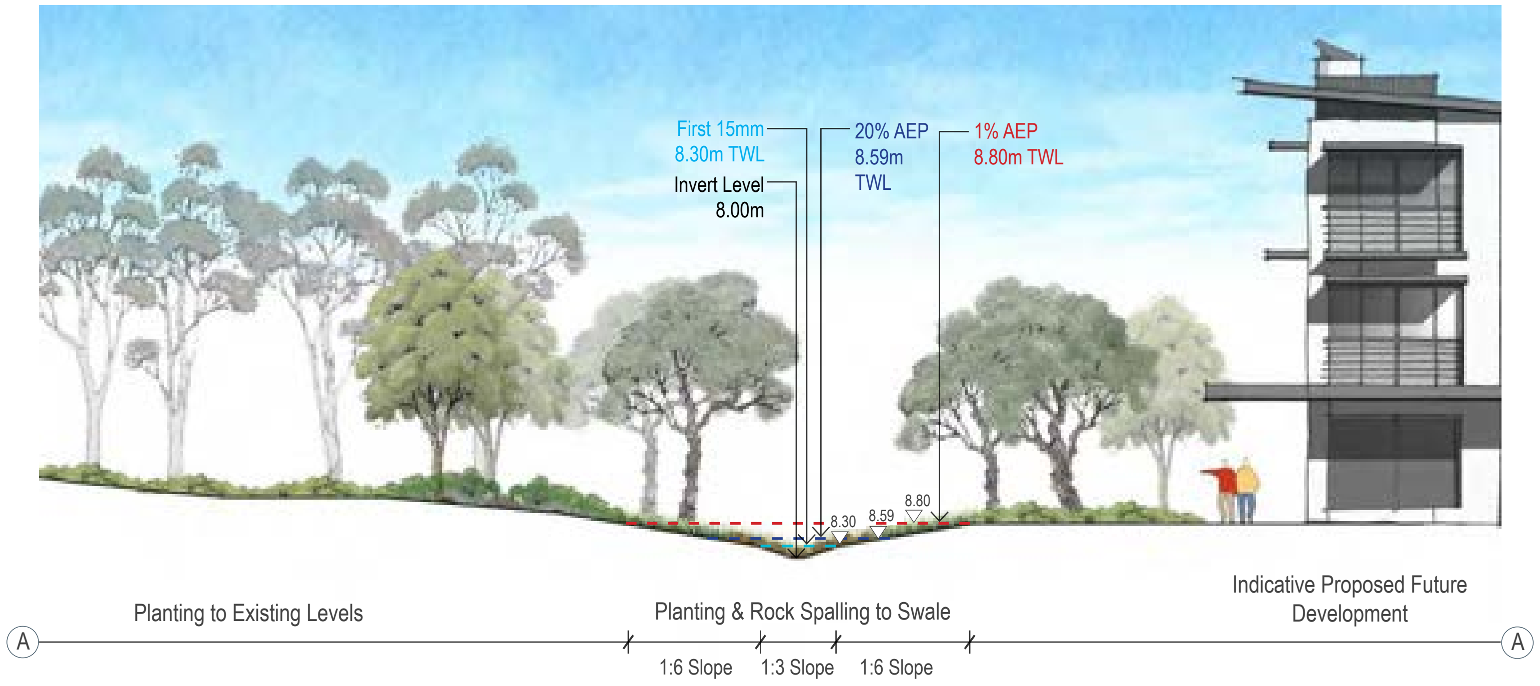
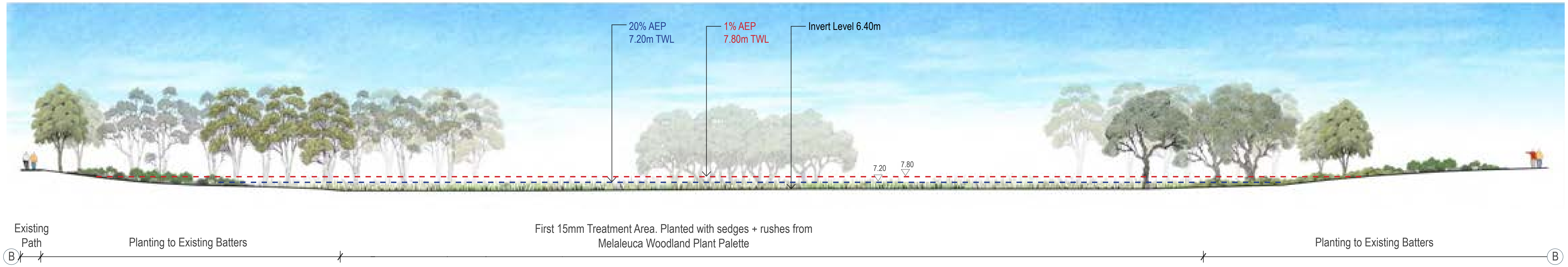


SECTION AA: 1:200 @A3

Section AA Swale Flood Storage Top of Water Levels and Volumes

Bio-retention	**Base**	8.00m	– – – – –
First 15mm -	**TWL**	8.3m	– – – – –
	Depth	0.3m	
20% AEP -	**TWL**	8.59m	– – – – –
	Depth	0.59m	
1% AEP -	**TWL**	8.8m	– – – – –
	Depth	0.8m	



SECTION BB: 1:400 @A3

GREATER CURTIN LWMS - JACK FINNEY LAKE

LANDSCAPE CONCEPT

DWG DES
REV B
DATE 28-11-2018

SCALE NTS

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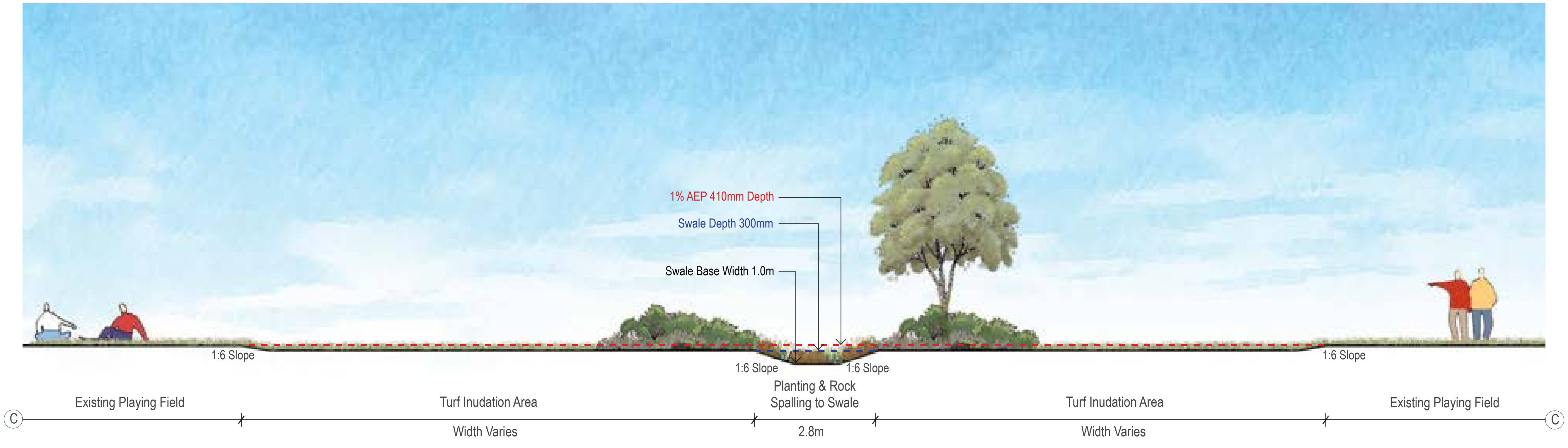

SECTION CC: 1:200 @A3

GREATER CURTIN LWMS - SOUTHERN OVAL STORAGE

LANDSCAPE CONCEPT

DWG DES
REV A
DATE 28-11-2018

SCALE NTS

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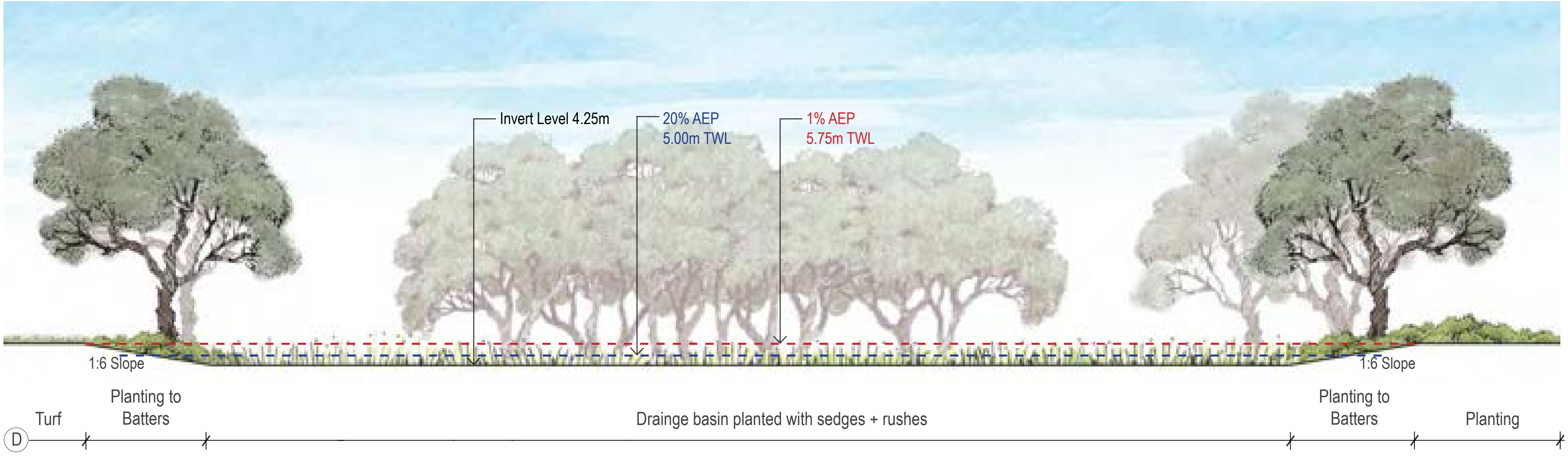

SECTION DD: 1:200 @A3

LOCATION PLAN: NTS

Basin Flood Storage Top of Water Levels and Volumes

Bio-retention	**Base**	4.25m	━ ━ ━ ━ ━
BRA -	**Area**	2270m2	━ ━ ━ ━ ━
20% AEP -	**TWL**	5.00m	━ ━ ━ ━ ━
	Depth	0.75m	
	Area	5472m2	
	Volume	3652 cu.m	
1% AEP -	**TWL**	5.75m	━ ━ ━ ━ ━
	Depth	1.5m	
	Area	6742m2	
	Volume	8170 cu.m	

GREATER CURTIN LWMS - KENT STREET CB
LANDSCAPE CONCEPT

DWG DES
REV A
DATE 28-11-2018

0 7.5 15 22.5 30 37.5 m
SCALE 1 : 1500 @ A3

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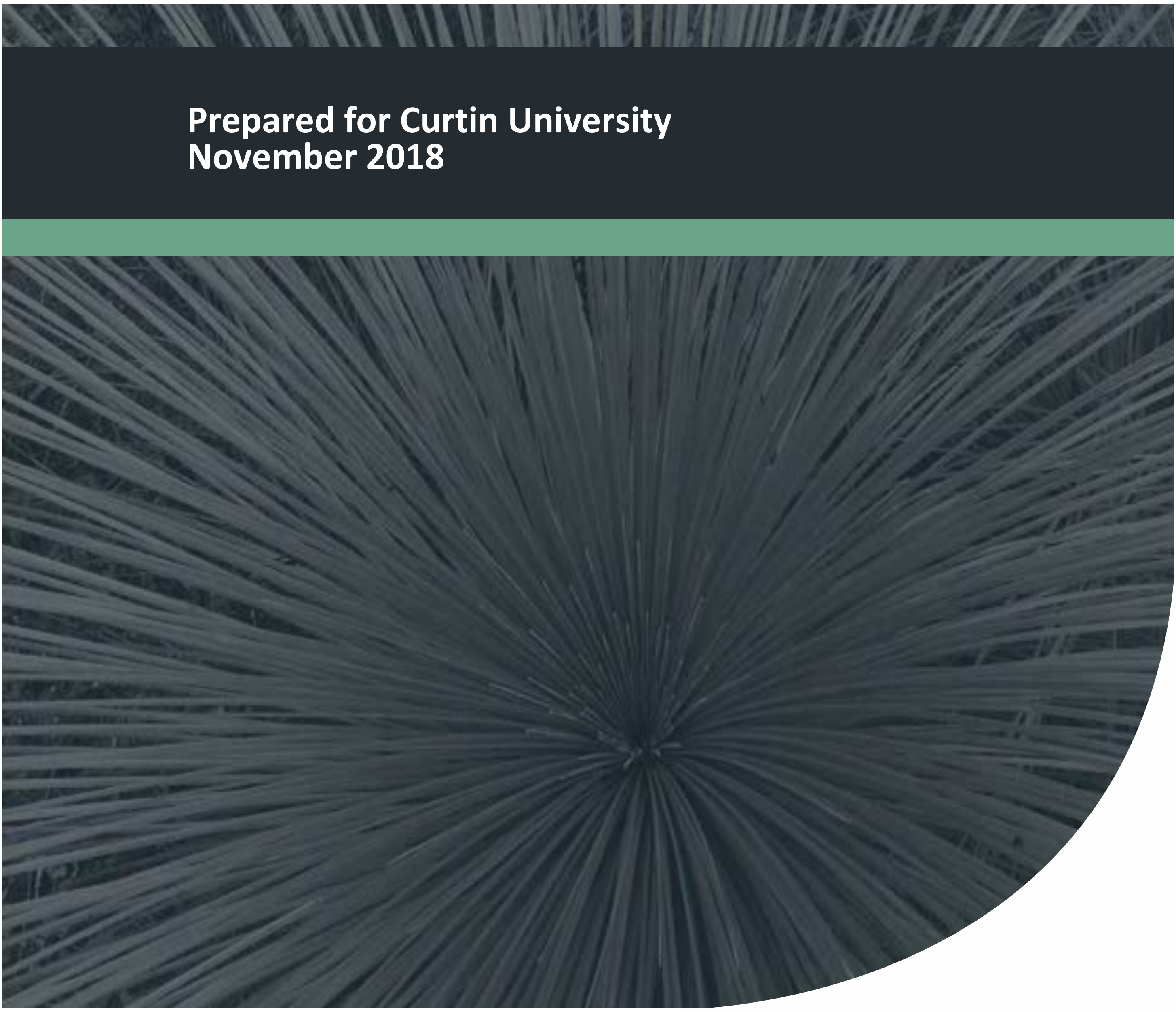
Appendix H

Modelling Assumptions Report

Greater Curtin Master Plan

Modelling Assumptions Report

Project No: EP18-089(01)



Prepared for Curtin University
November 2018

Document Control

Doc name:	**Greater Curtin Modelling Assumptions Report**				
Doc no.:	**EP18-089(01)--004**				
Version	**Date**	**Author**		**Reviewer**	
1	November, 2018	Justin Temmen	JRT	Dave Coremans	DPC
	Appendix to LWMS				

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1 Modelling Assumptions

XPSWMM hydrologic and hydraulic modelling software (v18.1) was used to calculate the surface water runoff volumes within the Greater Curtin Master Plan development area and external upstream catchments discharging to compensation basins within the Curtin University campus site boundary.

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

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

Runoff from each sub-catchment is routed through the catchment using the hydraulic component of 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 the length of 10 m and slope of 0.05 to minimise the lag time of conveying the water from a sub-catchment node to a ‘storage’ node, a ‘dummy intermediate’ node or a conduit/link.
- Links between sub-catchment storages act as conveyance channels (e.g. sheet flow within roads in a 100 year average recurrence interval (ARI) event / 1% annual exceedance probability (AEP)). These links are given lengths and slopes that are representative of the site conditions and actual pathway lengths between catchments.
- All 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.
- Where relevant median swales, bio-retention areas (BRAs), and flood storage areas (FSAs) are modelled as nodal-reservoirs with infiltration depth-rating curves to account for differential infiltration rates with changing depth.

2 Post-development Model

The post-development model uses an "initial loss - continual loss" infiltration model. The post-development catchment area and land types within Catchments were informed by the Greater Curtin Master Plan (provided in Appendix A of the Local Water Management Strategy (LWMS) (Emerge Associates 2018) and aerial imagery of the existing campus (Landgate 2018). **Table 1** gives the loss parameters used within the post-development model.

Table 1 Curtin University post-development parameters

Land type	Initial loss (mm)	Continual loss (mm/hr)	Manning's number (n)
Road and Path Pavements	1	0.1	0.02
Road Verge	9	1.5	0.05
Lot Impervious	15	0.1	0.02
Lot Pervious	25	3.5	0.05
Pre-dev Impervious	1	0.1	0.02
Pre-dev Turf	22.5	2	0.05
Pre-dev Other Softscape	25	3.5	0.05

A summary of post-development catchment information is provided in **Table 2.** A summary of the pre-development land use area remaining post development is provided in **Table 2.** A catchment plan and basin locations are shown in Figures 5 and 6 of the LWMS (Emerge Associates 2018).

Table 2 Curtin University post-development catchment areas

Catchment	Slope	Area (ha)						
		Total catchment area	Total pavement reserve	Paved (impervious)	Verge (pervious)	Total lot area	Lot impervious	Lot pervious
Ct_01a	0.02	2.73	0.41	0.29	0.12	1.48	1.18	0.30
Ct_01b	0.01	3.08	0.40	0.28	0.12	0.05	0.04	0.01
Ct_02	0.01	10.70	1.09	0.76	0.33	2.91	2.32	0.58
Ct_03	0.014	5.23	1.45	1.06	0.39	1.92	1.54	0.38
Ct_04	0.038	37.47	5.10	3.99	1.12	12.77	10.21	2.55
Ct_05	0.016	23.01	2.53	2.23	0.30	4.73	3.78	0.95
Ct_06	0.01	6.62	0.32	0.32	0	0.69	0.55	0.14
Ct_07	0.01	22.39	5.02	3.63	1.39	9.26	7.41	1.85
Ct_08	0.013	3.18	0.97	0.68	0.29	0.73	0.58	0.15
Total		**114.42**	**17.28**	**13.2**	**4.05**	**34.52**	**27.62**	**6.90**

Table 3 Pre-development land use areas

Catchment	Slope	Area (ha)		
		Impervious	Pervious (Turf)	Pervious (other softscape)
Ct_01a	0.02	0	0	0.84
Ct_01b	0.01	0	2.19*	0.44
Ct_02	0.01	1.00	3.36*	2.34
Ct_03	0.014	0	0	1.87
Ct_04	0.038	8.82	2.93	7.86
Ct_05	0.016	11.27	1.03	3.46
Ct_06	0.01	0.71	3.44	1.47
Ct_07	0.01	2.12	0.23	5.75
Ct_08	0.013	1.06	0.26	0.18
Total		**24.97**	**13.43**	**24.21**

* Turf includes existing and future sporting fields as per the Greater Curtin Master Plan.

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

- Lot assumptions
  - All development lots retain the small event (first 15mm) event runoff from impervious surfaces (roofs and hardscape) on lot via soakwells or rainwater tanks, and infiltration in pervious garden areas.
  - Garden areas in lots will have high infiltration rates as it is likely that sand-based landscape mix or mulch will be used.
- Pavement reserve assumptions
  - There will be no infiltration on roads, footpaths, car parks, driveways or plazas. There will however be some minor absorption storage loss which is accounted for in the initial and continuing loss values.
  - Roads are nominated as 70% impervious, and pervious portions (verges) have reduced infiltration to account for footpaths, cross overs, etc.)
- Pre-development land use assumptions
  - Turfed and other softscaped areas are assumed to be 100% pervious.
  - Other softscaped areas are assumed comprised of dense vegetation or turf over a sand-based landscape mix.
- Storage assumptions
  - Where relevant, existing storage areas are modelled as per topographical contours or as provided by the Water Corporation.
  - BRAs retain small event runoff (first 15 mm) from road reserves.
  - FSAs retain runoff from events greater than the small event, up to the 1% AEP / 100 year ARI event.
  - Catchment Ct_02 is assumed to discharge to the existing Water Corporation compensation basin located on Hayman Road and shown on Figure 6 of the LWMS (Emerge Associates 2018).
  - Catchment 03 is assumed to discharge to Catchment 01b for treatment and retention.
  - Catchment Ct_04 and Ct_05 are assumed to discharge to the Jack Finney Lake (within catchment Ct_04). Catchment Ct_05 utilises an intermediate storage basin which discharges to Ct_04 via pipe under gravity. Infrastructure is shown on Figure 6 of the LWMS (Emerge Associates 2018).

  - Catchment Ct_07 is assumed to discharge to the existing Water Corporation compensation basin located on the corner of Kent Street and Manning Road, and shown on Figure 6 of the LWMS (Emerge Associates 2018).
  - Catchment Ct_08 is assumed to discharge to the existing sump on Hayman Road as shown on Figure 6 of the LWMS (Emerge Associates 2018).
- Storage infiltration assumptions
  - All stormwater retention and detention infrastructure (including BRAs, FSAs, compensating basins, and the Jack Finney Lake) have been modelled based on an infiltration rate of 4 m/day which is thought to reflect site conditions. BRAs are assumed to have a clogging factor / infiltration efficiency of 50 %.
  - Infiltration through base area and side slopes of the BRAs and FSAs is considered in the overall infiltration rating curve for these areas.
- Volumes leaving the system through evapotranspiration were assumed to be negligible when compared to the total runoff volume and since the duration of the model run was comparatively short. XPSWMM default evapotranspiration assumptions are therefore used.

2.1.1 Critical Duration Analysis

A critical duration analysis was completed for the 20% Annual Exceedance Probability (AEP), 10% AEP and 1% AEP storm events using durations varying from 30 minutes to 3 days. The critical duration analysis has been based on a maximum storage volume within design flood storage areas for each catchment.

Table 4 Post development catchment design assumptions summary

Catchment	1% AEP Design Storm Duration	10% AEP Design Storm Duration	20% AEP Design Storm Duration
Ct_01a	6 h	6 h	6 h
Ct_01b	6 h	6 h	6 h
Ct_02	12 h	6 h	6 h
Ct_03	6 h	6 h	6 h
Ct_04	6 h	6 h	6 h
Ct_05	6 h	6 h	3 h
Ct_06	6 h	6 h	6 h
Ct_07	6 h	6 h	6 h
Ct_08	6 h	6 h	6 h

Critical duration for the existing storage infrastructure on site was generally longer (12 or 24 hours) for each AEP storm event. Analysis upon the Kent Street compensating basin was also completed for the maximum flow rate for the 1% AEP storm event given that the basin discharges to a Water Corporation stormwater network. The result of the analysis indicates that the 6 hour event is critical based on discharge flow rate.

3 Post-development treatment and flood storage

Hydraulic and hydrological modelling of the Greater Curtin Master Plan area has been used to determine the requirements for small event treatment areas for catchments where infrastructure is not currently present within the site (see **Table 5** below). Treatment areas are assumed to be a maximum of 0.3 m deep with 1:3 side slopes. Catchments and potential locations of treatment areas are illustrated in Figures 5 and 6 of the LWMS (Emerge Associates 2018).

Table 5 Treatment area requirements for first 15 mm

Catchment	Depth (m)	TWL surface area (m2)	Volume (m3)	Length	Top Width
Ct_01a	0.3	145	40	--	--
Ct_01b	0.3	615	170	--	--
Ct_06 *	0.3	2500	44	200	3
Total		3260	254	--	--

* Discharged to central core of the living stream / swale.

Catchments Ct_02, Ct_04, Ct_07 and Ct_08 are assumed to discharge to existing stormwater compensation and storage areas on site. The existing infrastructure on the Curtin University site is discussed below. Stormwater runoff from catchment Ct_03 is routed to infrastructure at catchment Ct_03. Runoff from catchment Ct_05 is assumed to be detained in an intermediate storage area before ultimate discharge by gravity to Jack Finney Lake in catchment Ct_04 via pipes.

Hydraulic and hydrological modelling of the Greater Curtin Master Plan area has been determine the requirements for flood attenuation for catchments where flood storage is not currently present within the site (see

Table 6). Flood storage areas are assumed to be a maximum of 1.2 m deep with 1:6 side slopes. Catchments and potential locations of flood storage areas are illustrated in Figures 5 and 6 of the LWMS (Emerge Associates 2018).

Table 6 New flood storage area requirements

	1% AEP				*10% AEP*				*20% AEP*			
Catchment	**Depth (m)**	**TWL surface area (m²)**	**Volume (m³)**	**Side Slope**	**Depth (m)**	**TWL surface area (m²)**	**Volume (m³)**	**Side Slope**	**Depth (m)**	**TWL surface area (m²)**	**Volume (m³)**	**Side Slope**
Ct_01a	1.2	1125	855	1/6	0.7	739	363	1/6	0.5	636	251	1/6
Ct_01b	1.2	2805	2530	1/6	0.5	744	342	1/6	0.3	1757	457	1/6
Ct_05 *	1.0	1775	1775	Vertical	--	--	--	--	--	--	--	--
Ct_06 **	0.11	6520	682	1/6	0.01	6520	54	1/6	<0.01	6520	37	1/6
Total		**12225**	**5842**			**1482**	**705**			**2393**	**708**	

* Catchment discharges by gravity to Jack Finney Lake in Ct_04 via an intermediate storage area. Intermediate storage for major (1% AEP) event indicated. Infiltration from base of storage assumed.

** Inundation of design flood plain area of Living Stream.

Where pre-development catchments have historically discharged to Water Corporation and Local Government / Main Road basins, these basins have been modelled on topographic contours or staged basin designs (Kanex Kanagaratnam 2018 pers. comm. October 2). Existing flood storage details are shown in **Table 7**.

Table 7 Existing flood storage details

Catchment	Name of retention / detention structure	Depth (m)	Bottom surface area (m^2)	TWL surface area (m^2)
Ct_02	Hayman Road CB	3.8	1,428	6,856
Ct_04	JF Lake	2.2	6,439	26,288
Ct_07	Kent Street CB	1.5	10	12,942
Ct_08	Sump (Hayman Road bus port)	2.8	31	515

External catchment peak inflows were provided by the Water Corporation for catchment Ct_02 (0.36 m^3/s) (Kanex Kanagaratnam 2018 pers. comm. October 2) and Catchment Ct_07 (~0.92 m^3/s) (Kanex Kanagaratnam 2018 pers. comm. November 11).

Hydraulic and hydrological modelling shows that the Jack Finney Lake and Hayman Road basins are sized appropriately for receiving the runoff from those catchments redeveloped under the Greater Curtin Master Plan during the major (1% AEP) storm event. The simulation results show that the design of the Kent Street compensation basin (BG&E 2006) is appropriately sized for receiving runoff from directly connected catchments and the external upstream catchments, allowing for a discharge rate of 0.302 m^3/s in the major (1% AEP) storm event. It is noted that the sump located on Hayman Road at the bus port (and adjacent to Vickery House) is currently appropriate for retention of the minor (20% AEP) storm event.

Simulation results for the existing infrastructure are shown in **Table 8**. Catchments and the locations of existing stormwater infrastructures are illustrated in Figures 5 and 6 of the LWMS (Emerge Associates 2018).

Table 8 Inundation of existing storage infrastructure

		1% AEP			*10% AEP*			*20% AEP*		
Catchment	**Name of retention / detention structure**	**Depth (m)**	**TWL surface area (m²)**	**Volume (m³)**	**Depth (m)**	**TWL surface area (m²)**	**Volume (m³)**	**Depth (m)**	**TWL surface area (m²)**	**Volume (m³)**
Ct_02	Hayman Road CB	2.7	5,030	8,433	2.2	4,238	6,005	1.9	3,852	4,929
Ct_04	JF Lake*	1.4	20,481	21,604	1.0	18,149	13,747	0.8	17,065	10,283
Ct_07	Kent Street CB	1.4	12,692	7,091	1.3	12,117	5,009	1.1	11,728	3,652
Ct_08*	Sump (Hayman Road bus port)	4.7	515	1672	3.5	515	1,052	2.9	515	762
Total			**26,026**	**31,710**		**22,902**	**20,804**		**21,432**	**15,973**

* Catchment Ct_08 is assumed to discharge to the sump adjacent to the Vickery House and bus port on Hayman Road. Modelling shows that the sump is currently designed to retain the 20% AEP only. Future redesign will need to accommodate the required volume.

4 References

BG&E 2006, *Drawing CWD0001A: Resources and Chemistry Precinct Proposed Trenching Plan*, BG&E

Emerge Associates 2018, *Curtin Master Plan Local Water Management Strategy,* Subiaco WA

Innovyze 2018*, XPSWMM Stormwater & Wastewater Management Model Reference Manual*, Innovyze 2018

Landgate 2018, *Landgate Map Viewer,* viewed October 2018, <https://maps.landgate.wa.gov.au/maps-landgate/registered/>.

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