Whitehead & Associates
Environmental Consultants

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(via email)

Ref: WMR_3028_004

24 October 2024

On-site Wastewater Management Report for proposed residential subdivision (Cangon Park – Stages 2 and 3) at Tabbil Creek, NSW

Whitehead & Associates Environmental Consultants Pty Ltd ("W&A") were engaged by John Lidbury (the "Client") to prepare an On-site Wastewater Management Report (WMR) for the residential subdivision of the 'Cangon Park' development at Hanleys Creek Road, Tabbil Creek NSW (the "Site"). The Site, identified as Lot 32 in DP1282790, is zoned R5 (large lot residential) and RU1 (primary production) under the Dungog Local Environmental Plan (LEP) (2014) and has a total area of ~240ha. The proposed subdivision is to occur within the R5 zoning, with a residual lot within the RU1 zoning.

'Stage 1' (Fairways Precinct) of the subdivision previously created 30 rural-residential lots within the northern portion of the Site in 2014. The proposed 'Stages 2 and 3' subdivision will create an additional 88 rural-residential lots (the "Lots") in the central and southern portion of the Site, ranging in size from 0.8ha to 3.53ha. One (1) 111.34ha residual Lot will be created to the south. Access to the proposed Lots will be via a newly constructed internal road accessed by Hanleys Creek Road.

The Site consists of undulating terrain that is largely cleared, comprising of open pasture with scattered vegetation throughout paddocks, hill crests and along Cangon Creek. The Site is bound by Hanleys Creek Road to the north, Clarence Town Road to the east, and private property to the south and west. The Lots will be serviced by onsite (tank) water supply, and no reticulated sewer service is available (or anticipated).

Cangon Creek flows from the southwest to the northeast of the Site towards Clarence Town Road, with multiple drainage lines and dams throughout the Site. The Site is located within the Williams River drinking water catchment. The property is marginally bushfire prone with vegetation category 1 and buffer mapped on the Site, and is flood impacted in areas adjacent waterways.

Dungog Shire Council ("DSC" or "Council") have adopted a comprehensive Development Assessment Framework (DAF, 2015) for On-site Sewage Management (OSSM), which sets out required standards for investigation, acceptable solutions and minimum standards for sewage management in unsewered areas of the Dungog Local Government Area (LGA).

The DSC DAF (2015) identifies each allotment within the LGA as having Low, Medium, High or Very High hazard for OSSM. Council have confirmed the Site to be a “High Hazard” allotment for an unsewered subdivision. As such, Council requires a comprehensive WMR to be provided with the Development Application (DA), in accordance with the minimum standards for a “High Hazard” property as set out in Section 2.3 of the DSC DAF (2015).

As per ‘Note 1’ of Table 2-5 in the DSC DAF (2015), a Cumulative Impact Assessment (CIA) is mandatory within drinking water catchment areas to ensure that water quality exported from the Site is protected. A critical component in the assessment of subdivisions is that created lots must demonstrate that ≥4,000m^2 of ‘useable land’ (UL) is available for effluent management (lots area, less areas inside surface water setbacks).

Given the proposed Lot layout and identified surface water features, ≥4,000m^2 of UL can be achieved within all created lots with a >50% reduction in the applied buffers. Therefore, as in Table 2-13 of the DSC DAF (2015), a ‘Detailed’ CIA is to be provided as part of the application to support the design and demonstrate compliance with environment and health protection (E&HP) targets. This approach is supported by the DSC DAF (2015) for ‘High Hazard’ allotments.

The following table presents the minimum standards required to comply with the DSC DAF (2015) for the subdivision of a “High Hazard” allotment.

DSC Minimum Standards for WMR (High Hazard – Subdivision)		
Report Element	**Minimum Standard**	**Completed**
Introduction and Background	• Name, contact details and qualifications of author(s);	✓
	• Site location and owner;	✓
	• Allotment sizes (m² or ha);	✓
	• Proposed / existing water supply;	✓
	• Number of new building entitlements;	✓
	• Availability of sewer;	✓
Site and Soil Assessment	• Broad overview of locality and landscape characteristics;	✓
	• Details of the date of assessment in addition to statements confirming the methods used to complete the assessment;	✓
	• Site assessment that considers all parameters listed in Table 28 of the DAF in accordance with *AS/NZS 1547:2012*;	✓
	• Detailed review of available published soils information for the Site;	✓
	• Soil assessment that considers all parameters listed in Table 6-1 of the DAF in accordance with *AS/NZS 1547:2012*;	✓
	• Where multiple soil facets are present the site plan should show the approximate boundary between facets;	✓
	• Detailed explanation of the implications of observed site and soil features for system design and performance;	✓
	• Assessment of the existing condition of the receiving environment and sensitivity to on-site system impacts;	✓
System Selection and Design	• Summarise potential treatment and land application systems considered including advantages and limitations;	✓
	• Brief statement justifying selection of potential treatment and land application systems;	✓

DSC Minimum Standards for WMR (High Hazard – Subdivision)		
Report Element	**Minimum Standard**	**Completed**
	• Sizing of land application systems using the most limiting of soil water and annual nutrient balances (see *Technical Manual*);	✓
Site Plan	• Survey plan;	✓
	• Location of soil test pits;	✓
	• Proposed allotment boundaries, dimensions and area;	✓
	• Location of existing buildings, swimming pools, paths, groundwater bores, dams and waterways;	✓
	• Location of exclusion zones (e.g. setback distances and unsuitable site and soil conditions) and useable land;	✓
	• Location of EMAs and an indicative LAA and reserves (where applicable) to clearly demonstrate viability;	✓
	• Two (2) metre elevation contours;	✓
	• Location of existing and proposed drainage pipework (centreline);	Completed at single lot level.
Cumulative Impacts (where required)	• Summary of approach taken and confirmation of compliance with the Minimum Standards documented in Section 2.7;	✓
	• Results demonstrating compliance with local water quality objectives and adequate management of health risk as defined and demonstrated in Section 10.1.1 of the Technical Manual;	✓
	• Brief discussion of long-term risks to health and environment and recommended management measures to address impacts;	✓
Appendices	• Soil bore logs for all test pits;	✓
	• Raw laboratory results for soil analysis; and	✓
	• All design calculations and assumptions including screenshots of cumulative impact spreadsheets/models.	✓

1 Author Statement

This WMR was prepared by Connor Morton. Connor is an Environmental Consultant with W&A, holding a B. EnvSc. and Mgmt. (Earth Systems) from the University of Newcastle (2019). Connor has completed the On-site Wastewater Management professional short-course with the Centre for Environmental Training (CET) and has completed multiple WMR's across the Central Coast, Hunter and MidCoast regions.

2 Introduction

This assessment has been undertaken in reference to the assessment and design principles of:

- Standards Australia / Standards New Zealand (2012), *On-site Domestic Wastewater Management* (*AS/NZS 1547:2012*);
- NSW Department of Local Government (1998), *Environment & Health Protection Guidelines: On-site Sewage Management for Single Households* (NSW DLG, 1998);
- Dungog Shire Council (2015), *On-site Sewage Development Assessment Framework* (DSC DAF, 2015); and
- Dungog Shire Council (2015), *On-Site Sewage Management Technical Manual* (DSC Technical Manual, 2015).

The following table presents information on the property investigated.

Feature	Description
Site Address	Hanleys Creek Road, Tabbil Creek NSW
Lots	Lot 32 in DP1282790
Local Government Area	Dungog Shire Council
Land Zoning	R5 (large lot residential) with rural-residential Lots, RU1 (primary production) within residual Lot
Site Size (ha)	~240
Water Catchment	Williams River Drinking Water Catchment
Hazard Class	High
Climate Zone	Southern Rainfall Zone
Sewer Connection Available (within 75m)	No
Potable Water Supply	On-site (tank) water supply

3 Site and Soil Assessment

The site investigation was undertaken by Connor Morton and Ben Colautti of W&A on 7 February 2022. A description of site physical constraints and the degree of limitation they pose to OSSM is provided in the following table. Reference is made to the rating scale in Table 4 of NSW DLG (1998) and, where appropriate, the DSC DAF (2015).

SITE ASSESSMENT			
Parameter	**Data / Observation**	**Reference**	**Classification/ Outcome**
Climate	Temperate climate with mean annual rainfall of 929mm; minimum of 37mm (August), maximum of 122 (February).	Table 8-2 DSC DAF Technical Manual (2015)	Minor limitation
	Mean annual evaporation of 1,570mm. Potential evaporation exceeds rainfall for one (1) month of the year (June).		
	Climate Zone: Southern Rainfall Zone (Climate Zone 1: CAF = 0mm/day).	Figure 8-1 DSC Technical Manual (2015)	
Sizing			
Hydraulic modelling attached:	Yes	As per DSC DAF (2015), NSW DLG (1998), and *AS/NZS 1547:2012* procedures	
Nutrient modelling attached:	Yes		
Land application area (LAA) sizing attached:	Yes		

SITE ASSESSMENT				
Parameter	**Data / Observation**		**Reference**	**Classification/ Outcome**
Wet weather storage requirement:		N/A	N/A	
Flooding				
Inundation	The Site is flood impacted adjacent Cangon Creek and its tributaries (refer Figure 4, Appendix A).		Torrent Consulting 'Flood Assessment' (L.T2426.002)	Major limitation
LAAs above 5% AEP flood level:		Yes	All (nominal) LAAs located above flood impacted lands	Minor limitation
LAAs above 1% AEP flood level:		Yes		
Electrical components above 1% AEP flood level:		Yes	To be confirmed at the individual Lot scale	
Exposure and Aspect	The Site is primarily cleared with scattered trees in paddocks, hill crests and along Cangon Creek. Moderate to high exposure to sun and prevailing wind within available effluent management area (EMA). Aspect is primarily north and east facing, with some proposed Lots south facing.		Minor to Moderate limitation	
Slope	5% – 27% slope across the Site. Majority of steeper slopes located within riparian zones and proposed residual Lot.		Minor to Major limitation	
Landform	Landform mixed between convex convergent and convex divergent slope configurations, dependent upon location in relation to drainage features.		Minor to Moderate limitation	
Run-on and Seepage	No run-on or up-slope seepage observed in the vicinity of the available EMA at the time of the Site investigation. Stormwater from upslope areas and roof run-off must be directed away from the LAAs (refer Section 8.3).		Minor limitation	
Erosion Potential	Moderate erosion observed in areas without vegetation coverage, most prevalent along the banks of waterways. Address potential concerns using erosion and sediment controls during construction and revegetation of LAAs after installation using turf (refer Section 8.2).		Moderate limitation	

<table>
<tr><th colspan="5">SITE ASSESSMENT</th></tr>
<tr><th>Parameter</th><th colspan="2">Data / Observation</th><th>Reference</th><th>Classification/ Outcome</th></tr>
<tr><td>Site Drainage</td><td colspan="2">Moderately well drained. Minor signs of surface saturation in the form of ponding within heavy vehicle traffic areas.
Mottling observed in subsoils indicating locally restricted vertical drainage during periods of extended wet weather.</td><td colspan="2">Moderate limitation</td></tr>
<tr><td>Fill</td><td colspan="2">None observed or apparent.</td><td colspan="2">Minor limitation</td></tr>
<tr><td>Groundwater</td><td colspan="2">No shallow groundwater (GW) encountered during soil survey.
NSW Office of Water GW bore registry indicates no registered ‘domestic’ bores are located within 250m of the Site.</td><td colspan="2">Minor limitation</td></tr>
<tr><td colspan="3">Applicable Buffers</td><td colspan="2"></td></tr>
<tr><td colspan="2">Permanent rivers and creeks (100m):</td><td>Yes</td><td colspan="2" rowspan="2">Not achievable in Lots 205-207, 209-220, 222, 225, 227, 228, 230, 232-234, 245, 248, 249, 301-303, 305, 308, 309, 313-315, 325-327, 329, 332-334 and 337.
Reduced setbacks proposed, with mitigation (refer Section 7).</td></tr>
<tr><td colspan="2">Intermittent creeks, drainages and dams (40m):</td><td>Yes</td></tr>
<tr><td colspan="2">Domestic GW bores and wells (250m):</td><td>N/A</td><td colspan="2"></td></tr>
<tr><td colspan="2">Lot boundaries (3m if EMA downslope-6m if EMA upslope):</td><td>Yes</td><td colspan="2">Achievable</td></tr>
<tr><td colspan="2">Buildings, driveways and swimming pools (3m if EMA downslope-6m if EMA upslope):</td><td>Yes</td><td colspan="2">Achievable</td></tr>
<tr><td colspan="2">Limiting horizon (GW, bedrock etc.) (0.6m):</td><td>Yes</td><td colspan="2">Achievable</td></tr>
<tr><td colspan="2">Other sensitive receptors:</td><td>N/A</td><td colspan="2"></td></tr>
<tr><td>Surface Rock / Outcrop</td><td colspan="2">Minor areas of surface rock observed on steeper slopes during the Site investigation.</td><td colspan="2">Moderate limitation</td></tr>
<tr><td>Useable Land</td><td colspan="2">Available UL calculated for proposed lots (refer Figure 2, Appendix A).
<4,000m²: Lots 205-207, 209-220, 222, 225, 227, 228, 230, 232-234, 245, 248, 249, 301-303, 305, 308, 309, 313-315, 325-327, 329, 332-334 and 337.
>4,000m²: Lots 201-204, 208, 221, 223-234, 226, 229, 231, 235-244, 246, 247, 250, 251, 304, 306, 307, 310-312, 316-324, 328, 330, 331, 335 and 336.</td><td colspan="2">Major limitation</td></tr>
</table>

SITE ASSESSMENT			
Parameter	**Data / Observation**	**Reference**	**Classification/ Outcome**
Concluding Remarks Flooding, exposure / aspect, slope, landform, drainage, and presence of surface rock outcrops pose a moderate to major limitation to OSSM at the Site; however, can be mitigated or avoided through conservative LAA location, design and installation. Erosion potential poses a moderate limitation to OSSM at the Site; however, this can be overcome by using erosion and sediment controls during construction and revegetation of LAA using turf (refer Section 8.2). The proposed subdivision cannot satisfy the DSC DAF (2015) 'deemed to comply' minimum standard of >4,000m² of UL on all proposed Lots due to required buffer distances to surface water features. Additional modelling (Cumulative Impact Assessment) and justification is provided in this WMR for a >50% reduction in the required setbacks to surface water features within proposed Lots to achieve ≥4,000m² UL criteria (refer Section 7), as per Table 2-13 DSC DAF (2015).			

A description of the soil physical / chemical constraints and the degree of limitation they pose to OSSM is provided in the following table. Soils information is informed by the latest soil investigation by W&A (2022) and earlier soil investigations by NORTHROP (2012) and W&A (2014). Reference is made to the rating scale in Table 6 of the NSW DLG (1998) and, where appropriate, the DSC DAF (2015).

SOIL ASSESSMENT (physical)			
Parameter	**Data/ Observation**	**Reference**	**Classification/ Outcome**
Soil Depth	400mm – 1,500mm	Minor to Major limitation	
Allocation of Soil Profiles	To allow for recommendations specific to each proposed Lot, soil profiles have been assigned by means of proximity and elevation. **W&A, 2022** **BH1:** Lots 249-251; **BH2:** Lots 204-206, 229-233; **BH3:** Lots 240-245; **BH4:** Lots 302, 303; **BH5:** Lots 304, 305, 310-312; **BH6:** Lots 313-320; and **BH7:** Lots 207-210. **W&A, 2014** **TP6:** Lots 211-215, 235; **TP7:** Lots 218-221, 246; **TP8:** Lots 247, 248;		

SOIL ASSESSMENT (physical)			
Parameter	**Data/ Observation**	**Reference**	**Classification/ Outcome**
	TP9: Lots 212, 321-327; **TP10:** Lots 328-332; **TP11:** Lots 333-337; and **TP12:** Lots 301, 306-309. **NORTHROP, 2012:** **NR2:** Lots 201-203, 222-228; and **NR3:** Lots 216, 217, 236-239.		
Soil Profile	**W&A, 2022** **BH1-3, & 6:** A: 0mm – 200/300mm, moderately structured, light clay (Cat 5). B: 200/300mm – 400/650mm, moderately structured / massive, medium clay (Cat 6). **BH4:** A: 0mm – 200mm, moderately structured, silty clay loam (Cat 4). B_1: 200mm – 350mm, moderately structured, light clay (Cat 5). B_2: 350mm – 450mm, weakly structured, medium clay (Cat 6). **BH5:** A: 0mm – 200mm, moderately structured, silty clay loam (Cat 4). B_1: 200mm – 350mm, massive structured, light clay (Cat 5). B_2: 350mm – 600mm, weakly structured, medium clay (Cat 6). **BH7:** A: 0mm – 250mm, moderately structured, clay loam (Cat 4). B: 250mm – 1,000mm, massive, heavy clay (Cat 6). **W&A, 2014** **TP6, 8 & 12:** A: 0mm – 100mm, weakly structured, loam (Cat 3). B: 100mm – 400/1,400mm, weakly structured medium / heavy clay (Cat 6).	Minor to Major limitation	

SOIL ASSESSMENT (physical)			
Parameter	**Data/ Observation**	**Reference**	**Classification/ Outcome**
	TP7 & 9: A: 0mm – 300/450mm, loam / silty clay loam (Cat 3/4). B: 300/450 – 700/1,050mm, sandy clay (Cat 5). **TP10 & 11:** A: 0mm – 300mm, moderately structured, loam /sandy clay loam (Cat 3/4). B: 300mm – 400mm, weakly structured, sandy loam (Cat 2). **NORTHROP, 2012** **NR2 & 3:** A: 0mm – 100/150mm, strongly structured, loam (Cat 3) / clay loam (Cat 4). B_1: 100/150mm – 300/400mm. strongly structured, sandy clay (Cat 5). B_2: 300/400mm – >600mm, weakly / strongly structured, sandy clay (Cat 5) / clay (Cat 6). Locations of boreholes shown in Figures 2 – 4, Appendix A. Soil borelogs and laboratory results presented as Appendix B.		
Depth to Water Table	Shallow (episodic) water table not encountered.	Minor limitation	
Coarse Fragments (%)	2% – 40% (<2mm – 20mm).	Minor to Moderate limitation	
Soil Permeability	<0.06m/d (indicative).	Massive medium clay (Cat 6)	Major limitation
Modified Emerson Aggregate Class (EAT)	**W&A, 2022** **BH1:** 8. **BHs 2, 3, 5, 7:** 7 – 8 (topsoil), 2(1) – 2(3) (subsoil). **BH4:** 8 (topsoil), 5 (subsoil). **BH6:** 2(1) – 2(3). **W&A, 2014** **TP 6:** 8 (topsoil), 2(1) – 2(3) (subsoil). **TPs 7 – 12:** 2(1) – 2(2).	Minor to Major limitation	

SOIL ASSESSMENT (physical)			
Parameter	**Data/ Observation**	**Reference**	**Classification/ Outcome**
	NR, 2012 **NR2 & 3:** 2(1) – 2(2).		
Soil Landscape	The available EMA within proposed lots is located on the Dungog ('du'), Dungog Variant A ('dua') and Dungog Variant B ('dub') Soil Landscape (refer Figure 5, Appendix A). Landscape consists of rolling hills and low hills within the 'du' landscape, undulating hills and ridge tops within the 'dua' soil landscape, and imperfectly drained drainage plains within the 'dub' soil landscape. Relief of 40m – 120m, elevations of 60m – 200m, and slopes of 10% – 20%. Soils typically consists of brown sandy clay loam / bleached sandy clay loam topsoil, underlain by yellowish brown light to medium clay. Limitations within the 'du' and 'dua' soil landscapes consists of seasonal waterlogging, high run-on potential, high sheet erosion hazards, high gully erosion risk, shallow soils and rock outcrops. Permanently high watertables, seasonal waterlogging, high run-on, very high gully erosion risk, engineering hazard and high sheet erosion risk within the 'dub' soil landscape.	Soils of the Dungog 1:100,000 Sheet (Henderson, L.E. 2000)	

Concluding Remarks

Limited available topsoil / soil profile depth is identified within proposed Lots 201-206, 211-251, 301-337. Soil stability limitations are identified within proposed Lots 201-248, 301, 304-337. These limitations can be mitigated through soil improvement recommendations (refer Section 8.1).

Soil permeability presents moderate to major limitations to OSSM at the Site; however, can be mitigated through conservative LAA location, sizing and design.

Coarse fragments >20% are only recorded in TP9 (W&A, 2014). Mitigation considered unnecessary.

SOIL ASSESSMENT (chemical)				
Parameter	**Data/ Observation**		**Reference**	**Classification / Outcome**
pH	Topsoil: 5.7 – 6.7 Subsoil: 5.5 – 6.9	Neutral to strongly acidic.	Moderate limitation	
EC (EC_e)	Topsoil: 0.06 – 0.54 Subsoil: 0.08 – 3.25	Non-saline to slightly saline	Minor limitation	
ESP (%)	7.2 – 20.3	Sodic to strongly sodic	Based on previous soil analysis at the Site (NORTHROP, 2012 and W&A, 2014)	Major Limitation
CEC (me/100g)	8.4 – 32.4	Moderate to high fertility		Moderate limitation
P-sorption (mg/kg)	115 – 557	Moderate to high		Moderate limitation

Concluding Remarks

Soil pH presents a moderate limitation to proposed Lots 201-206, 211-233, 235-251 and 301-337, with sodicity (ESP) and cation exchange capacity (CEC) posing a moderate to major constraint to OSSM within all proposed Lots.

Potential negative impacts can be mitigated through soil improvement recommendations (refer Section 8.1.2). Limiting P-sorption can be mitigated through conservative LAA design and adoption of nutrient buffers (refer Section 6.4).

General notes on soil chemistry parameters are presented in Appendix F.

4 Wastewater Generation

4.1 Wastewater Quantity

Once subdivided, each proposed Lot is required to have a separate OSSM system. For the basis of this assessment, W&A have conservatively assumed a maximum five (5) bedroom dwelling on each Lot. The expected wastewater hydraulic load associated with each Lot is presented in the following table, with potable water to be provided by on-site (tank) supply.

	Value	Description
Number of bedrooms	5	Assumed 5-bedroom dwellings
Occupancy rate (persons per bedroom)	1.6	Section 6.2 of DSC DAF (2015)
Design Occupancy (EP)	8	5-bedrooms x 1.6EP
Wastewater generation allowance (L/person/day)	120	Table 6-2 of DSC DAF (2015) for roof (on-site) water supply
Design hydraulic load (L/day)	**960**	(8EP x 120L/person/day)

4.2 Wastewater Quality

The contaminants in wastewater have the potential to create undesirable public health concerns and pollute waterways unless managed appropriately. As a result, wastewater must be treated to remove the majority of pollutants and enable attenuation of the remaining pollutants through soil processes and plant uptake.

Wastewater generated by the future dwellings on proposed Lots is expected to be of 'typical' domestic nature, with combined wastewater; blackwater (toilet) and greywater (kitchen, laundry and shower) streams. As such, untreated wastewater is expected to have characteristics similar to that described in the following table; which incorporates information taken from NSW DLG (1998).

Parameter	Loading	Greywater %	Blackwater %
Daily Flow		65	35
Biochemical Oxygen Demand	200 – 300mg/L	35	65
Suspended Solids	200 – 300mg/L	40	60
Total Nitrogen	20 – 100mg/L	20 – 40	60 – 80
Total Phosphorus	10 – 25mg/L	50 – 70	30 – 50
Faecal Coliforms	10^3 – 10^{10}cfu/100ml	Medium – High	High

5 Proposed Wastewater Treatment

Given the identified site and soil limitations, primarily proximity to surface water features and low permeability of subsoils, primary treatment systems (i.e. septic tanks) are not recommended as they significantly limit effluent disposal and reuse options and pose a higher risk to human and environmental health compared to secondary or tertiary treatment systems. Therefore, a minimum effluent quality standard of 'secondary treatment' (with disinfection) is recommended.

5.1 Recommended Wastewater Treatment System

Secondary treatment is aimed at the removal of dissolved and suspended organic material by a combination of physical and biological methods, usually incorporating both aerobic and anaerobic phases. Secondary treatment presents a significantly lower risk to human health and the environment when compared to conventional primary (septic tank) systems.

The NSW Ministry of Health ("NSW Health") provides accreditation for domestic secondary treatment systems (STS) in NSW. The system selected for use on each of the proposed Lots must hold such an accreditation. Appropriate secondary treatment technologies include (but are not limited to) the following:

- Aerated wastewater treatment systems (AWTS);
- Media / textile filter systems; and
- Aerobic sand filters (accredited or site-specific design required).

A detailed list of suitable NSW Health accredited systems can be found at:

http://www.health.nsw.gov.au/environment/domesticwastewater/Pages/default.aspx

Disinfection units are typically installed as a standard component of proprietary STS', or can be installed as an add-on by the system supplier. A disinfection unit must be installed with the chosen system. Domestic systems typically use one or a combination of the following disinfection methods:

- Ultra violet (UV) irradiation; and / or
- Chlorination.

Final system selection will be the responsibility of the future property Owners; however, selection and installation of the system must follow the requirements of Section 6.3 of the DSC DAF (2015) and the recommendations of this WMR.

5.1.1 Treated Effluent Quality

Section 6.3.1 of the DSC DAF (2015) describes the minimum effluent quality standards for secondary treatment systems. The selected STS is expected to achieve the following (minimum) secondary effluent quality standards, as outlined in the following table.

Parameter	Loading
Biochemical Oxygen Demand	≤20mg/L (>90% of samples)
Suspended Solids	≤30mg/L (>90% of samples)
Faecal Coliforms	≤30cfu/100mL (>90% of samples)
Total Nitrogen	≤30mg/L
Total Phosphorus	≤10mg/L

The listed phosphorus and nitrogen concentration values are targets and have been adopted for nutrient balance modelling (only).

5.1.2 System Siting

The final positioning of the treatment systems will depend on the local gradient and level controls and can be determined in consultation with a licensed plumber and Council prior to obtaining consent for the installation.

Final plumbing design will be the responsibility of a certified plumber and must adhere to relevant codes and standards as described in Section 6.3.8 of the DSC DAF (2015).

5.1.3 System Operation and Management

Successful performance of wastewater treatment systems relies on periodic monitoring and maintenance, which will be the responsibility of future property Owners. The selected treatment systems should be serviced by a suitably qualified technician at the prescribed intervals.

6 Proposed Effluent Management

This section describes the Site capability for effluent management and provides design details, including sizing of the required LAAs for the future dwellings on the proposed Lots. As detailed above, secondary treatment is considered the most appropriate wastewater treatment option for the proposed lots.

6.1 On-site Effluent Management Options

W&A have considered the suitability of various land application systems with regard to the identified site and soil limitations at the Site. In determining the suitability of the various options, we have assessed the Site constraints and the relative environmental and public health risks associated with each.

The following table provides a summary analysis of the effluent land application options considered for the proposed Lots, and presents recommendation for the preferred approach to be used in conjunction with the proposed secondary treatment system selected.

<table>
<tr><th>Land Application Option</th><th>Suitable</th><th>Reasoning</th></tr>
<tr><td>Absorption Trenches/ Beds</td><td rowspan="2">Possible</td><td rowspan="2">Subsoil absorption systems are not supported by AS/NZS 1547:2012 for a majority of the proposed Lots due to available soil depth, slope and low permeability of subsoils.
Secondary subsoil absorption systems, with adequate engineered design, may be feasible within select Lots; however, other LAA options are considered more suitable.</td></tr>
<tr><td>ETA Beds</td></tr>
<tr><td>Mounds</td><td>Possible</td><td>Mounds considered suitable in areas where slope is <15%; however, option discounted due to substantial cost and availability of suitable alternatives.</td></tr>
<tr><td>Surface Irrigation</td><td>No</td><td>Surface irrigation generally not permitted for new OSSM systems, as per Section 6.6.1 DSC DAF, 2015.</td></tr>
<tr><td>Subsurface Irrigation</td><td>Yes</td><td>Considered most suitable as effluent is able to be applied high in the soil profile, maximising evapotranspiration and effluent reuse (AS/NZS1547:2012: Section M3).</td></tr>
</table>

Based on the above analysis, subsurface irrigation (SSI) is the preferred option for the future dwellings on the proposed Lots. A description of the preferred effluent management method, LAA setbacks and sizing are presented in the following sections.

6.2 Subsurface Irrigation (SSI)

SSI is suitable within lawn and landscaped areas and applies effluent within the root-zone of plants for optimum irrigation efficiency. It is an ideal option for ensuring even, widespread coverage of the proposed irrigation area. SSI installation does not require any bulk materials or heavy machinery; irrigation lines can be simply installed with a small trench digger or "ditch-witch".

Proprietary, pressure-compensating subsurface drip (PCSD) irrigation pipe designed for use with treated effluent should be used that will ensure distribution of effluent at uniform, controlled application rates. These products have been specifically designed for use with effluent and allow for the higher BOD_5, suspended solids, nutrient and biological loads usually present in effluent compared to potable water.

They contain specially designed emitters that reduce the risk of blockage, typically incorporating chemicals that provide protection against root intrusion and biofilm development (e.g. Trifluralin or copper). The dripper lines are coloured lilac to clearly identify that they are irrigating treated effluent.

6.3 Buffers

Buffer (or setback) distances are recommended to provide a form of mitigation against unidentified hazards and reduce potential pathways of human and environmental exposure. Standard environmental buffers required for SSI systems are presented in the following, based on Table 6-8 of the DSC DAF (2015).

- 250m from domestic GW bores;
- 100m from permanent watercourses;
- 40m from intermittent watercourses, drainage channels and dams;
- 15m to retaining walls, embankments, escarpments and cuttings; and
- 6m if area up-gradient and 3m if area down-gradient of dwellings and buildings, swimming pools, property boundaries and driveways.

Most of the recommended buffer distances are achievable on the Site except for the setback to Cangon Creek and tributary drainages within Lots 205-207, 209-220, 222, 225, 227, 228, 230, 232-234, 245, 248, 249, 301-303, 305, 308, 309, 313-315, 325-327, 329, 332-334 and 337 (refer Figure 2, Appendix A).

6.3.1 *Buffer Reduction*

In order to achieve the required minimum UL of 4,000m^2 on all proposed Lots, the buffer distances to surface water features must be reduced, as follows:

- 40m to Cangon Creek (60% reduction); and
- 20m to the intermittent drainage features and dams (50% reduction).

Therefore, as prescribed in Table 2-13 of the DSC DAF (2015), a Detailed CIA has been undertaken to demonstrate that the reduction in the available setback and associated OSSM risk will be effectively mitigated through secondary treatment and effluent land application design on each lot (refer Section 7).

6.4 LAA Sizing

Preliminary sizing of the required SSI LAAs for the future dwellings on the proposed Lots have been determined using the DSC DAF (2015) procedures and relevant guidelines. For simplicity, inputs for modelling such as the 'design irrigation rate' (DIR) and P-sorption have been based on the 'worst-case' scenario.

Therefore, a <u>DIR of 2mm/day</u> (based on limiting Cat 6 subsoils) and a <u>P-sorption of 115mg/kg</u> (based on limiting p-sorption within TP9, W&A 2014) have been used for hydraulic and nutrient modelling (respectively).

6.4.1 Soil Loading Rate

As in Table M2 of *AS/NZS 1547:2012*, 20% reduction in DIR is recommended for LAAs with slopes between 10% – 20% to ensure effluent migration down slope is taken up adequately within the topsoil and plant root system.

To assess this, the 'Slope' and 'Zonal statistics' QGIS tools were used to obtain the average slope within the available EMA of the proposed Lots. Proposed Lots with available EMA slopes of ≥10% were identified, and a 20% reduction in DIR was applied.

This impacts Lots 303-305 and 311, with the required DIRs for these Lots reduced to 1.6mm/day (2mm/day x 80%). The DIR of Lots with average slopes <10% remain unchanged.

6.4.2 Hydraulic Sizing

Section 6.4.3 of the DSC DAF (2015) and Section 9.2 of the DSC DAF Technical Manual (2015) provides a simplified hydraulic sizing equation, with a climate adjustment factor (CAF) for use in sizing LAAs for residential developments on low, medium and high hazard allotments.

The Site is situated in the Southern Rainfall Zone (Climate Zone 1), as identified in Figure 8-1 of the DSC DAF Technical Manual (2015). As such, a CAF of 0mm/day has been adopted for use in LAA sizing, as shown:

$$LAA = Q / (DIR – CAF)$$

Where;

LAA = Land Application Area (basal area in m^2);

Q = Design Wastewater Generation Rate (L/day);

DIR = Design Irrigation Rate (mm/day); and

CAF = Climate Adjustment Factor (mm/day).

The SSI LAA required to assimilate the estimated hydraulic loads from proposed Lots with an available EMA of <10% slope is 480m^2 (960L/day / 2mm/day), and 600m^2 for Lots with an available EMA of ≥10% slope (960L/day / 1.6mm/day).

6.4.3 *Nutrient Sizing*

Nutrient balance modelling was also undertaken to determine the area required to sustainably manage the expected nutrient loads from the proposed Lots. Nutrient sizing requirements are outlined in Section 9.3 of the DSC DAF Technical Manual (2015) which generally follows NSW DLG (1998) procedure.

The nutrient balance used here is based on the simplistic NSW DLG (1998) methodology but improves this by more accurately accounting for natural nutrient cycles and processes. It acknowledges that a proportion of nitrogen will be retained in the soil through processes such as ammonification (the conversion of organic nitrogen to ammonia) and a certain amount will be lost by denitrification, microbial digestion and volatilisation (Patterson, 2003). Patterson (2002) estimates that these processes may account for up to 40% of total nitrogen lost from soil. In this case, a more conservative estimate of 20% is adopted for the nitrogen losses due to soil processes.

The nutrient balance was undertaken using a design hydraulic load of 960L/day (refer Section 4.1) and the expected standards for secondary effluent. The inputs and results are presented in the following table. Full nutrient balance results are presented in Appendix C.

Parameter	Units	Value	Comments
Design (daily) hydraulic load	L/day	960	Maximum wastewater generation (refer Section 4.1)
Effluent total nitrogen concentration	mg/L	≤30	Target effluent quality following secondary treatment in accredited STS.
Effluent total phosphorus concentration	mg/L	≤10	Target effluent quality following secondary treatment in accredited STS.
Nitrogen conversion rate (soil processes)	annual percentage	20	Conservative estimate of in-soil conversion processes.
Nitrogen plant uptake	kg/ha/yr	260	Section 9.3 of DSC Technical Manual (2015).
Phosphorus plant uptake	kg/ha/yr	30	
Soil phosphorus sorption capacity	mg/kg	115	Limiting P-sorption value from prior soil laboratory analysis at the Site (W&A, 2014)
Design life of system	Years	50	Reasonable service life for system.
Results			
Nitrogen Balance (m^2)	323		
Phosphorus Balance (m^2)	771		

6.4.4 *Limiting LAA Sizing*

Modelling results indicate that an area of 771m^2 is required for nutrient (phosphorus) assimilation. However, W&A recommend that the required LAA is sized on the minimum hydraulic requirement as there is sufficient available EMA on each proposed Lot to allow for a nutrient buffer from the proposed LAA.

Therefore, a minimum SSI LAA of 480m^2 with a 291m^2 nutrient buffer is recommended to service proposed Lots with an available EMA on <10% slope, while a minimum SSI LAA of 600m^2 with a 171m^2 nutrient buffer is recommended for Lots with ≥10% slope. This nutrient buffer can include the immediate surrounds and downslope area of the LAA installation.

6.5 Installation and Detail

A critical element of the design process is hydraulic design including selection of appropriate dripline, dosing and flush manifold pipe, lateral and emitter spacing and pump performance. Dripline typically needs an operating pressure at the emitter of 10m – 40m (head) to maintain pressure compensation. As such, higher head, low flow pumps are required to service drip irrigation systems that differ from pumps traditionally used in OSSM.

Lateral pipes should be spaced to provide good and even coverage of the area they service. Generally, they should be no more than 1m apart, roughly parallel and along the contour as close as possible.

SSI shall be installed at a depth of 100mm – 150mm into the topsoil as per *AS/NZS 1547:2012*. The DSC DAF (2015) also requires a minimum depth of 600mm of soil to exist from the bottom of the irrigation laterals to the limiting layer (bedrock or weathered rock) or water table. Lots that cannot achieve this separation will require the importation of topsoil material (refer Section 8.1.1).

General specifications for SSI land application systems are as follows:

- Effluent must be applied evenly across the LAA;
- PCSD line specifically designed for effluent irrigation (e.g. Toro Drip-in, Netafim Dripnet PC AS XR or Wasteflow) shall be installed. 1.6 – 2.1 litres per hour emitters should be used;
- An in-line 120µm disc filter may be installed to minimise the amount of solids entering the pipelines and emitters. This must be removed and cleaned regularly (at least at 3-monthly intervals). Alternately, a flush main may be installed to periodically clean-out the irrigation lines to provide effective long-term performance. Either manual or automatic flush valves may be installed, with flush water directed back to the treatment system;
- Air release valves will be installed at the high points in individual irrigation areas to prevent soil particles being sucked into the lines at the end of pump cycles as pipelines depressurise; and
- An ‘as-built’ layout of the OSSM system (treatment and LAA) shall be provided to Council and the system Owner upon completion.

Figure 7 in Appendix A provides a schematic representation of a generic SSI system. Specialist advice must be obtained for designing and installing the irrigation systems.

6.6 LAA Positioning

Available areas for effluent application are shown as ‘Available EMA’ in Figure 4 of Appendix A. These areas exclude minimum setback distances as described in Section 6.3.1. Nominal LAA locations are presented in Figure 4 of Appendix A.

The required LAA can be located anywhere within the available EMA on each Lot. However, the final LAA location will need to incorporate the minimum setbacks to future Lot improvements, such as a dwellings, driveways and swimming pools.

6.7 Reserve LAA

Land application areas dosed with secondary effluent do not require provision of a reserve area, as per Section 6.4.4 of the DSC DAF (2015).

7 Cumulative Impact Assessment

Section 2.3 (Table 2-5) of the DSC DAF (2015) specifies mandatory completion of a cumulative impact assessment (CIA) if ≥4,000m² of 'useable' land is not achievable on each lot created by subdivision with standard setbacks applied.

As shown on the Site Plan (refer Figure 2, Appendix A), the buffers to permanent waterways, intermittent drainages and dams on the created lots require reduction of setbacks as follows to ensure the required minimum UL of 4,000m^2 is achievable.

- 40m to Cangon Creek (60% reduction); and
- 20m to the drainage features and dams (50% reduction).

Therefore, a CIA is provided to demonstrate the sustainability of the proposed subdivision layout. Table 2-13 of the DSC DAF (2015) confirms that a 'Detailed' CIA is required where <50% of standards setbacks are achieved and ≥4,000m^2 of useable land is identified on each Lot.

CIA is an indicative risk assessment tool that involves the use of continuous daily soil / water modelling to maximise potential to achieve a sustainable design and provide a high level of assurance when assessing potential impacts on receiving environments. The adopted methodology involves establishing background pollutant loads and contaminant concentrations, calculation of catchment surface and subsurface discharge characteristics, and integration of site-specific OSSM inputs using the Land Application Mass balance (LAM) model to estimate the potential for human health and environmental impacts from OSSM systems.

Preliminary LAA sizing for each lot is provided in Section 6.4 of this WMR and is compared to DSC's established environment and health protection (E&HP) targets. Table 2-15 in the DSC DAF (2015) and Table 10-8 in the DSC Technical Manual (2015) describe the minimum assessment requirements for a 'Detailed' CIA which are reproduced in the following table.

Risk Assessment Component	Minimum Standard
On-lot LAA Assessment **(refer Sections 7.3 and 7.5)**	Daily water and nutrient mass balance modelling for each general on-site system LAA type within the subject site used to derive average annual hydraulic and pollutant loads to surface and subsurface export routes (refer Section 7.3). Viral die-off modelling (refer Section 7.5).
Rainfall-Runoff **(refer Section 7.2)**	Continuous daily rainfall-runoff, nutrient and pathogen mass balance modelling using MUSIC (or equivalent) used to derive average annual values.
Background Pollutant Loads / Concentrations **(refer Section 7.2.3)**	Sourced from Chapter 2 of Fletcher *et al*. (2004). Acceptable export rates / concentrations sourced from published local studies. Site specific data where available or necessary.
Surface and Subsurface Pollutant Export **(refer Sections 7.3.2 and 7.4)**	Site specific calculation of catchment attenuation factors for both surface and subsurface on-site loads based on data obtained through desktop and field site and soil investigations and representative of the characteristics of the receiving environment. Mass balance combining attenuated on-site system flows and loads with catchment input.

Risk Assessment Component	Minimum Standard
E&HP Targets **(refer Section 7.4)**	No more than 10% increase in average annual nitrogen and phosphorus loads (kg/year) based on existing undeveloped background loads. Average virus concentration <1 MPN/100ml after application of attenuation rates. All land application areas sized to ensure hydraulic failure (surcharge) accounts for only 5% of total wastewater generated (i.e. 95% containment via evapotranspiration and deep drainage).

7.1 Modelling Overview

Available desktop and field data was used to build spatial model(s) to simulate hydrology, catchment pollutant export, OSSM system operation, GW recharge, pollutant discharge, and nutrient / pathogen attenuation in GW flow for the Site. The modelling operates on a daily time-step and has been parameterised using site-specific data to provide the best representation of actual conditions. The preferred land application systems for the proposed Lots were assessed to determine their sustainability and compatibility E&HP objectives.

Modelling has been used to estimate the long-term hydraulic, nutrient and pathogen loads exported from proposed Lots to show the difference between the background (pre-development) and proposed (post-development) conditions, including indicative long-term average concentrations of the Site runoff and GW discharge. It also provides an estimate of the frequency, magnitude and distribution of the surface failure of OSSM to assist in estimating local risks to human health and the environment.

In principle, the daily mass balance modelling simulates soil-water and pollutant processes of the Site for the purpose of estimating long-term hydraulic, nutrient and pathogen loads potentially discharging to receiving surface and ground waters. It should be noted that modelling is designed for use as a decision making tool and will not necessarily produce results that accurately reflect measured pollutant loads to receiving waters. Instead it aims to assess predicted increases in pollutant loads against existing conditions or alternative development concepts.

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) stormwater design tool was used by 'DRB Consulting Engineering' (stormwater consultants for the Site) to derive average annual export values for rainfall-runoff and GW recharge (refer Section 7.2).

The LAM was used to derive average annual hydraulic and pollutant loads from OSSM systems to surface and subsurface export routes (refer Sections 7.3 and 7.4).

The combined average annual loads from the LAM are compared to derived background loads from MUSIC to demonstrate that OSSM associated with the proposed subdivision has a neutral or beneficial effect to the receiving environment (refer Section 7.4). Viral die-off modelling is also conducted to determine the minimum buffer distances required to protect GW from any pathogens remaining in the effluent (refer Section 7.5).

7.2 Existing Baseline Condition

7.2.1 Overview of MUSIC

MUSIC modelling was carried out by 'DRB Consulting Engineering' to simulate rainfall and runoff processes and anticipated nutrient loads associated with sources other than wastewater (principally stormwater runoff) at the Site. It also provides an estimate of GW recharge and associated nutrient concentrations. The model results have been provided to W&A and have been used to as background pollutant (N and P) loads of the undeveloped site.

7.2.2 Catchments

Based on a digital elevation model (DEM) and 'r.watershed' toolbox within QGIS, three (3) catchments were identified at the Site (refer Figure 6, Appendix A). Details on the catchments are outlined in the following table.

Parameter	Proposed Lots	Area (m^2)
Catchment 1	202-221, 224-251, 301-316, 321-337	2,920,224
Catchment 2	201, 222, 223	212,273
Catchment 3	318-320	131,977

7.2.3 Annual Hydraulic and Pollutant Loads

Mean annual stormwater flows, suspended solids and nutrient loads for the undeveloped, background site are shown in the following table (model output also provided in Appendix D). These values have been used to assess the increase in background loads, as required by the DSC DAF (2015).

Parameter	Value		
	Catchment 1	Catchment 2	Catchment 3
Flow (ML/year)	1,283.00	93.16	58.01
Total Suspended Solids (kg/year)	12,850	9,128	5,761
TP (kg/year)	288.4	21.7	13.1
TN (kg/year)	2,528.0	183.3	112.7

7.3 Daily Modelling Overview

The LAM is a Microsoft Excel based daily water, nutrient and pathogen mass balance model developed by BMT WBM for predicting the performance of OSSM systems under varying environmental conditions. The algorithms in the model have been derived from the Decentralised Sewer Model (DSM) and tailored to suit a single site application. It can assess long-term environmental and human health performance of wastewater systems.

The LAM requires a range of bio-physical parameters as inputs to determine whether a LAA option would be sustainable at the Site. The model predicts OSSM performance by simulating the movement of pollutants within the effluent load as it travels from the point source (on-site or community-scale systems) as surface or subsurface flows. The LAM does not predict the minimum area required to achieve zero surface runoff or deep drainage, instead, like the nominated area approach of the monthly water balance, the model predicts the surface and subsurface discharges based on a set of nominated conditions such as receptor sensitivity, soil, slope, climate, wastewater input and available area.

A summary of the model processes, inputs and results is provided in the following section.

7.3.1 Model Inputs

The simulation was run for a data period of ~62 years (1961-2022) and represents a conservative estimate of long-term performance based on available information and a set of assumptions as detailed within this WMR.

Proposed Lots were allocated to catchments outlined in Section 7.2.2 (refer Figure 6, Appendix A), and further broken down by DIR reductions outlined in Section 6.4.1 to assess the impact of OSSM systems on nutrient and virus loads exported from the Site. The allocations are outlined in the following.

- Catchment 1, no DIR reduction ("RUN001") – Lots 202-221, 224-251, 301, 302, 306-310, 312-317 and 321-337 (total 78-lots);
- Catchment 1, 20% DIR reduction ("RUN002") – Lots 303-305 and 311 (total 4-lots);
- Catchment 2, no DIR reduction ("RUN003") – Lots 201, 222, 223 (total 3-lots); and
- Catchment 3, no DIR reduction ("RUN004") – Lots 318-320 (total 3-lots).

Simulations were carried out for the preferred land application options for each situation, as follows:

- RUN001 – 74,880L/day (78-lots x 960L/day) of secondary treated effluent to 37,440m^2 of SSI (78-lots x 480m^2);
- RUN002 – 3,840L/day (4-lots x 960L/day) of secondary treated effluent to 2,400m^2 of SSI (4-lots x 600m^2);
- RUN003 – 2,880L/day (3-lots x 960L/day) of secondary treated effluent to 1,440m^2 of SSI; (3-lots x 480m^2); and
- RUN004 – 2,880L/day (3-lots x 960L/day) of secondary treated effluent to 1,440m^2 of SSI; (3-lots x 480m^2).

Daily climate data used in the model was sourced from 'SILO Data Drill' information available through the QLD Department of Environment and Science. The adopted SILO data set uses 'grid' point rainfall data and the (FAO56) Penman-Monteith methodology to estimate reference evapotranspiration (ET_0), which is a function of both evaporation and transpiration factors, based on a specific reference crop planted in the LAA (assumes turf).

Rather than simplistic loading rates, as utilised in monthly modelling, the LAM inputs include a more detailed estimation of the soils ability to receive, store and transmit water by approximating parameters such as effective saturation, field capacity, and the infiltration exponent. Soil input data is based on the most limiting soil analysis most applicable to the catchments from site investigations by W&A in (2022) and NORTHROP (2012), as follows.

- RUN001 and RUN002 – BH2 (W&A, 2022);
- RUN003 – NR2 (NORTHROP, 2012); and
- RUN004 – BH6 (W&A, 2022).

Soil phosphorus sorption capacity for each catchment has been based on the most limiting 5-point isotherm analytical results for a composite soil sample previously taken from the Site (TP9, W&A 2014). These results have been provided by an independent ‘NATA’ accredited laboratory (Lanfax Laboratories Pty Ltd). For reference, a copy of the laboratory report is attached in Appendix B. The LAM input data sheets used in the modelling are presented in Appendix D.

7.3.2 Pollutant Attenuation Factors

Natural attenuation of excess effluent nutrient loads from a LAA will occur within the underlying soil and groundwater, providing reductions in contaminant concentrations to mitigate off-site export.

Established pollutant attenuation rates for hydraulics, pathogens, nitrogen and phosphorus are adopted from Table 10-7 in the DSC DAF Technical Manual (2015). These attenuation rates have been established through modelling undertaken in several case studies for both ‘Inland / Rolling Hills’ and ‘Coastal / Estuarine’ catchment scenarios and depending on whether DSC prescribed setbacks are achievable.

Based on the location and soil characteristics of the property, the ‘Inland / Rolling Hills’ catchment scenario has been adopted, with attenuation rates of 20% for hydraulics, 80% for nitrogen, 98% for phosphorus and 99% for pathogens considered appropriate based on achieving >50% of standard setbacks.

7.4 LAM Results and Compliance

Hydraulic and nutrient generation is divided into surplus loads discharged to the ground surface as ‘surface surcharge’ or draining below the root zone with subsequent (eventual) groundwater migration to surface water bodies or aquifers as ‘deep drainage’. The following sections outline the results of the modelling and their compliance with the required acceptance criteria.

The model was run to confirm that the proposed OSSM system options for each Lot can sustainably assimilate the projected wastewater loads. Modelling of the preliminary LAA sizing outputs demonstrates compliance with the performance targets of the DSC DAF (2015). Sensitive receptors are not expected to be impacted, with pathogen assimilation occurring well within the available setbacks.

7.4.1 Hydraulic Loads

Modelling of the movement of water, from both applied effluent and rainfall, through the soil is a key component of the LAM, ultimately determining the nutrient movement throughout the LAAs. The following table presents the surface surcharge and deep drainage predicted for each catchment over the ~60-year modelling period.

Parameter	RUN001	RUN002	RUN003	RUN004
Run Description	Secondary to SSI			
Catchment	1		2	3
Total LAA (m²)	37,440	2,400	1,440	1,440
Wastewater Generation (L/day)	74,880	3,840	2,880	2,880
Surface Surcharge Frequency (days/year)	0	0	0	0

Parameter	RUN001	RUN002	RUN003	RUN004
Surface Surcharge as (%) total WWF	0	0	0	0
Deep Drainage (m^3/year)	12,331.3	612.5	335.1	434.1
Deep Drainage (mm/day)	0.90	0.70	0.64	0.83
Combined Catchment Deep Drainage (mm/day)	1.60		0.64	0.83
Total Site Deep Drainage (mm/day)	**3.06**			

The modelling results show that surface surcharge is not expected to occur for either OSSM system during the 60-year modelling period. Thus, the DSC DAF (2015) requirement of 95% containment via deep drainage and evapotranspiration is achieved. Additionally, following application of the specified hydraulic attenuation factor (20%), the total daily deep drainage from the LAAs is expected to be <2.5mm/day.

7.4.2 Nutrient and Pathogen Results

The following table summarises the predicted mean annual nutrient and pathogen loads generated by the proposed LAA designs and released beyond the LAA footprints.

Parameter	RUN001	RUN002	RUN003	RUN004
TP (kg/year)				
Deep Drainage Output	148.7	5.4	5.0	5.2
Surface Surcharge Output	0.0	0.0	0.0	0.0
Total Catchment OSSM System Output	154.1		5.0	5.2
TN (kg/year)				
Deep Drainage Output	1.3	0.0	0.0	0.0
Surface Surcharge Output	0.0	0.0	0.0	0.0
Total Catchment OSSM System Output	1.3		0.0	0.0
Total Virus (MPN/L)				
Deep Drainage Output	5.0	4.0	5.9	4.9
Surface Surcharge Output	0.0	0.0	0.0	0.0
Total Catchment OSSM System Output	9.0		5.9	4.9

LAM modelling shows that nutrient export through surface surcharge is not expected to occur, deep drainage is the principal pathway for nutrient export beyond the LAA footprints. Based on this, the combined output expected from proposed subdivision is estimated as 164.3kg (P) and 1.3kg (N) annually, with an associated pathogen concentration of 19.8MPN/L.

7.4.3 Catchment Pollutant Attenuation

Pollutant (nutrient and pathogen) loads generated at the LAAs will continue to undergo assimilation (capture, conversion, destruction etc.) within the soil environment as treated effluent moves away from the LAA.

The extent to which this occurs is based generally on the area available for assimilation (applied buffers) and the nature of the soil environment (landform / morphology). The attenuation factors specified in Section 7.3.2 have been applied for nitrogen, phosphorus and pathogen loads from the combined LAAs.

The resulting pollutant export concentrations are presented in the following table.

Parameter	TP (kg/yr)	TN (kg/yr)	T_{Virus} (MPN/L)
Catchment 1			
Background Load (Catchment)	288.4	2,528.0	N/A
Total (Catchment) OSSM Export	154.1	1.3	9.0
Attenuation Factor (%)	98	80	99
Attenuated Export Load	3.08	0.26	**0.09**
Background Load + Attenuated Export Load	291.48	2,528.26	N/A
Increase from Background Export Load (%)	**1.1**	**1.0**	N/A
Catchment 2			
Background Load (Catchment)	21.7	183.3	N/A
Total (Catchment) OSSM Export	5.4	0.0	4.0
Attenuation Factor (%)	98	80	99
Attenuated Export Load	0.11	0.00	**0.04**
Background Load + Attenuated Export Load	21.81	183.30	N/A
Increase from Background Export Load (%)	**1.0**	**0.0**	N/A
Catchment 3			
Background Load (Catchment)	13.1	112.7	N/A
Total (Catchment) OSSM Export	5.2	0.0	4.9
Attenuation Factor (%)	98	80	99
Attenuated Export Load	0.10	0.00	**0.05**

Parameter	TP (kg/yr)	TN (kg/yr)	T_{Virus} (MPN/L)
Background Load + Attenuated Export Load	13.20	112.80	N/A
Increase from Background Export Load (%)	**1.0**	**0.0**	N/A
Combined			
Combined (Site) Increase from Background Export Load (%)	**3.1**	**1.0**	X
		T_{Virus} (MPN/L)	**0.18**

As shown, attenuated nutrient export loads are expected to achieve the required E&HP target of <10% increase over (background) average annual nutrient (~3%) loads (kg/year). The pathogen export target of <1MPN/100ml (<10MPN/L) is also readily achievable (0.18MPN/L).

Taking into consideration the proposed LAA locations, application methods and nutrient buffers, sensitive receptors are not expected to be impacted. Pathogen assimilation occurs well within the available setbacks, as presented in the following section.

7.5 Viral Die-off

To address concerns regarding the transport of pathogens away from the LAA towards sensitive surface and subsurface receptors, we have considered the movement of viruses away from the LAA using an established 1-dimensional viral die-off model developed by Beavers and Gardner (1993) and refined by Cromer *et al.* (2001). Details of the methodology can be found in Cromer *et al.* (2001).

The model generally applies to wastewater moving in saturated soils, i.e. in shallow GW beneath a LAA. These conditions are considered most conducive to pathogen transport. In unsaturated (vadose zone) soils, the travel distances will be substantially less. As such, the method is considered very conservative when applied to sites with well drained soils and deep water tables. Surface transport in stormwater runoff is another obvious transport pathway for pathogens.

Some key assumptions used in the modelling are provided in the following:

- Bacteria have lesser die-off times than viruses and can therefore be assumed to be eliminated within a shorter distance than viruses (Cromer *et al*. 2001);
- Viral reduction has been set at three (3) orders of magnitude. This value is used for secondary treatment with disinfection; and
- Cooler temperatures allow viruses to reside longer in the soil and hence provide potentially greater travel distances. Average GW temperatures closely approximate mean air temperatures; therefore, the assumption of 12.1°C is considered conservative based on annual mean minimum temperature from Paterson (Tocal AWS)[1].

The assumptions used in the modelling exercise and predicted maximum viral transport distances at the Site are provided in the following table. Slope has been based on the highest average slope within an available EMA at the Site (~16%). Appendix E provides additional information on the modelling methodology and full results.

[1] IDCJAC0004_061250.pdf (bom.gov.au)

Parameter	Value
GW temperature (°C)	12.1
Porosity of soil (decimal)	0.47
K_{sat} (m/ day)	0.06
Slope (%)	16.0
Depth to GW (m)	0.80
Horizontal distance for 100% viral reduction (m)	**0.69**

Viral die-off modelling demonstrates that with secondary treatment, as proposed for future dwellings at the Site, 100% pathogen reduction within the soil would occur within <0.7m from the LAA boundaries. Therefore, the subsurface export of pathogens off-site is negligible.

Shallow GW was not encountered during the Site investigations and the permanent GW table is expected to be >0.8m below the natural ground surface. If poorly treated effluent were to percolate to GW, viral die-off modelling demonstrates a low pathogen travel distance under saturated conditions, presenting no appreciable risk to public health or sensitive environmental receptors. With effluent disinfection, this is expected to further reduce the pathogen transport at the Site.

7.6 CIA Summary

The CIA addressed the various risks on each proposed Lot by confirming that the proposed OSSM system designs presented in this WMR are sustainable and the potential for contaminant migration away from the LAAs is low.

Modelling shows that predicted hydraulic loads are manageable, with no surface surcharge expected. Nutrients will also be retained within the LAAs and surrounding setbacks, with no appreciable increase in nutrient export concentrations over background conditions, and pathogens will be effectively attenuated well before they can reach property boundaries or sensitive receptors.

Based on our analysis, the risk of hydraulic, nutrient and pathogen export to surface waters and groundwater posed by the proposed OSSM systems will not be significant. Furthermore, the human and environmental health risk to surrounding land is considered negligible.

8 Mitigation Measures

8.1 Soil Improvement

8.1.1 Soil Depth

To increase topsoil / soil profile depth to achieve the minimum 600mm on select Lots, addition of 200mm of good-quality topsoil (such as sandy loam) is recommended. The topsoil must be applied evenly throughout the LAA footprint prior to the installation of the SSI system. A typical installation procedure is as follows:

- 200mm of good quality topsoil must be added to the LAAs during installation;
- Scarify (lightly till) the proposed LAA footprint;
- Install SSI system on the imported topsoil material;
- Cover with 100mm of good quality topsoil material;
- Finish perimeter of ‘raised’ LAA with a 3 (horizontal): 1 (vertical) batter slope; and
- Revegetate with a suitable groundcover species (refer Section 8.2).

This will ensure that SSI laterals can achieve a (minimum) 600mm separation from the most-limiting soil horizon, as per the recommendations of the DSC DAF (2015), and are installed below 100mm – 150mm of good quality topsoil as per the recommendations of *AS/NZS 1547:2012*.

The ‘raised’ irrigation area on these lots should have a (maximum) batter slope of 3 (horizontal): 1 (vertical) around the perimeter of the LAA to minimise erosion potential and ensure a stable incline for mowing.

8.1.2 Soil Chemistry

Given that Site soils are identified as acidic, slightly sodic and potentially unstable; they may be susceptible to impaired vegetative growth and impaired permeability. These properties can combine to reduce the soils capacity to sustainably manage wastewater.

Prolonged application of sodium rich wastewater can exacerbate the situation. Application of calcium minerals is a recognised way of reducing the effects of soil instability. It does this by supplying calcium to the affected soil and thereby elevating calcium concentrations with respect to sodium.

Typically, gypsum would be the preferred soil amendment; however, given the identified acidity concern a 50:50 application of gypsum and lime may be more suitable for the Site. Both gypsum and lime are slowly soluble in water, so simply broadcasting at the surface can be of limited benefit as it can take a long time for the calcium to penetrate the soil and reach the deeper soil layers. Therefore, it is necessary to incorporate the amendment into the subsoil prior to construction of the land application system. This can be done by shallow ripping of the natural soil and applying the 50:50 gypsum/lime.

A suitable gypsum/lime application rate of approximately 0.2kg/m^2 is recommended.

8.2 Vegetation Establishment

Vegetation that is suited to the application of effluent, preferably with high water and nutrient requirements (such as turf) should be established over the LAAs following construction. A complete vegetation cover is important to reduce the erosion hazard and optimise water and nutrient uptake.

It is recommended to establish and maintain a vegetated buffer around the LAAs. It should be planted with moisture-tolerant vegetation and remain well maintained to maximise moisture uptake. Plants must be selected that will not be so large as to shade the LAAs once fully grown. It is important that the LAAs receive maximum exposure to sun and wind to maximise evapotranspiration.

To maximise assimilation of effluent-borne nutrients within the LAAs, vegetation clippings should be removed from the LAAs and mulched elsewhere on-site for use in other landscaped areas that are not used for wastewater application. Mulching the clippings back onto the area from which they were cut is not recommended. An alternative is to dispose clippings in the general waste bin, or green waste bin collection service, if provided.

8.3 Stormwater Management

The performance of LAAs (and potentially treatment systems) can be adversely affected if stormwater is allowed to run onto these areas. Stormwater diversion devices should be designed and constructed to collect, divert and dissipate collected run-on away from the LAAs. The structure(s) should be designed and installed by a suitably qualified professional and be compliant with relevant guidelines and standards.

A diagram of a ‘typical’ stormwater diversion, which would be appropriate for this purpose, is provided in Appendix A, Figure 8. The outlet must be stabilised and must discharge water in a safe location where it will not create an erosion hazard or impact on structures or neighbouring properties.

8.4 Water Saving Measures

To minimise wastewater generation, it is recommended that all domestic water use fixtures in the proposed dwellings be installed in accordance with BASIX requirements, including installation of ‘standard’ water reduction fittings.

Standard water reduction fixtures for internal and external water use include:

- Taps – WELS 4-star (or better) rated;
- Toilets – 4.5 / 3.0 litre dual flush pan and cistern;
- Showers – WELS 3-star (or better) rated; and
- Dishwashers (if used) – AAA rated using as little as 18 litres per wash.

Implementation of these measures is expected to reduce water use, and thereby wastewater generation, by as much as 10% – 15%.

9 Conclusions and Recommendations

This completes our assessment of the Site's capability for sustainable OSSM in relation to the proposed (Stage 2) residential subdivision (Cangon Park) at Hanleys Creek Road, Tabbil Creek NSW. Specifically, W&A recommend the following:

- Generated wastewater from future dwellings in the proposed lots is to be treated to a secondary standard in an appropriately sized and located NSW Health accredited STS (with disinfection);
- Secondary treated effluent is to be dispersed on-site via pressure compensating SSI within a LAA of;
    - 480m^2 with a nutrient buffer of 291m^2 for Lots 201-251, 301-302, 306-310, 312-337;
    - 600m^2 with a nutrient buffer of 171m^2 for Lots 303-305 and 311;
- The future LAAs must be located within the available EMA as in Figure 4, Appendix A;
- Addition of good quality topsoil (sandy loam) to increase available topsoil / soil profile depth with selected lots;
- The irrigation area should be designed and installed by an experienced professional, considering the expected flows and other recommendations contained within this report;
- Stormwater should be prevented from running onto the LAA by diverting any runoff away using a stormwater diversion drain;
- A suitable lime application rate of approximately 0.2kg/m^2 should be applied at the base of the land application systems during installation;
- Vegetation must be established over the LAAs immediately after installation;
- Stormwater run-on must be directed away from the proposed LAAs; and
- Vehicles and grazing animals must be prevented from entering the designated LAAs.

Yours Sincerely,

CMorton

Connor Morton

Environmental Consultant
Whitehead and Associates Environmental Consultants Pty Ltd

Appendix A

Figures

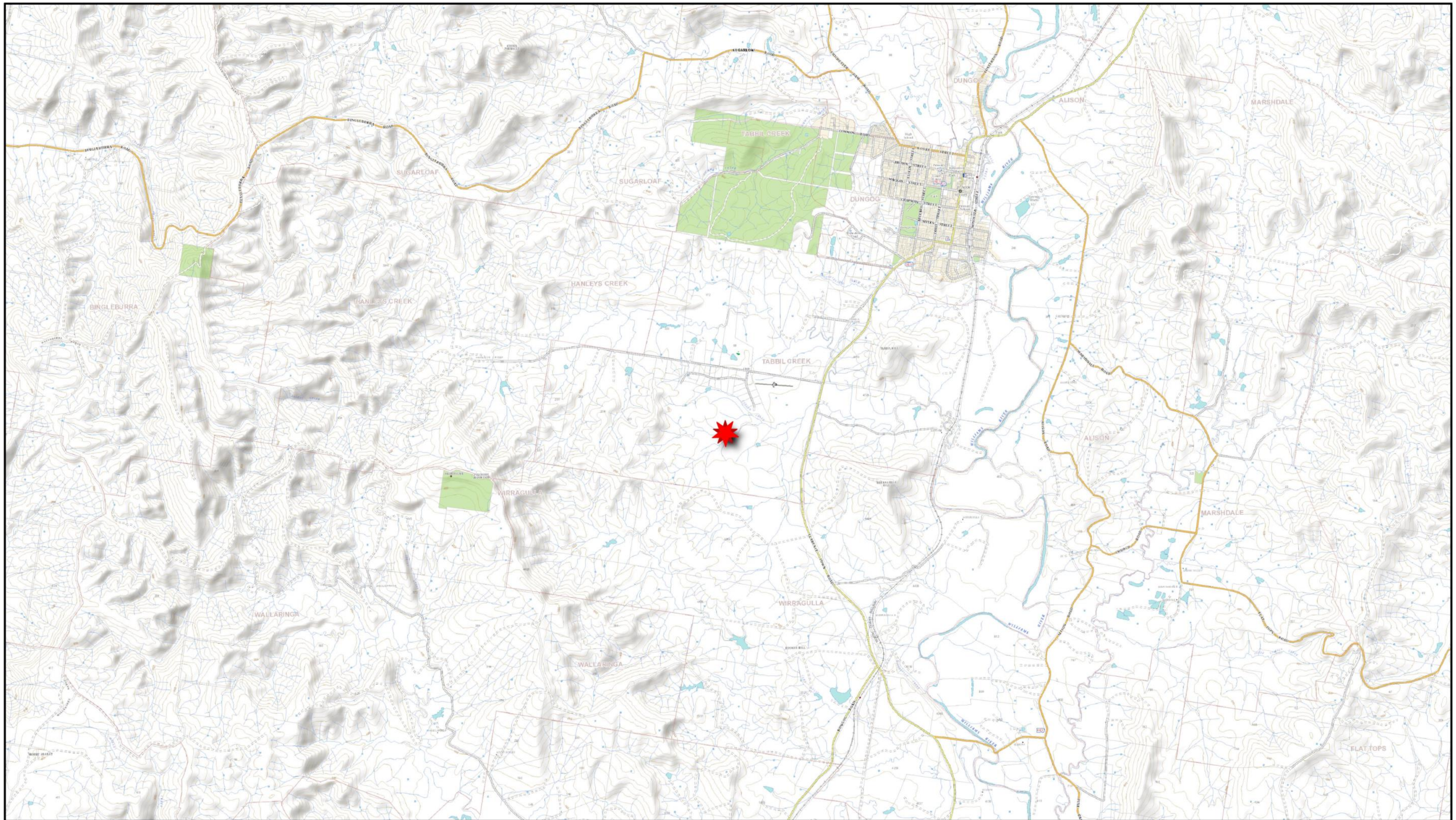

Figure 1: Site Plan Showing Locality

3028: Cangon Park Stage 2 Subdivision - WMR

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0 1 2 3 4 5 6 7 8 9 10 11 km

(Approx Scale)

N

Revision	002
Drawn	CM
Approved	MS

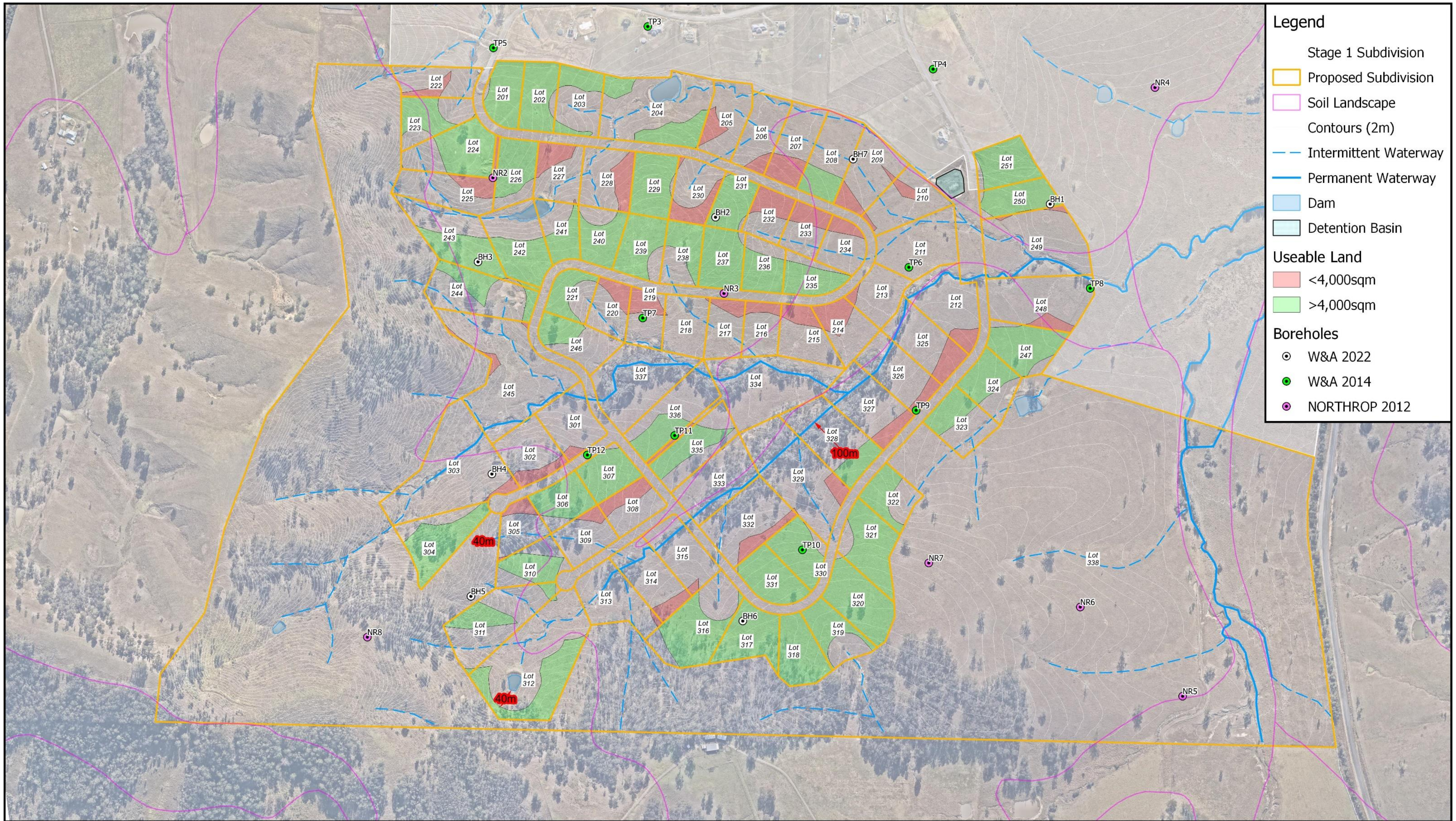

Figure 2: Site Plan Showing Useable Land (Standard Buffers)

3028: Cangon Park Stage 2 Subdivision - WMR

N

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0 0.5 1 1.5 km

(Approx Scale)

Revision	004
Drawn	CM
Approved	MS

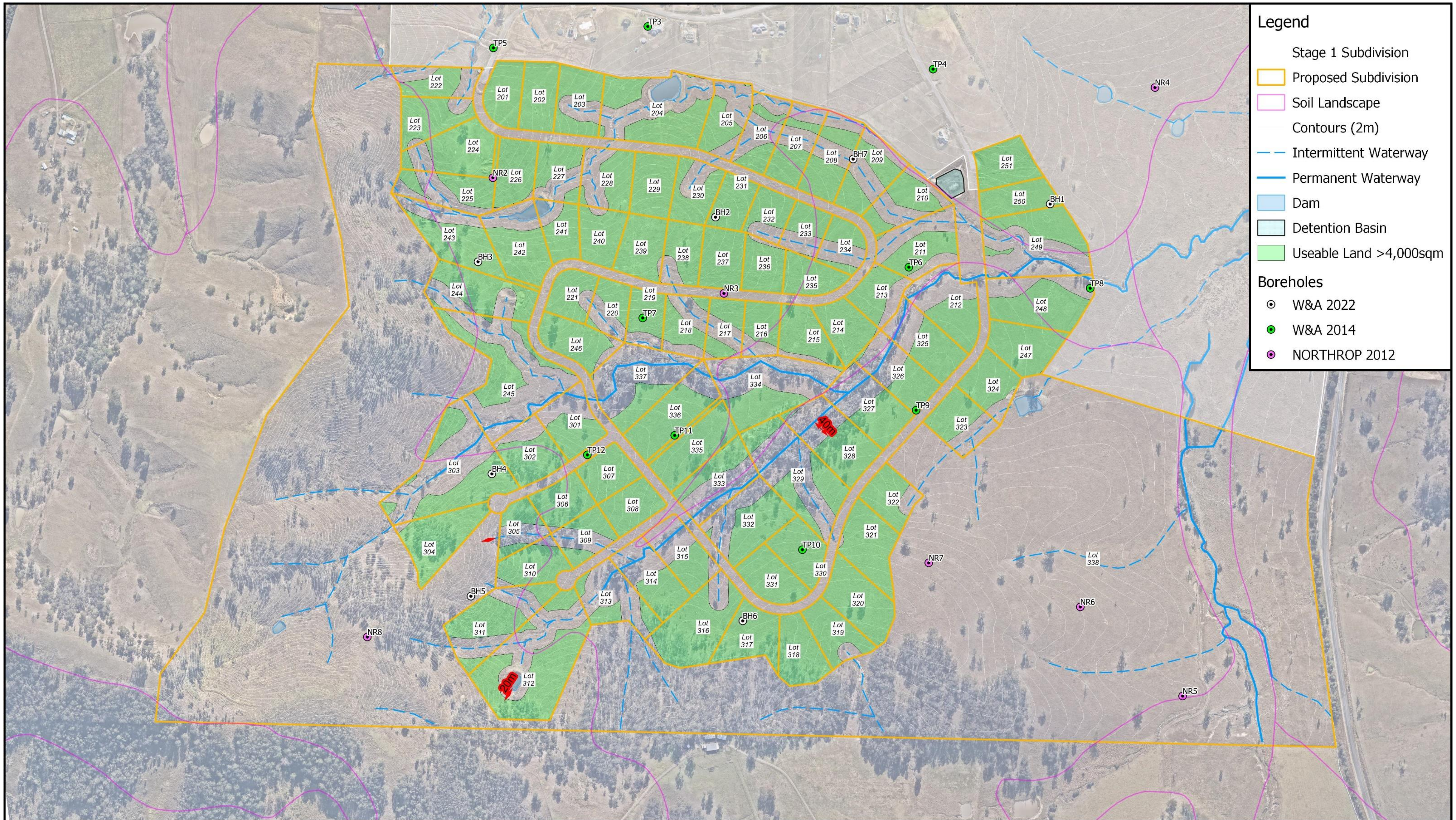

Figure 3: Site Plan Showing Useable Land (Reduced Buffers)

3028: Cangon Park Stage 2 Subdivision - WMR

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0 0.5 1 1.5 km

(Approx Scale)

Revision	004
Drawn	CM
Approved	MS

Figure 4: Site Plan Showing Available EMA and Nominal LAA Locations

3028: Cangon Park Stage 2 Subdivision - WMR

N

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0 0.5 1 1.5 km
(Approx Scale)

Revision	004
Drawn	CM
Approved	MS

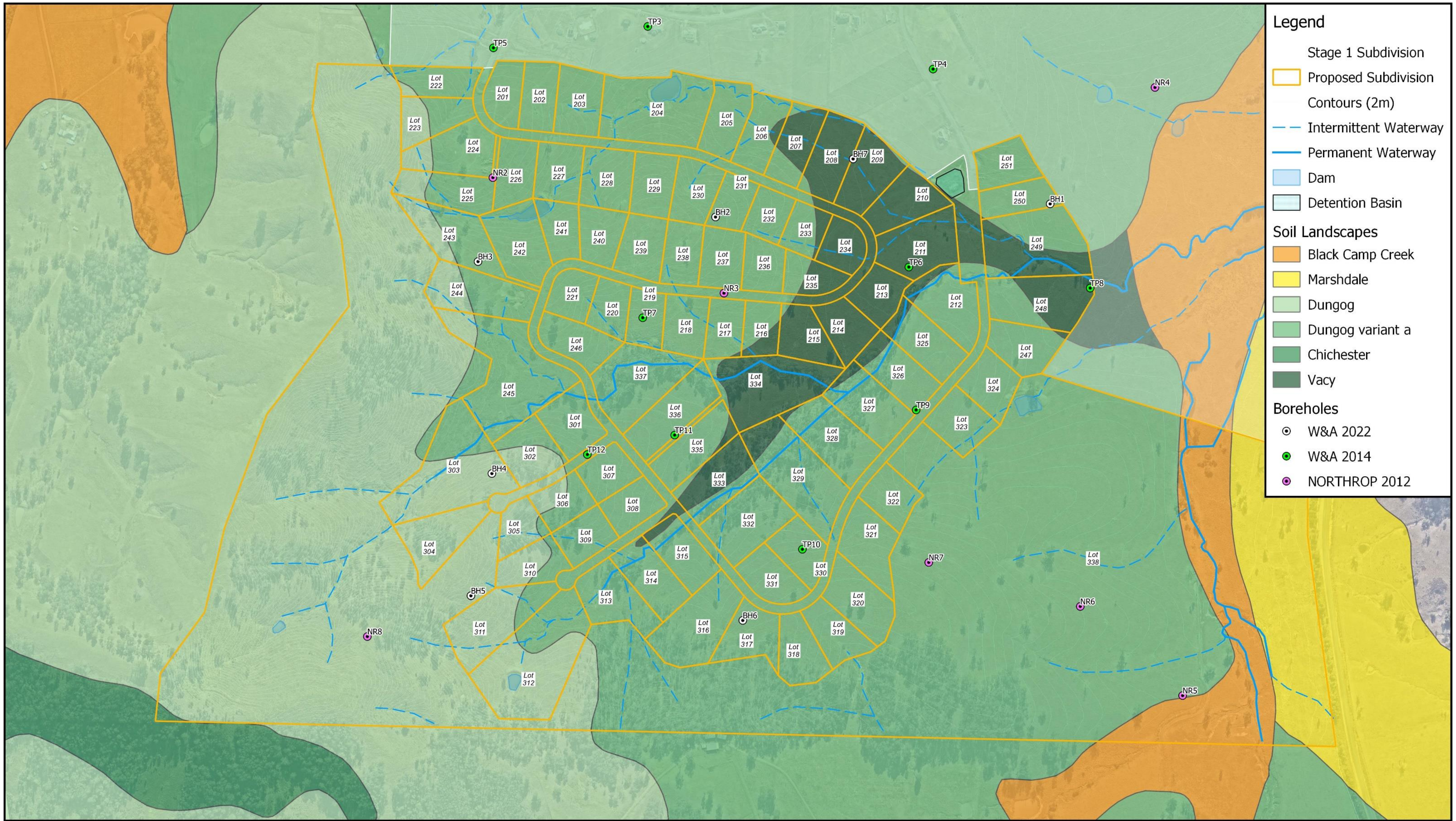

Figure 5: Site Plan Showing Soil Landscapes

3028: Cangon Park Stage 2 Subdivision - WMR

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Revision	004
Drawn	CM
Approved	MS

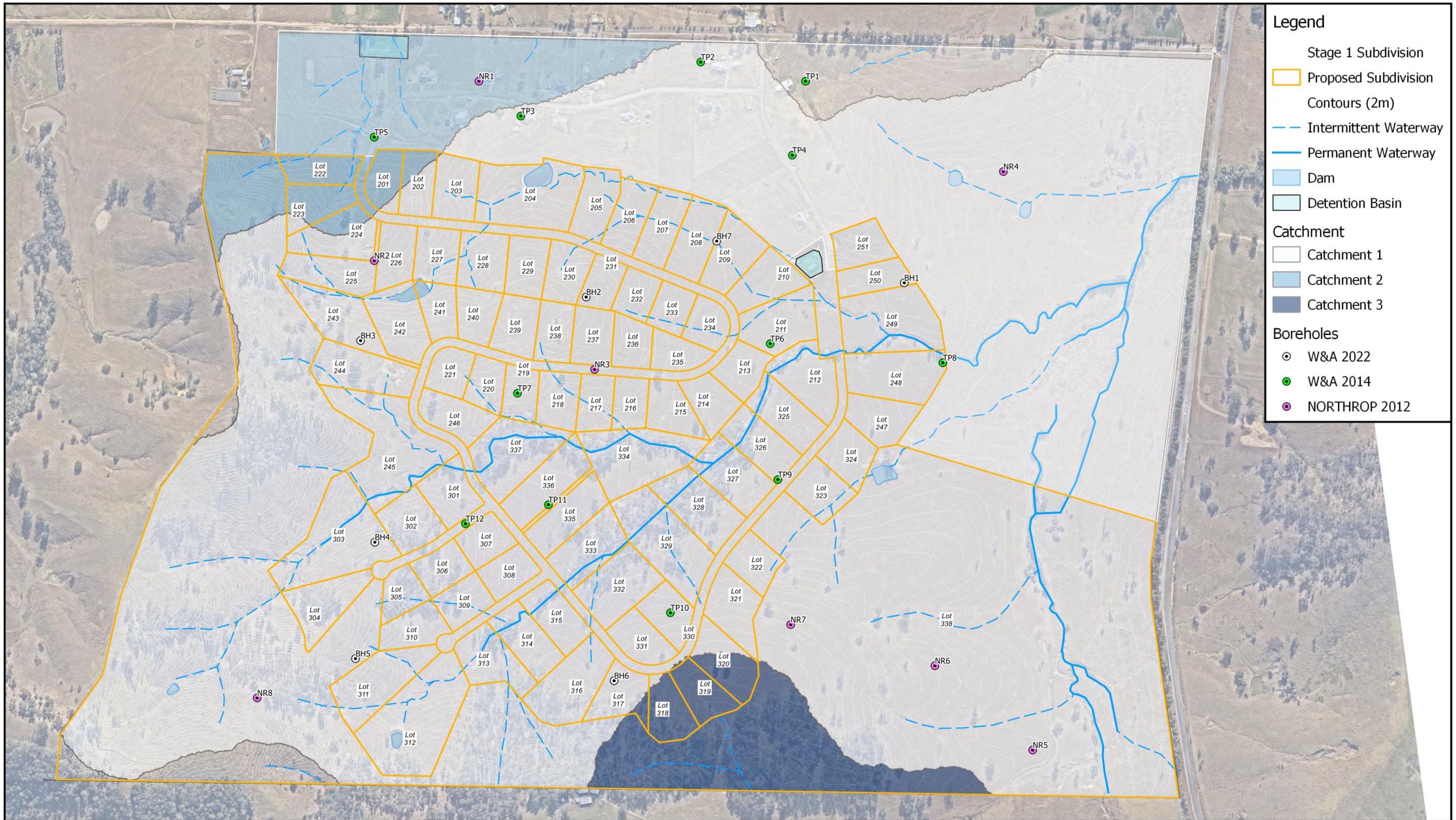

Figure 6: Site Plan Showing Catchments

3028: Cangon Park Stage 2 Subdivision - WMR

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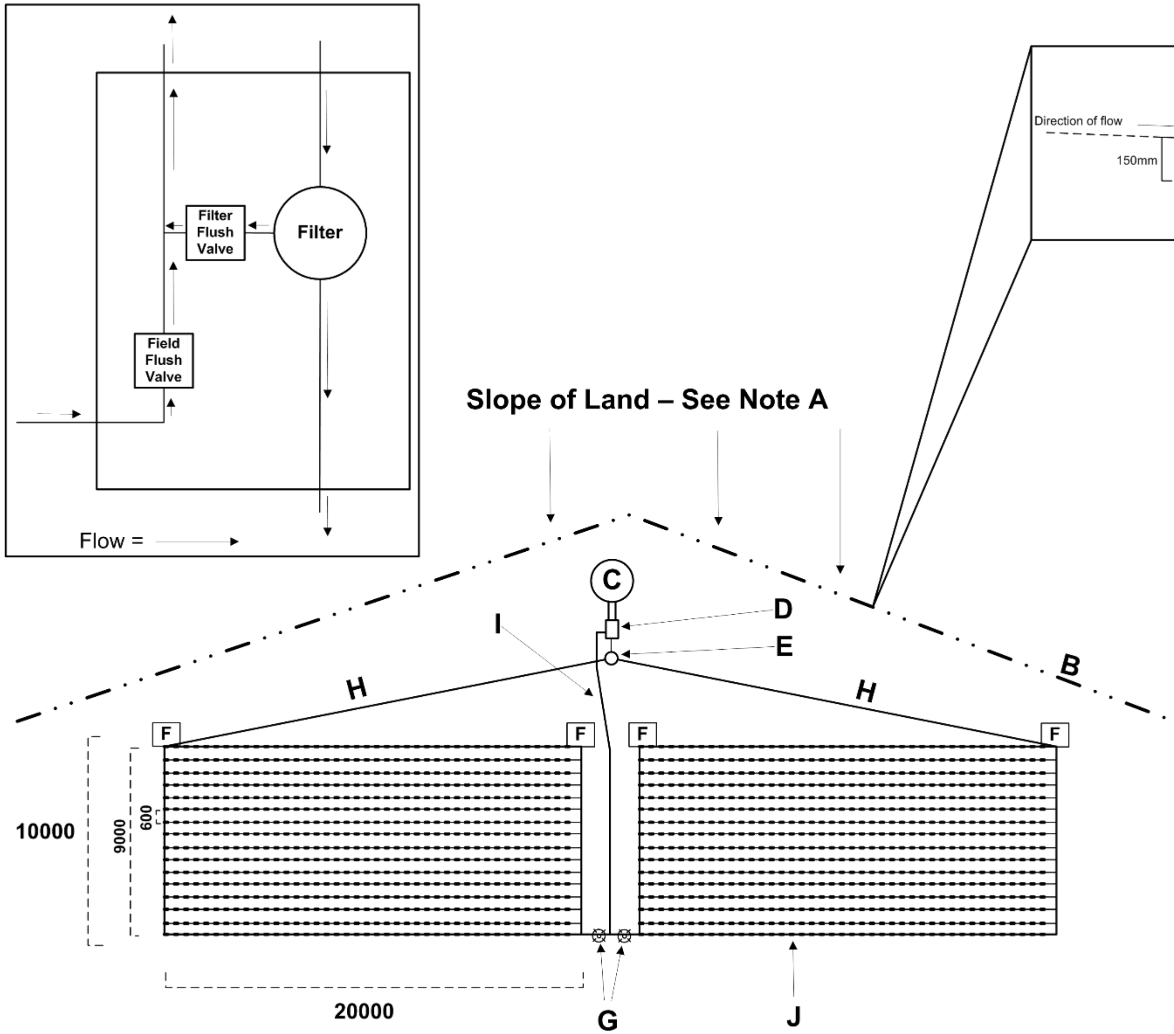
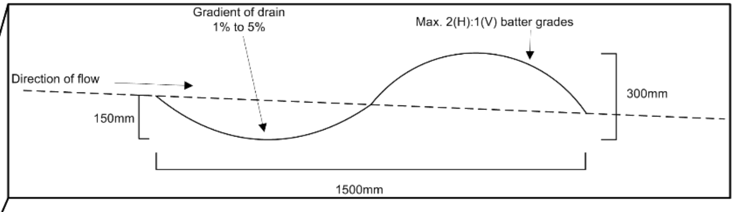
Revision	004
Drawn	CM
Approved	MS





NOTES

A Design for relatively uniform slope. Additional design work may be required where slope exceeds 12% or if system is to be installed over undulating ground.

B An earth bank diversion drain must be constructed upslope of the area to divert stormwater run-on if this is appreciable (see inset B).

C Secondary Treatment System – the irrigation pump must provide a *minimum* 20m head and a flow rate that matches the design output of the selected dripline. Flow rate will vary depending on emitter spacing, flow rate and lineal metres of line. A full hydraulic design must be carried out. Each area should be capable of discharging a minimum of 80L/min.

D Filtration and flushing mechanism (see inset A) – a field flush valve must be installed on the return line to facilitate periodic flushing to the treatment tank. An additional filter flush valve should be installed downstream of the field flush valve. A (minimum) 150 mesh, 100 micron cylindrical filter should be installed and cleaned regularly.

E An automatic, hydraulically operated sequencing valve should be installed to deliver effluent evenly to the two areas.

F Air release valves must be installed at high points in each area. Additional air release valves may be required in undulating terrain.

G Check valves are required for each irrigation field to facilitate periodic flushing.

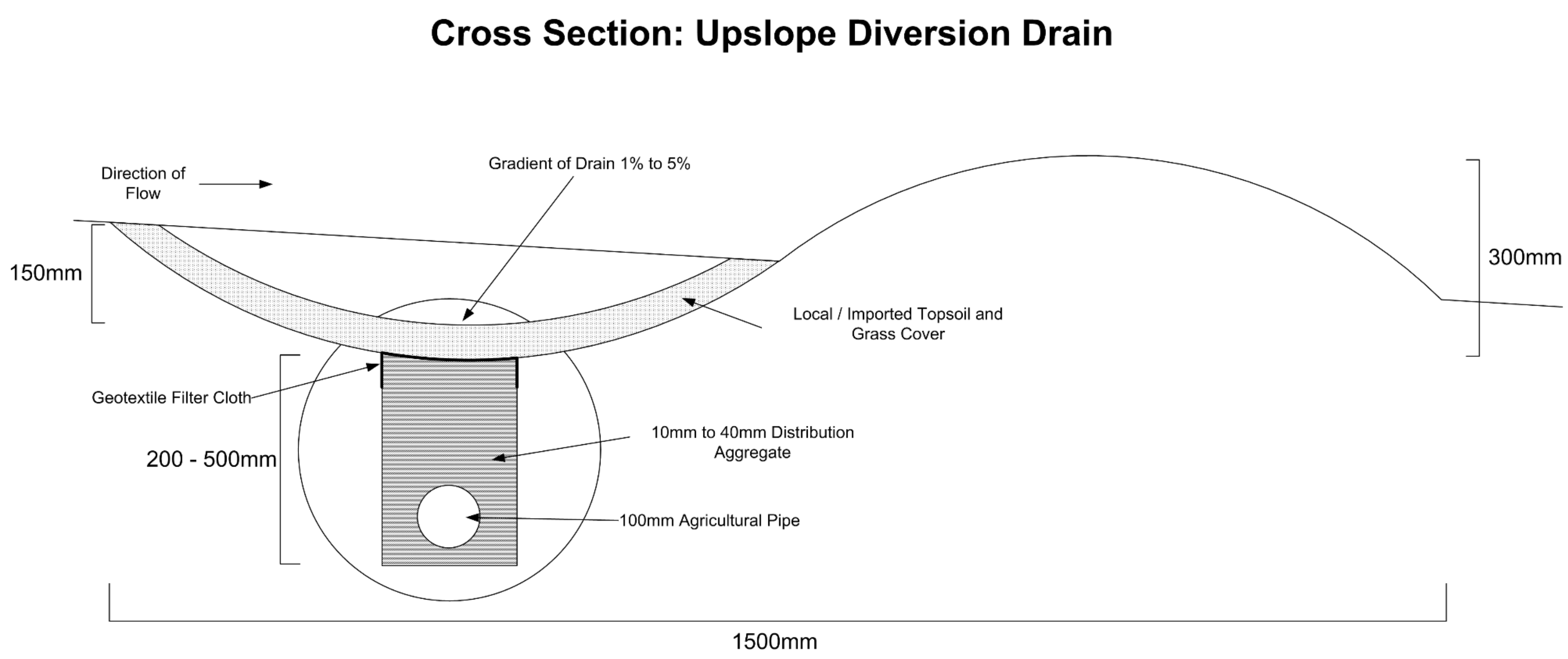
H Distribution manifolds should be 25mm PVC or polyethylene pipe buried 100-150mm below the ground surface.

I Flushing return manifold should be 25mm PVC or polyethylene pipe buried 100-150mm below the ground surface.

J Pressure Compensating (PC) subsurface drip line with emitters (typically 13mm) and laterals at 600mm spacings and buried to a depth 100-150mm. A pressure regulator will be required where non-PC line is used. Only subsurface dripline specifically designed for effluent irrigation must be used.

This standard design has been based on a generic area of 400m² for irrigation based on typical conditions. It does not eliminate the need for a site and soil evaluation to be carried out or any additional consideration of site specific issues. It should be used as a generic guide only.

Whitehead & Associates Environmental Consultants	**FIGURE 7: SUBSURFACE IRRIGATION OF EFFLUENT**	Project: 3028 Drawn: CM Approved: MS Scale: NTS



Whitehead & Associates Environmental Consultants	**FIGURE 8:** **STANDARD DRAWING OF AN UPSLOPE DIVERSION DRAIN**	Project: 3028 Drawn: CM Approved: MS Scale: NTS

Appendix B

Soil Borelogs and Laboratory Results

Soil Bore Log

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Client:	John Lidbury	**Test Pit No:**	**BH1**
Site:	Cangon Park (Stage 2) Subdivision, Tabbil Creek	Excavated/logged by:	CM & BC
Date:	7 February 2022	Excavation type:	Auger & crowbar
Notes:	- refer to site plan for position of test pit - 'dua' soil landscape		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Size of Coarse Fragments	Moisture Condition	Comments
0.1		BH1/1	A	LC	Moderate	Dark brown	No	2 - 10%	2-6mm	SM	
0.2											
0.3		BH1/2	B	MC	Massive	Very dark grey	Gley (minor)	2 - 10%	2-6mm	SM	
0.4											
0.5											
0.6											
	~ Refusal on rock layer										

Soil Bore Log

Whitehead & Associates
Environmental Consultants

Client:	John Lidbury	**Test Pit No:**	**BH2**
Site:	Cangon Park (Stage 2) Subdivision, Tabbil Creek	Excavated/logged by:	CM & BC
Date:	7 February 2022	Excavation type:	Auger & crowbar
Notes:	- refer to site plan for position of test pit - 'dua' soil landscape		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Size of Coarse Fragments	Moisture Condition	Comments
0.1 0.2		BH2/1	A	LC	Moderate	Very dark greyish brown	No	2 - 10%	2-6mm	SM	
0.3 0.4		BH2/2	B	MC	Moderate	Dark yellowish brown	Orange (minor)	2 - 10%	2-6mm	D	
	~ Refusal on rock layer										

SOIL BORE LOG

Whitehead & Associates
Environmental Consultants

Client:	John Lidbury	**Test Pit No:**	**BH3**
Site:	Cangon Park (Stage 2) Subdivision, Tabbil Creek	Excavated/logged by:	CM & BC
Date:	7 February 2022	Excavation type:	Auger & crowbar
Notes:	- refer to site plan for position of test pit - 'dua' soil landscape		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Size of Coarse Fragments	Moisture Condition	Comments
0.1 0.2 0.3		BH3/1	A	SiC	Moderate	Dark brown	No	2 - 10%	2-6mm	D	
0.4 0.5 0.6		BH3/2	B	MC	Massive	Brown	Orange (minor)	2 - 10%	2-6mm	SM	
0.7	~ Refusal on rock layer										

SOIL BORE LOG

Whitehead & Associates
Environmental Consultants

Client:	John Lidbury	**Test Pit No:**	**BH4**
Site:	Cangon Park (Stage 2) Subdivision, Tabbil Creek	Excavated/logged by:	CM & BC
Date:	7 February 2022	Excavation type:	Auger & crowbar
Notes:	- refer to site plan for position of test pit - 'du' soil landscape		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Size of Coarse Fragments	Moisture Condition	Comments
0.1 0.2		BH4/1	A	SiCL	Moderate	Very dark brown	No	2 - 10%	2-6mm	SM	
0.3		BH4/2	B_1	LC	Moderate	Brown	No	2 - 10%	2-6mm	SM	
0.4		BH4/3	B_2	MC	Moderate	Yellowish brown	No	2 - 10%	2-6mm	D	
0.5	~ Refusal on rock layer										

SOIL BORE LOG

Whitehead & Associates
Environmental Consultants

Client:	John Lidbury	**Test Pit No:**	**BH5**
Site:	Cangon Park (Stage 2) Subdivision, Tabbil Creek	Excavated/logged by:	CM & BC
Date:	7 February 2022	Excavation type:	Auger & crowbar
Notes:	- refer to site plan for position of test pit - 'du' soil landscape		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Size of Coarse Fragments	Moisture Condition	Comments
0.1 0.2		BH5/1	A	SCL	Moderate	Very dark greyish brown	No	2 - 10%	2-6mm	SM	
0.3		BH5/2	B_1	LC	Massive	Dark yellowish brown	Orange (minor)	2 - 10%	6-20mm	SM	
0.4 0.5 0.6		BH5/3	B_2	MC	Weak	Yellowish brown	No	2 - 10%	6-20mm	D	
	~ Refusal on rock layer										

SOIL BORE LOG

Whitehead & Associates
Environmental Consultants

Client:	John Lidbury	**Test Pit No:**	**BH6**
Site:	Cangon Park (Stage 2) Subdivision, Tabbil Creek	Excavated/logged by:	CM & BC
Date:	7 February 2022	Excavation type:	Auger & crowbar
Notes:	- refer to site plan for position of test pit - 'dub' soil landscape		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Size of Coarse Fragments	Moisture Condition	Comments
0.1 0.2		BH6/1	A	LC	Moderate	Dark greyish brown	No	2 - 10%	2-6mm	SM	
0.3 0.4		BH6/2	B_1	MC	Moderate	Yellowish brown	Orange (minor)	2 - 10%	2-6mm	SM	
0.5		BH6/3	B_2	MC	Moderate	Yellowish brown	Gley (minor)	2 - 10%	2-6mm	SM	
0.6	~ Refusal on rock layer										

SOIL BORE LOG

Whitehead & Associates
Environmental Consultants

Client:	John Lidbury	**Test Pit No:**	**BH7**
Site:	Cangon Park (Stage 2) Subdivision, Tabbil Creek	Excavated/logged by:	CM & BC
Date:	7 February 2022	Excavation type:	Auger & crowbar
Notes:	- refer to site plan for position of test pit - 'dua' soil landscape		

PROFILE DESCRIPTION

Depth (m)	Graphic Log	Sampling depth/name	Horizon	Texture	Structure	Colour	Mottles	Coarse Fragments	Size of Coarse Fragments	Moisture Condition	Comments
0.1		BH7/1	A	CL	Moderate	Black	No	2 - 10%	2-6mm	SM	
0.2											
0.3		BH7/2	B	HC	Massive	Oive brown	Gley (minor)	2 - 10%	2-6mm	SM	
0.4											
0.5											
0.6											
0.7											
0.8											
0.9											
1.0											

Project 3028: Cangon Park (Stage 2) Subdivision, Tabbil Creek

Sheet 1 - Soil Sampling Schedule and Results of pH, EC and Emerson Aggregate Test Analysis

Site	Sample Name	Sample Depth (mm)	Texture Class	EAT [1]	Rating [2]	pH_f [3]	$pH_{1:5}$ [4]	Rating	$EC_{1:5}$ (µS/cm)	ECe (dS/m) [5]	Rating	Other analysis [6]
W&A, 2022												
BH1	1/1	200	LC	8	Negligible	n/a	5.9	Moderately acid	52	0.42	Non-saline	
	1/2	600	MC	8	Negligible	n/a	6.7	Neutral	78	0.55	Non-saline	
BH2	2/1	200	LC	7	Negligible	n/a	5.9	Moderately acid	64	0.51	Non-saline	
	2/2	400	MC	2(1)	Mod-High	n/a	6.5	Slightly acid	112	0.78	Non-saline	
BH3	3/1	300	SiC	8	Negligible	n/a	6.5	Slightly acid	68	0.54	Non-saline	
	3/2	650	MC	2(1)	Mod-High	n/a	5.7	Moderately acid	120	0.84	Non-saline	
BH4	4/1	200	SiCL	8	Negligible	n/a	6.2	Slightly acid	28	0.25	Non-saline	
	4/2	350	LC	5	Slight	n/a	6.6	Neutral	29	0.23	Non-saline	
	4/3	450	LC	5	Slight	n/a	6.8	Neutral	25	0.20	Non-saline	
BH5	5/1	200	SCL	8	Negligible	n/a	6.3	Slightly acid	16	0.14	Non-saline	
	5/2	350	LC	2(1)	Mod-High	n/a	6.8	Neutral	67	0.54	Non-saline	
	5/3	600	MC	2(2)	High	n/a	6.9	Neutral	79	0.55	Non-saline	
BH6	6/1	200	LC	2(3)	Very High	n/a	5.7	Moderately acid	55	0.44	Non-saline	
	6/2	400	MC	2(1)	Mod-High	n/a	6.0	Moderately acid	144	1.01	Non-saline	
	6/3	550	MC	2(3)	Very High	n/a	5.5	Strongly acid	282	1.97	Non-saline	
BH7	7/1	250	CL	8	Negligible	n/a	5.9	Moderately acid	33	0.30	Non-saline	
	7/2	1000	MC	2(3)	Very High	n/a	6.4	Slightly acid	464	3.25	Slightly saline	
W&A, 2014												
TP6	6/1	100	CL	8	Low	n/a	6.0	Moderately acid	27	0.24	Non-saline	
	6/2	400	HC	2(1)	Mod	n/a	6.5	Slightly acid	495	2.97	Slightly saline	
	6/3	1400	MC	2(1)	Mod	n/a	6.5	Slightly acid	364	2.55	Slightly saline	
TP7	7/1	100	CL	2(1)	Mod	n/a	6.5	Slightly acid	46	0.41	Non-saline	
	7/2	550	SC	2(2)	Mod	n/a	6.0	Moderately acid	210	1.68	Non-saline	
TP8	8/1	100	L	2(2)	Mod	n/a	6.2	Slightly acid	17	0.17	Non-saline	
	8/2	600	MC	2(1)	Mod	n/a	6.7	Neutral	380	2.66	Slightly saline	
TP9	9/1	100	L	2(1)	Mod	n/a	6.0	Moderately acid	24	0.24	Non-saline	
	9/2	400	SC	2(2)	Mod	n/a	6.3	Slightly acid	103	0.82	Non-saline	
	9/3	700	SC	2(3)	High	n/a	6.4	Slightly acid	173	1.38	Non-saline	
TP10	10/1	100	L	2(1)	Mod	n/a	6.7	Neutral	6	0.06	Non-saline	
	10/2	350	SL	2(1)	Mod	n/a	6.5	Slightly acid	9	0.10	Non-saline	
TP11	11/1	100	CL	2(1)	Mod	n/a	6.5	Slightly acid	10	0.09	Non-saline	
	11/2	350	SL	n/a	Mod	n/a	6.6	Neutral	7	0.08	Non-saline	
TP12	12/1	100	L	2(1)	Mod	n/a	6.0	Moderately acid	47	0.47	Non-saline	
	12/2	400	MC	2(1)	Mod	n/a	6.7	Neutral	27	0.19	Non-saline	
NORTHROP, 2012												
NR2	NR2/1	150	CL	2(1)	Mod	n/a	4.6	Very strongly acidic	n/a	0.05	Non-saline	
	NR2/2	400	SC									
	NR2/3	600	HC									
NR3	NR3/1	100	L	2(2)	Mod	n/a	5.4	Strongly acidic	n/a	0.10	Non-saline	
	NR3/2	300	SC									
	NR3/3	600	SC									

Notes:- (also refer Interpretation Sheet 1)

n/a not available

n/t not tested

[1] The modified Emerson Aggregate Test (EAT) provides an indication of soil susceptibility to dispersion.

[2] Ratings describe the likely hazard associated w ith land application of treated w astew ater.

[3] pH measured in the field using Raupac Indicator.

[4] pH measured on 1:5 soil:w ater suspensions using a *Hanna Combo* hand-held pH/EC/temp meter.

[5] Electrical conductivity of the saturated extract (Ece) = $EC_{1:5}$(µS/cm) x MF / 1000. Units are dS/m. MF is a soil texture multiplication factor.

[6] External laboratories used for the follow ing analyses, if indicated:

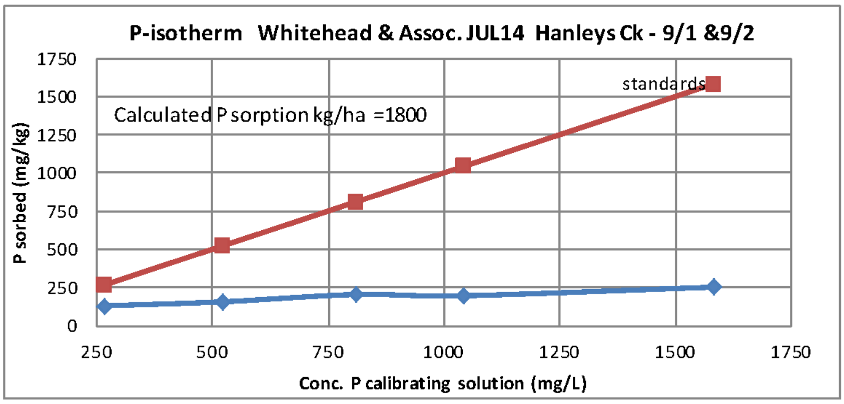
- CEC (Cation exchange capacity)
- Psorb (Phosphorus sorption capacity)
- Bray Phosphorus
- Organic carbon
- Total nitrogen

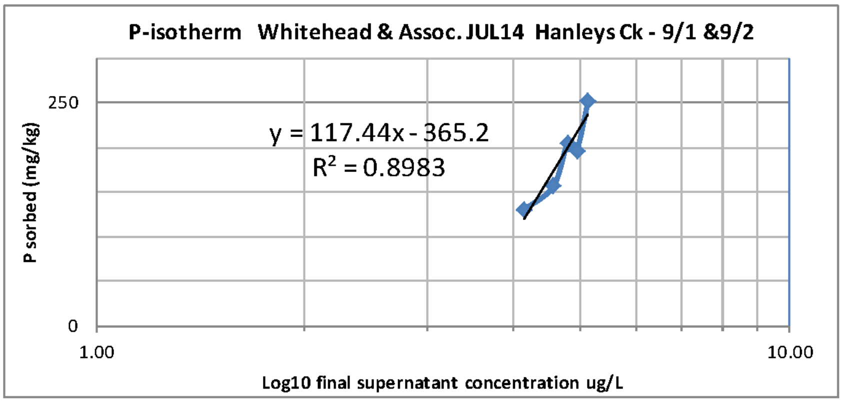
Project 3028: Cangon Park (Stage 2) Subdivision, Tabbil Creek

Sheet 2 - Results of External Laboratory Analysis

Site	Name	Depth (mm)	CEC (me/100g)	Rating	Ca (mg/kg)	Rating	Mg (mg/kg)	Rating	Na (mg/kg)	Rating	K (mg/kg)	Rating	ESP (%)	Rating	P-sorp. (mg/kg)	Rating
W&A, 2014																
TP4 (composite)	4/1 & 4/3	100	13.2	M	913	L	725	H	244	H	102	L	8.0	S	220	M
TP7	7/1	100	8.4	L	709	L	441	H	160	M	50	VL	8.3	S	160	M
	7/2	XX	17.1	M	948	L	1031	VH	799	VH	49	VL	20.3	SS	120	L
TP9 (composite)	9/1 & 9/2	100	15.4	M	669	L	1085	VH	587	VH	55	VL	16.5	SS	115	L
TP12 (composite)	12/1 & 12/2	100	8.9	L	803	L	457	H	148	M	83	L	7.2	S	180	M
NORTHROP, 2012																
NR2	x	600	32.4	H	8.7	VL	16.9	VL	2.6	VL	0.6	VL	8.0	S	557	H
NR3	x	600	13.2	M	3.7	VL	8.4	VL	2.4	VL	0.1	VL	18.2	SS	156	M
NR7	x	600	15.5	M	4.1	VL	4.3	VL	1.8	VL	0.1	VL	11.6	S	262	MH

Lanfax Labs. Armidale Soil Results





Percent sorbed is the proportion of the initial P sorbed during equilibration

P-isotherm Whitehead & Assoc. JUL14 Ha

Initial P mgP/L	filtrate P mg/L	sorbed P mg/kg	Sample I.D.	Percent sorbed (%)	Std line	filtrate C ugP/L	Y axis Log C	X axis
26.6	13.66	129.6	Whitehead & Assoc. JUL14	48.7	266	13660	4.14	129.6
52.2	36.55	156.2	Hanleys Ck - 9/1 &9/2	29.9	522	36550	4.56	156.2
81.0	60.63	204.0		25.2	810	60630	4.78	204.0
104.1	84.52	195.8		18.8	1041	84520	4.93	195.8
158.2	133.00	252.0		15.9	1582	133000	5.12	252.0

Calculated P sorption kg/ha = 1800

Appendix C

Nutrient Balance Modelling

Nutrient Balance

Project 3028: Cangon Creek (Stage 2) Subdivision, Tabbil creek

Whitehead & Associates
Environmental Consultants

Please read the attached notes before using this spreadsheet.

SUMMARY - LAND APPLICATION AREA REQUIRED BASED ON THE MOST LIMITING BALANCE = 771 m^2

INPUT DATA [1]

Wastewater Loading			Nutrient Crop Uptake					
Hydraulic Load	960	L/day	Crop N Uptake	260	kg/ha/yr	which equals	71.23	mg/m^2/day
Effluent N Concentration	30	mg/L	Crop P Uptake	30	kg/ha/yr	which equals	8.22	mg/m^2/day
t to Soil Processes (Geary & Gardner 1996)	0.2	Decimal	**Phosphorus Sorption**					
Total N Loss to Soil	5,760	mg/day	P-sorption result	115	mg/kg	which equals	1,288	kg/ha
Remaining N Load after soil loss	23,040	mg/day	Bulk Density	1.4	g/cm^3			
Effluent P Concentration	10	mg/L	Depth of Soil	0.8	m			
Design Life of System	50	yrs	% of Predicted P-sorp. [2]	0.6	Decimal			

METHOD 1: NUTRIENT BALANCE BASED ON ANNUAL CROP UPTAKE RATES

Minimum Area required with zero buffer			on of Buffer		
Nitrogen	323	m^2	Nominated LAA Size	480	m^2
Phosphorus	771	m^2	Predicted N Export from LAA	-4.07	kg/year
			Predicted P Export from LAA	1.32	kg/year
			Phosphorus Longevity for LAA	18	Years
			Minimum Buffer Required for excess nutrient	291	m^2

PHOSPHORUS BALANCE

STEP 1: Using the nominated LAA Size

Nominated LAA Size	**480**	m^2			
Daily P Load	0.0096	kg/day	→ Phosphorus generated over life of system	175.2	kg
Daily Uptake	0.0039452	kg/day	→ Phosphorus vegetative uptake for life of system	0.150	kg/m^2
Measured p-sorption capacity	0.1288	kg/m^2			
Assumed p-sorption capacity	0.077	kg/m^2	→ Phosphorus adsorbed in 50 years	0.077	kg/m^2
Site P-sorption capacity	37.09	kg	→ Desired Annual P Application Rate	2.182	kg/year
			which equals	0.00598	kg/day
P-load to be sorbed	2.06	kg/year			

NOTES

[1]. Model sensitivity to input parameters will affect the accuracy of the result obtained. Where possible site specific data should be used. Otherwise data should be obtained from a reliable source such as,

- *Environment and Health Protection Guidelines: Onsite Sewage Management for Single Households*
- *Appropriate Peer Reviewed Papers*
- *EPA Guidelines for Effluent Irrigation*
- *USEPA Onsite Systems Manual.*

[2]. A multiplier, normally between 0.25 and 0.75, is used to estimate actual P-sorption under field conditions which is assumed to be less than laboratory estimates.

Appendix D

LAM Modelling Inputs / Results

MUSIC Modelling Results

LAM RUN001:

BMT WBM

Land Application Management Tool

Run Model

Site Data

Application Area (m^2)	37440
Land Application Type	2
Storage Type	1
Application Method	1
Storage Capacity (m^3)	1
Storage Depth (m)	1
Average Slope (%)	6.3
Soil Type	CATCH1
Crop Type	Default

Soil Data

Add New

	Layer # (Single Layer Version) 1
Effective Saturation (mm)	523.3
Field Capacity (mm)	386.7
Permanent Wilting Point (mm)	260.0
Saturated Hydraulic Conductivity (mm/day)	70.0
Soil Depth for P Sorption (m)	0.8
Bulk Density (kg/m^3)	1283.3
Depression Storage (mm)	0.0
Infiltration Rate (mm/day)	200.0
Infiltration Exponent	3.2
Coefficient P Sorption	59.8
Exponent P Sorption	0.28
Exponent P Desorption	0.14

Land Application and Acceptance Rates

Storage Seepage (mm/day)	0
Fixed Application Depth (mm)	0
Soil Water Trigger (mm)	0
Additional Application Depth (mm)	0
Nitrogen Crop Uptake (kg/ha/yr)	260
Phosphorus Crop Uptake (kg/ha/yr)	30

Wastewater Characteristics

Constant Daily WWF (m^3/day)	78.88
Total Nitrogen (mg/L)	30
Total Phosphorus (mg/L)	10
Virus (MPN/L)	300

Use WWF timeseries instead? No

View Data

m^3/day

Crop Data

Add New

January	1
February	1
March	1
April	1
May	1
June	1
July	1
August	1
September	1
October	1
November	1
December	1

Meteorological Data

View Data

Number of Years 62.6

	R	ET	E	T
Max	242.5	9.2	16.2	34.0
Min	0.0	0.4	0.0	5.9
Average	2.8	3.3	3.8	17.5
Median	0.0	3.0	3.5	17.6
Standard Deviation	8.8	1.6	2.1	4.8

ONLY grey cells require input.

Refer to comments within cells for instructions

BMT WBM

Land Application Management Tool

Summary of Results

View Timeseries Results

Runoff (surcharge) frequency	**0.0**	days/year
Runoff (surcharge) volume	**0.0**	% of total WWF volume
Deep drainage volume	**12331.3**	m3/yr
Total phosphorus load in runoff	**0.0**	kg/yr
Total nitrogen load in runoff	**0.0**	kg/yr
Total phosphorus load in deep drainage	**148.7**	kg/yr
PO4 concentration in deep drainage	**9.6**	g/cub.m
Total nitrogen load in deep drainage	**1.3**	kg/yr
NO3 concentration in deep drainage	**0.0**	g/cub.m
Total site virus load	**62209679**	MPN/yr
Total site virus concentration	**5.0**	MPN/L
Total site phosphorus load	**148.7**	kg/yr
Total site nitrogen load	**1.3**	kg/yr
Storage overflow frequency	**0**	number of years
	0.0	days/year
Storage overflow volume	**0.0**	cub.m/yr
	0.0	% of total WWF volume

LAM RUN002:

BMT WBM — **Land Application Management Tool** — Run Model

Site Data

Application Area (m^2)	2400
Land Application Type	2
Storage Type	1
Application Method	1
Storage Capacity (m^3)	1
Storage Depth (m)	1
Average Slope (%)	14.8
Soil Type	CATCH1
Crop Type	Default

Soil Data — Add New

	Layer # (Single Layer Version) 1
Effective Saturation (mm)	523.3
Field Capacity (mm)	386.7
Permanent Wilting Point (mm)	260.0
Saturated Hydraulic Conductivity (mm/day)	70.0
Soil Depth for P Sorption (m)	0.8
Bulk Density (kg/m^3)	1283.3
Depression Storage (mm)	0.0
Infiltration Rate (mm/day)	200.0
Infiltration Exponent	3.2
Coefficient P Sorption	59.8
Exponent P Sorption	0.28
Exponent P Desorption	0.14

Land Application and Acceptance Rates

Storage Seepage (mm/day)	0
Fixed Application Depth (mm)	0
Soil Water Trigger (mm)	0
Additional Application Depth (mm)	0
Nitrogen Crop Uptake (kg/ha/yr)	260
Phosphorus Crop Uptake (kg/ha/yr)	30

Wastewater Characteristics

Constant Daily WWF (m^3/day)	3.84
Total Nitrogen (mg/L)	30
Total Phosphorus (mg/L)	10
Virus (MPN/L)	300

Use WWF timeseries instead? No — View Data — ###### m^3/day

Crop Data — Add New

January	1
February	1
March	1
April	1
May	1
June	1
July	1
August	1
September	1
October	1
November	1
December	1

Meteorological Data — View Data

Number of Years: 62.6

	R	*ET*	*E*	*T*
Max	242.5	9.2	16.2	34.0
Min	0.0	0.4	0.0	5.9
Average	2.8	3.3	3.8	17.5
Median	0.0	3.0	3.5	17.6
Standard Deviation	8.8	1.6	2.1	4.8

ONLY grey cells require input.
Refer to comments within cells for instructions

BMT WBM — **Land Application Management Tool**

Summary of Results

View Timeseries Results

Runoff (surcharge) frequency	**0.0**	days/year
Runoff (surcharge) volume	**0.0**	% of total WWF volume
Deep drainage volume	**612.5**	m3/yr
Total phosphorus load in runoff	**0.0**	kg/yr
Total nitrogen load in runoff	**0.0**	kg/yr
Total phosphorus load in deep drainage	**5.4**	kg/yr
PO4 concentration in deep drainage	**6.2**	g/cub.m
Total nitrogen load in deep drainage	**0.0**	kg/yr
NO3 concentration in deep drainage	**0.0**	g/cub.m
Total site virus load	**2432171**	MPN/yr
Total site virus concentration	**4.0**	MPN/L
Total site phosphorus load	**5.4**	kg/yr
Total site nitrogen load	**0.0**	kg/yr
Storage overflow frequency	**0**	number of years
	0.0	days/year
Storage overflow volume	**0.0**	cub.m/yr
	0.0	% of total WWF volume

LAM RUN003:

BMT WBM

Land Application Management Tool

Run Model

Site Data

Application Area (m^2)	1440
Land Application Type	2
Storage Type	1
Application Method	1
Storage Capacity (m^3)	1
Storage Depth (m)	1
Average Slope (%)	8
Soil Type	CATCH2
Crop Type	Default

Soil Data — *Layer # (Single Layer Version)*

Add New

	1
Effective Saturation (mm)	516.7
Field Capacity (mm)	288.3
Permanent Wilting Point (mm)	213.3
Saturated Hydraulic Conductivity (mm/day)	200.0
Soil Depth for P Sorption (m)	0.8
Bulk Density (kg/m^3)	1300.0
Depression Storage (mm)	0.0
Infiltration Rate (mm/day)	200.0
Infiltration Exponent	4.0
Coefficient P Sorption	59.8
Exponent P Sorption	0.28
Exponent P Desorption	0.14

Land Application and Acceptance Rates

Storage Seepage (mm/day)	0
Fixed Application Depth (mm)	0
Soil Water Trigger (mm)	0
Additional Application Depth (mm)	0
Nitrogen Crop Uptake (kg/ha/yr)	260
Phosphorus Crop Uptake (kg/ha/yr)	30

Wastewater Characteristics

Constant Daily WWF (m^3/day)	2.88
Total Nitrogen (mg/L)	30
Total Phosphorus (mg/L)	10
Virus (MPN/L)	300

Use WWF timeseries instead? No

View Data

m^3/day

Crop Data

Add New

January	1
February	1
March	1
April	1
May	1
June	1
July	1
August	1
September	1
October	1
November	1
December	1

Meteorological Data

View Data

Number of Years 62.6

	R	*ET*	*E*	*T*
Max	242.5	9.2	16.2	34.0
Min	0.0	0.4	0.0	5.9
Average	2.8	3.3	3.8	17.5
Median	0.0	3.0	3.5	17.6
Standard Deviation	8.8	1.6	2.1	4.8

ONLY grey cells require input.

Refer to comments within cells for instructions

BMT WBM

Land Application Management Tool

Summary of Results

View Timeseries Results

Runoff (surcharge) frequency	**0.0**	days/year
Runoff (surcharge) volume	**0.0**	% of total WWF volume
Deep drainage volume	**335.1**	m3/yr
Total phosphorus load in runoff	**0.0**	kg/yr
Total nitrogen load in runoff	**0.0**	kg/yr
Total phosphorus load in deep drainage	**5.0**	kg/yr
PO4 concentration in deep drainage	**14.8**	g/cub.m
Total nitrogen load in deep drainage	**0.0**	kg/yr
NO3 concentration in deep drainage	**0.0**	g/cub.m
Total site virus load	**1975095**	MPN/yr
Total site virus concentration	**5.9**	MPN/L
Total site phosphorus load	**5.0**	kg/yr
Total site nitrogen load	**0.0**	kg/yr
Storage overflow frequency	**0**	number of years
	0.0	days/year
Storage overflow volume	**0.0**	cub.m/yr
	0.0	% of total WWF volume

LAM RUN004:

BMT WBM

Land Application Management Tool

Run Model

Site Data

Application Area (m^2)	1440
Land Application Type	2
Storage Type	1
Application Method	1
Storage Capacity (m^3)	1
Storage Depth (m)	1
Average Slope (%)	7.7
Soil Type	CATCH3
Crop Type	Default

Soil Data Add New

	Layer # (Single Layer Version) 1
Effective Saturation (mm)	523.3
Field Capacity (mm)	386.7
Permanent Wilting Point (mm)	260.0
Saturated Hydraulic Conductivity (mm/day)	70.0
Soil Depth for P Sorption (m)	0.8
Bulk Density (kg/m^3)	1283.3
Depression Storage (mm)	0.0
Infiltration Rate (mm/day)	200.0
Infiltration Exponent	3.2
Coefficient P Sorption	59.8
Exponent P Sorption	0.28
Exponent P Desorption	0.14

Land Application and Acceptance Rates

Storage Seepage (mm/day)	0
Fixed Application Depth (mm)	0
Soil Water Trigger (mm)	0
Additional Application Depth (mm)	0
Nitrogen Crop Uptake (kg/ha/yr)	260
Phosphorus Crop Uptake (kg/ha/yr)	30

Wastewater Characteristics

Constant Daily WWF (m^3/day)	2.88
Total Nitrogen (mg/L)	30
Total Phosphorus (mg/L)	10
Virus (MPN/L)	300

Use WWF timeseries instead? No

View Data

m^3/day

Crop Data Add New

January	1
February	1
March	1
April	1
May	1
June	1
July	1
August	1
September	1
October	1
November	1
December	1

Meteorological Data View Data

Number of Years 62.6

	R	*ET*	*E*	*T*
Max	242.5	9.2	16.2	34.0
Min	0.0	0.4	0.0	5.9
Average	2.8	3.3	3.8	17.5
Median	0.0	3.0	3.5	17.6
Standard Deviation	8.8	1.6	2.1	4.8

ONLY grey cells require input.

Refer to comments within cells for instructions

BMT WBM

Land Application Management Tool

Summary of Results

View Timeseries Results

Runoff (surcharge) frequency	**0.0**	days/year
Runoff (surcharge) volume	**0.0**	% of total WWF volume
Deep drainage volume	**434.1**	m3/yr
Total phosphorus load in runoff	**0.0**	kg/yr
Total nitrogen load in runoff	**0.0**	kg/yr
Total phosphorus load in deep drainage	**5.2**	kg/yr
PO4 concentration in deep drainage	**9.2**	g/cub.m
Total nitrogen load in deep drainage	**0.0**	kg/yr
NO3 concentration in deep drainage	**0.0**	g/cub.m
Total site virus load	**2105514**	MPN/yr
Total site virus concentration	**4.9**	MPN/L
Total site phosphorus load	**5.2**	kg/yr
Total site nitrogen load	**0.0**	kg/yr
Storage overflow frequency	**0**	number of years
	0.0	days/year
Storage overflow volume	**0.0**	cub.m/yr
	0.0	% of total WWF volume

MUSIC Modelling Results:

Latest Run : Mean Annual Load : Catchment 1 - Central Major Catchment

	Outflow
Flow (ML/yr)	1283
Total Suspended Solids (kg/yr)	1.285E+05
Total Phosphorus (kg/yr)	288.4
Total Nitrogen (kg/yr)	2528
Gross Pollutants (kg/yr)	0

Latest Run : Mean Annual Load : Catchment 2 - North

	Outflow
Flow (ML/yr)	93.16
Total Suspended Solids (kg/yr)	9128
Total Phosphorus (kg/yr)	21.66
Total Nitrogen (kg/yr)	183.3
Gross Pollutants (kg/yr)	0

Latest Run : Mean Annual Load : Catchment 3 - South

	Outflow
Flow (ML/yr)	58.01
Total Suspended Solids (kg/yr)	5761
Total Phosphorus (kg/yr)	13.05
Total Nitrogen (kg/yr)	112.7
Gross Pollutants (kg/yr)	0

Appendix E

Viral Die-off Modelling

Beavers, Cromer, Gardner Viral Dieoff Model

Project: 3028: Cangon Creek Subdivision, Tabbil Creek

Whitehead & Associates
Environmental Consultants Pty Ltd

Step 1	Use Figure 1 in Cromer *et al.* (2001) (reproduced below) to determine days travel time using groundwater temperature* and a selected order of magnitude reduction.
	* If mean groundwater temperature is unavailable, mean daily air temperature can be used in most cases.

Groundwater Temperature (^oC)	12.1	From BOM
Order of magnitude reduction	3	3 orders of magnitude required for secondary treatment
Days required for viral reduction	**40**	(from Figure 1, below)

Step 2	Calculate the predicted travel distance using Equation 4 from Cromer *et al.* (2001). $Dg = (t\text{-}d_v.P/K)/(P/K.I)$

Time in days	t =	40	days	See notes below for description of values
Effective porosity of soil (fraction)	P =	0.47		
Saturated hydraulic conductivity	K =	0.06	m/day	
Groundwater gradient (fraction)	I =	0.16		
Vertical drainage before entering groundwater	d_v =	0.80	m	

Setback Distance	**Distance travelled in groundwater**	**d_g =**	**0.69**	**m**

<u>Notes:</u>

Porosity (P):	Worst case assumption for medium clay soil (Hazelton & Murphy, 2007)
Ksat (K):	Assumed average Ksat of 0.06m/day for light clay soil.
Groundwater gradient (I):	Assumed groundwater gradient of 16%
Vertical drainage (d_v):	Assumed 0.8m of unsaturated flow before reaching groundwater.

$f = 1 - p_b/p_s$ ⟵ Seciton 2.4.2 (Hazelton & Murphy 2007)

f = porosity

p_b = (bulk density of soil)g/cm^3 ⟵ Table 2.18 (Hazelton & Murphy, 2007)

p_s = 2.65g/cm^3 ⟵ Seciton 2.4.1 average specific gravity of soil particles (Hazelton & Murphy 2007)

p_b =	1.4
p_s =	2.65
f =	0.47

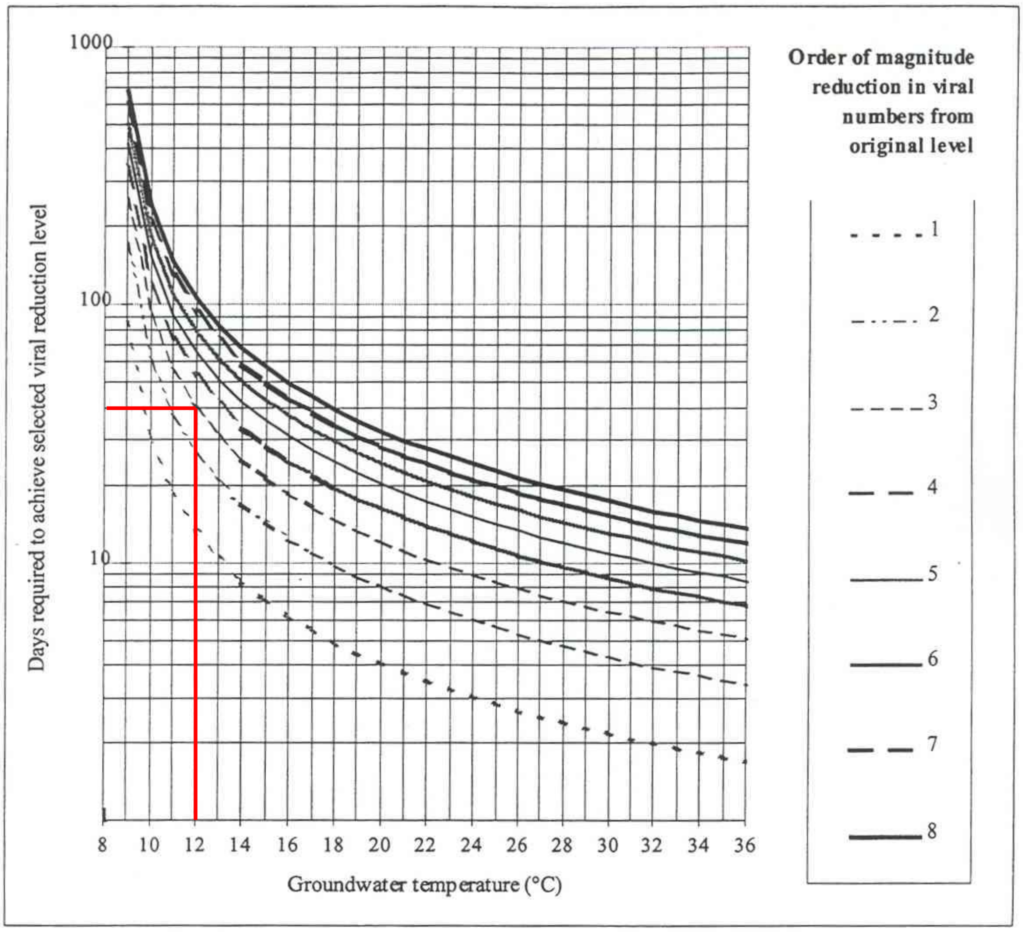


Figure 1. Relationship between Groundwater Temperature and Viral Die-Off Time for Various Order-of-Magnitude Reductions in Viral Numbers

(Figure 1 taken from Cromer et al., 2001)

Appendix F

General Notes

Soil Physical Properties / Chemistry

pH

This test is used to determine the acidity or alkalinity of native soils. pH is measured on a scale of 0 to 14, with 7 being neutral. Results below 7 are considered acid, while those above 7 are alkaline. For land application of effluent, soil with a pH of 4.5 to 8.5 should typically pose no constraints. Soil pH affects the solubility and fixation of some nutrients; this in turn reduces soil fertility and plant growth. By correcting soil pH beneficial plant growth is improved, assisting in the assimilation of nutrient and improving evapotranspiration of effluent. Most Australian soils are naturally acidic.

Electrical Conductivity

Electrical conductivity (EC) is a measure of a soil or soil/water extracts ability to conduct an electrical current. It is used as an indirect measure of a soil's accumulation of water-soluble salts, mainly of sodium, with minor potassium, calcium and magnesium. High EC within a land application area reflects general soil salinity and is undesirable for vegetation growth. The tolerance of vegetation species to soil salinity varies among plant types. Typically, EC readings of <4dS/m pose no constraints. There are a number of measures available to counter high soil EC values for land application of effluent; however, the most important measure relates to the conservative selection of application rates and appropriate application area sizing.

Emerson Aggregate Test

The Emerson Aggregate Test (EAT) is a measure of soil dispersibility and susceptibility to erosion and structural degradation. It assesses the physical changes that occur in a single ped of soil when immersed in water, specifically whether the soil slakes and falls apart or disperses and clouds the water. Dispersive soils pose limitations to on-site sewage management because of the potential loss of soil structure when effluent is applied. Soil pores can become smaller or completely blocked, causing a decrease in soil permeability, which can lead to system failure.

Cation Exchange Capacity

The cation exchange capacity (CEC) is the capacity of the soil to hold and exchange cations (positively charged molecules). Because some soils have a dominant negative charge, they can adsorb cations. Soils bind cations such as calcium, magnesium, potassium and sodium, preventing them from being leached from the soil profile and making them available as plant nutrients. CEC is a major controlling agent for soil structural stability, nutrient availability for plants and the soils' reaction to fertilisers and other ameliorants. A CEC of greater than 15 cmol+/kg or me/100g is recommended for land application systems. Adding organic matter (compost/humus) to soil can greatly increase its CEC.

Exchangeable Sodium Percentage

The exchangeable sodium percentage (ESP) is an important indicator of soil sodicity, which affects soil structural stability and overall susceptibility to dispersion. Sodic soils tend to have a low infiltration capability, low hydraulic conductivity, and a high susceptibility to erosion. When sodium dominates the exchangeable cation complex, soil structural stability declines significantly. Soil ESP is considered acceptable for effluent application areas when it is below 5%, marginal between 5% – 10% and limiting >10%. The ESP of application area soils can be improved by the measured application of calcium (lime/gypsum).

Phosphorus Sorption Capacity

Phosphorus sorption (P-sorption) capacity is a direct measure of a soils ability to adsorb phosphorus. Phosphorus is an important plant nutrient and is the limiting available nutrient in many aquatic environments. Excess phosphorus can increase the production of nuisance vegetative growth such as algae. The P-sorption capacity of the soil in an effluent application area relates to its ability to assimilate the phosphorus in the wastewater for the design life of the application area. P-sorption values greater than 400mg/kg is considered acceptable for land application of effluent, while values below 150mg/kg present a constraint.