On-site effluent management study

Daisy Hill Estate

Proposed subdivision of Lot 200 DP825059, Lots 661 and 662 DP565756, Lots 64 and 65 DP754287, Lots 316 and 317 DP754308 Eulomogo Road, Dubbo NSW

Ref: R13365e3
Date: 1 April 2019

Envirowest Consulting Pty Ltd ABN 18 103 955 246
• 9 Cameron Place, PO Box 8158, Orange NSW 2800 • Tel (02) 6361 4954 •
• Email admin@envirowest.net.au • Web www.envirowest.net.au •

Environmental
Geotechnical
Asbestos
Services

Prepared by:	Envirowest Consulting Pty Ltd 9 Cameron Place Orange NSW 2800
Client:	George Rice Bourke Securities Pty Ltd *Firgrove Homestead* 30R Eulomogo Road Dubbo NSW 2830
Assessor:	Leah Desborough BNatRes (Hons) Environmental Scientist
Checked by:	Andrew Ruming BSc Environmental Geologist
Authorising Officer:	Greg Madafiglio PhD Senior Environmental Scientist
Report number:	R13365e3
Date:	1 April 2019

Summary

Proposed development and situation
A rural-residential development (*Daisy Hill Estate*) consisting of approximately 222 lots is proposed for Lot 200 DP825059, Lots 661 and 662 DP565756, Lots 64 and 65 DP754287, Lots 316 and 317 DP754308 Eulomogo Road, Dubbo NSW. The *Daisy Hill Estate* has a total area of approximately 430 hectares. The proposed lot sizes range from a minimum lot size of 0.6 hectares to a minimum lot size of 3 hectares. The development is unlikely to be connected to municipal sewer. An on-site effluent management system is required for each dwelling on the site.

A desktop study and site and soil assessment was undertaken using the *On-site domestic wastewater management* (Australian Standard 1547:2012), and *On-site sewage management for single households* (Department of Urban Affairs and Planning 1998), as guidelines. Suitable wastewater application systems and sizing are recommended on a generic basis.

Site and soil assessment
A site inspection and assessment was undertaken in October 2010 and July and August 2013. Additional site inspection and soil investigations were undertaken in 2014 and 2017.

The historical land-use of the *Daisy Hill Estate* is agricultural. The terrain is generally flat with slightly inclined slopes of less than 1%. A drainage line is located in the central section of the site. The water from the site discharges into intermittent streams and eventually into Troy Creek.

Vegetation on the site consists of pasture species including ryegrass, lucerne, soft brome and oats.

The soil at twelve locations was described from boreholes and analysis of representative soil samples for physical and chemical properties.

A review of soil landscape maps indicated the *Daisy Hill Estate* is dominated by red earths with earthy sands in the north eastern section. Red earths have a topsoil of sandy loam and a subsoil of fine sandy clay loam. Earthy sands have a topsoil of loamy sands and a subsoil of sandy loam. Both soil types have depths to greater than 1,000mm.

Limitations to the application of effluent were identified and include soil type and landscape features.

Based on the site and soil limitations, practicality and cost considerations the following generic recommendation is made for the treatment and application of effluent.

On red earth soils, the generic recommended effluent application system is a **secondary treatment system** and **irrigation application with an area of 537m^2**. Other innovative systems such as an amended sand mound and composting toilets may also be suitable.

On earthy sand soils, the generic recommended effluent application system is a **secondary treatment system** and **irrigation application with an area of 723m^2**. Other innovative systems such as an amended sand mound and composting toilets may also be suitable.

All lots are expected to have sufficient areas for application systems after allowance for buffer distances to boundaries, buildings and bores.

These recommendations are made using the available data and should be considered as being generalised for the site as a whole. A detailed site and soil assessment of each lot should be undertaken to make recommendations of locations and suitable systems for individual lots prior to dwelling construction.

Contents

1. Introduction

1.1 Background

A rural-residential development (*Daisy Hill Estate*) consisting of approximately 222 lots is proposed for Lot 200 DP825059, Lots 661 and 662 DP565756, Lots 64 and 65 DP754287, Lots 316 and 317 DP754308 Eulomogo Road, Dubbo NSW. Daisy Hill Estate is unlikely to be connected to municipal sewer. An on-site effluent management system is required for the dwellings on the site.

The *Daisy Hill Estate* has a total area of approximately 430 hectares. The proposed lot sizes range from a minimum lot size of 0.6 hectares to minimum lot size of 3 hectares and currently consist primarily of grassland. The historical land-use for the property is pasture and cropping.

1.2 Scope of work

A preliminary site assessment and soil assessment was undertaken of the development using the Australian Standard 1547:2012, *On-site domestic wastewater management*, and the Environment and Health Protection Guidelines, *On-site sewage management for single households* (1998), (Department of Urban Affairs and Planning), as guidelines. Site limitations were identified and suitable wastewater application systems and sizing are recommended on a generic basis.

2. Site identification

2.1 Location

The site is bordered by Eulomogo Road, Pinedale Road and Torwood Road (Figure 1). The site is described as Lot 200 DP825059, Lots 661 and 662 DP565756, Lots 64 and 65 DP754287, Lots 316 and 317 DP754308 Eulomogo Road, Dubbo NSW (Figure 1). The lots are an aggregation of the following existing properties:

Lot number	Property name
Lot 200	*Firgrove*
Lot 661	*Mt Olivetta*
Lot 662	*Killara View*
Lot 64	*Peachville Park*
Lot 65	*Mt Olivetta*
Lots 316 and 317	*Peachville Park West*

2.2 Council area

Dubbo City Council

2.3 Owner/Developer

Bourke Securities Pty Ltd
Firgrove Homestead
30R Eulomogo Road
Dubbo NSW 2830

2.4 Development

The proposed subdivision will create approximately 222 rural-residential lots. Lots range in size from a minimum of 0.6ha to a minimum of 3ha (Figure 3). The development will involve the construction of roads and access driveways.

2.5 Area and lot sizes
The total area of the *Daisy Hill Estate* is approximately 430 hectares from which approximately 222 rural-residential lots are proposed. The whole site will be assessed for on-site effluent application from the rural residential subdivision.

2.6 Current land use
The current land-use is grazing of sheep.

2.7 Local experience of on site management systems
Septic treatment and absorption trench effluent systems are installed at the existing dwellings in the *Daisy Hill Estate*. The existing effluent application systems were working satisfactorily.

2.8 Setting
Minimum lot size in the development is 0.6ha. The average dwelling density is less than 1 dwelling per hectare. The proposed dwelling density and on-site effluent system density is less than the 1 dwelling per 0.4ha required for groundwater protection (Geary & Gardner 1996, Land Management for Urban Development, Australian Society of Soil Sciences, Qld).

3. Site assessment
An assessment of the site was made from a desktop study. Information for the desktop study was obtained from topographic maps, soil landscapes maps, aerial photographs and database searches.

A site inspection was undertaken in October 2010, July and August 2013. Additional inspected, soil sampling and investigation were undertaken in 2014 and 2017. The investigations in 2014 and 2017 were undertaken as part of a salinity investigation (Envirowest Consulting report R13365s6). At the time of the investigation surrounding land-use consisted of stock grazing.

3.1 Topography
The site is located on a flat within a mid-slope and upper slope landform. A low ridge is located through the central section of Lot 200 DP825059. Aspect is predominantly west with a southerly aspect in the southern section of Lot 200. Slopes range from very gently inclined (1%) to slightly inclined (4%). Elevation ranges between 311 and 377 metres above sea level.

No limitations to the application of effluent are expected from site topography or slope.

3.2 Climate
The locality has a temperate climate with an approximately uniform rainfall over the year of between 43 and 61mm per month and annual mean rainfall of 587mm. Summers are warm to hot and winters are cold with little or no effective evaporation, annual pan evaporation is 1471mm.

3.3 Hydrogeology
3.3.1 Surface Water
Surface water drains to the north west into several dams and poorly defined intermittent drainage lines. An intermittent drainage line is located through the central section of the *Daisy Hill Estate* and runs south east to north west. The stream channel is very shallow. Surface water over the

majority of the site flows into intermittent drainage lines which empty into Troy Creek located approximately 900m north west of the site. Surface water in the southern section of the site flows south and into Eulomogo Creek approximately 1km from the site.

The intermittent drainage lines may be relocated into roadside drains as part of the development. The relocation of drainage lines will be into open drains an pipes to be determined. The natural flow of water will not be restricted in the development.

Three dams are located on the site. The dams are used for stock watering. The dams are expected to be filled as part of the development.

3.3.2 Groundwater

Three operational bores are located on the site. One bore is located around the homestead of *Mt Olivetta*, one is located on *Peachville Park* and one is located in the south eastern section of *Peachville Park West*. Other bores were identified on the NSW Natural Resource Atlas as occurring on the site. Ground searches and information from the site owner indicated the bores were not located on the site or were not used. The bores were constructed between 1972 and 2012. These bores indicate shallow water does not occur on the site. Water description at the time of construction was good and salty, brackish.

The Office of Environment and Heritage (OEH) NSW Natural Resource Atlas (2013b) identifies fifty seven bores within 1km of the site. These bores are licensed for domestic, stock and irrigation supplies and monitoring. Depth of the bores ranged from 9 to 107m. Water bearing zones were located generally deeper than 10m in basalt and sandstone. Standing water levels at the time of bore construction ranged between 5 to 50m.

The site is located within the Eastern Porous Rock: Macquarie-Castlereagh Groundwater Management Unit (Murray-Darling Basin Authority 2012). Groundwater salinity ranges from 1,500-3,000mg/L.

No impact on groundwater is expected from the application of effluent on the site.

3.4 Vegetation

The natural woodland has been cleared from most of the site. The site is dominated by introduced pasture species including ryegrass, lucerne, soft brome and oats. Native pasture species includes weeping grass, spear grass, native medics and naturalised clovers. Weed species included saffron thistle, sheep sorrel, Paterson's curse and medic.

A small stand of remnant native trees is located in a central section of Lot 64. Tree species consisted of Inland grey box and fuzzy box. White cypress pines are located around the boundary of the site and isolated white cedar, white cypress pines and kurrajong trees occur throughout the paddocks.

3.5 Soils

3.5.1 Soil landscape and geology

The majority of the site is within the Eulomogo Soil Landscape and comprise red earths. The north eastern section is within the Goonoo Soil Landscape and comprises earthy sands (Murphy and Lawry 1998).

Soil was assessed on *Peachville Park* in October 2010 by drilling 12 boreholes to 1.5 metres. *Peachville Park* was found to be comprise red earths. Additional site inspection and soil investigations including boreholes were undertaken in 2014 and 2017.The profiles are considered indicative of other areas of the *Daisy Hill Estate*.

The soil profile was described and representative sample collected for the determination of physical and chemical properties. Soil physical properties measurements undertaken included: dispersion, texture, colour, pH, and salinity. The laboratory tests for physical properties were undertaken by Envirowest Testing Services and presented with the borelogs in Appendix 1. Additional information on the soil type is presented in the Salinity Investigation, Envirowest Consulting report number R13365s6.6)

Red earths have a topsoil of sandy loam and a subsoil of fine sandy clay loam. Earthy sands have a topsoil of loamy sands and a subsoil of sandy loam. Both soil types have a depth to greater than 1,000mm. The expected distribution of soil types is presented in Figure 4.

The subsoil has a low to moderate erodibility and erosion hazard. The erosion hazard is reduced by maintenance of adequate vegetation cover.

The geological unit is Piliga Sandstone and Ballimore Formation with lithology comprising massive to cross-bedded coarse pebbly lithic-quartz sandstone, minor lithic sandstone and siltstone (Colquhoun *et al.* 1997).

3.5.2 Soil description

Soil profile

The soil investigation determined two distinct soil types over the site, red earths and earthy sands (Figure 4). Red earths occur on the mid-slopes and are high to moderately drained. Red earths have a brown to yellowish red sandy loam to sandy clay loam topsoil and a subsoil comprising strong brown to yellowish red sandy clay. Medium clay was identified at depths greater than 1m in several boreholes. No indicators of poorly drained soils were identified. The soil samples collected were slightly to non-dispersive.

Earthy sands occur in the north eastern section of the site. Boreholes were not constructed in earthy sand soils.

Depth to bedrock

Depth to bedrock is expected to be greater than 1,500mm in the soil landscapes. Shallow soils may be present around the former quarry on Lot 200. The potential shallow soils are a limitation to the application of effluent.

Surface rocks, rock outcrops

Rock outcrops were observed on the site in the north western field of *Peachville Park* (Lot 64). These rock outcrops are a minor limitation to the application of effluent in specific areas. Rock outcrops are indicated in Figure 3.

Depth to groundwater

Groundwater monitoring wells installed over the site in 2014 and 2017 identified shallow aquifers generally greater than 10m below the surface. A small section in the north central location contains groundwater around 5m below the surface (Envirowest Consulting Salinity Report R13365s6). The depth of groundwater is not a limitation for on-site effluent application.

Coarse fragments
River gravel bands were identified in several boreholes at depths greater than 1m. The gravel is not a limitation to the application of effluent. Some areas contain cobbles on the surface.

Bulk density
Bulk density was estimated to be moderate from the land-use history. Bulk density will not limit plant growth.

pH
Red earths are generally moderately acidic to neutral. Earthy sands are slightly acidic. The levels present will not significantly affect the growth of most species.

Salinity
No salt tolerant vegetation was observed. The site is located within the Troy Gully catchment and a risk exists for soil salinity. Salinity investigation did not identify any areas of saline soil.

Risk of soil salinity is a limitation to the application of effluent. The effluent system will be designed to reduce wastewater infiltration.

Phosphorus sorption
Estimated to be moderate (9,000kg/ha) for red earths and low (5,000kg/ha) for earthy sands.

Phosphorous sorption of the soil is a minor limitation. The effluent system will be designed to contain phosphorus within the application area and prevent off-site movement. The phosphorus loading from each residence is estimated to be 3.18kg/year.

Nutrient balance
Nitrogen will be utilised by plant growth and denitrified or absorbed in the soil. The soil has capacity to support active vegetation which will contain nitrogen in the application area and prevent off-site movement. The nitrogen loading from each residence is estimated to be 9.8kg/year.

Cation exchange capacity (CEC)
The CEC is estimated to be low to moderate from the soil texture. The application of nutrient in the effluent will provide nutrients for plant growth that are naturally deficient in the soil. The soil will provide adequate retention of nutrients for plant growth.

Dispersiveness
Red earths with a sodic lower subsoil are common in the landscape. Earthy sands with a sodic upper subsoil (top 20cm of B horizon) are common in the landscape. The maintenance of vegetation on the application area and the regular application of gypsum will prevent any reduction in infiltration or erosion problems associated with the sodic soils. Sodic soils are a limitation to absorption system application of effluent.

Soil structure
The soils were assessed to have a moderate soil structure.

4. Effluent management and application area design

4.1 Limitation to on-site effluent application

Limitations to the application of effluent over the site were identified.

Limitation	Mitigation measure
Salinity hazard area	Surface irrigation to prevent infiltration and groundwater recharge
Dispersive subsoils	Surface irrigation to avoid impact
Potential shallow soils	Surface irrigation to ensure sufficient soil depth
Nutrient loading	Appropriate sizing of application area and buffer distances

4.2 Environmental concerns

Native Plants	Nil
High water table	Nil
Community water storage	None nearby
Waterway/wetland	None nearby

4.3 Buffers and available area

The lot size will enable sufficient buffer distances to bores, roads, dwellings and boundaries to be maintained. Recommended buffer distances to streams, bores, dwellings and boundaries are presented in Appendix 2.

4.3.1 Permanent waters, streams, lakes, rivers.

No permanent streams are located on the site or within 100 metres of the site.

A buffer distance of 100m to permanent streams will provide protection that nutrient or pathogen migration off-site will not occur. No impact on streams is expected as the distance to streams is greater than 500m.

4.3.2 Other waters, intermittent waterways

A drainage line and three dams are located on the site. The shallow drainage line is expected to become redundant following site development. Surface water flows are expected to be diverted into roadside drains. The dams will be filled. No buffers to the dams are required post development.

A buffer distance of 40m to dams and drainage lines will provide protection that nutrient or pathogen migration off-site will not occur. No impact on streams is expected as the distance to dams and drainage lines is greater than 100m.

4.3.3 Domestic groundwater wells

Bores are located around the *Mt Olivetta* homestead, *Peachville Park* and in the south eastern section of *Peachville Park West*.

The buffer distance to the bores is reduced by determining the radius of influence and set back distance (Cromer *et al.* 2004) as calculated in Appendix 6. This distance is expected to be sufficient to prevent contamination of the bore with effluent that may enter the bore. The calculated buffer distances are considered conservative as calculation of the radius of influence and setback distance is applicable to unconfined bores. The water bearing zones of each on-site bore are located in confined basalt and sandstone. A maximum buffer distance of 23m is required around the bore on *Mt Olivetta*, 28m around the bore on *Peachville Park* and 9m around the bore on *Peachville Park West*. This buffer distance is available.

4.3.4 Boundary lines

Buffers are required between the application areas and boundary lines.

4.3.5 Available area and reserve area

The minimum proposed lot size in the *Daisy Hill Estate* is 0.6ha. The required buffers on these lots are up to 6m to lot boundaries. Conservatively assuming up to 50% of the lot will form buffers to boundaries, 0.3ha will be available for application of effluent.

The largest buffer area around the bores is 28m and equates to approximately 2,500m^2. The bores are located on the minimum lot size of 0.6ha, minimum lot size of 1.5ha and minimum lot size of 3ha lots. Conservatively assuming 4,000m^2 of the site is required as buffers to boundaries, over 2,000m^2 will be available for application of effluent.

Application areas are up to 723m^2 and therefore sufficient area is available in each lot for effluent application.

4.4 Estimated flows

Typical effluent flow designs allowances in households with standard water fixtures is 145 litres/person/day where the water source is on-site roof water tank supply (AS1547:2012). Assuming the occupancy of the dwelling is 5 people the design flow rate for the dwelling is 725 litres/day.

The water balance is calculated using full water saving devices such as dual flush toilets (6/3 litre water closets), water reduction cycles on dishwashers, aerator faucets fitted to taps, front loader washing machines and water reducing shower heads.

4.5 Hydraulic balance calculations and nutrient balance

The interactions between soil, climate, topography and the hydraulic and nutrient loadings were modelled based on the design in DUAP (1998). The model provides estimates consistent with more complex models and meets environmental performance objectives.

The parameters used in the model were as follows:

- Effluent flow of 725 litres/day
- Estimated absorption rate of red earths for irrigation systems of 0mm/day. Minimal infiltration is recommended due to the risk of soil salinity. Trench systems are not suitable due to sodic soils and risk of soil salinity.
- Estimated absorption rate of earthy sands for irrigation systems of 0mm/day. Minimal infiltration is recommended due to the risk of soil salinity. Trench systems are not suitable due to sodic soils and risk of soil salinity.
- Estimated phosphorus sorption of 9,000kg/ha for red earths and 5,000kg/ha for earthy sands.

- Rainfall data for Dubbo
- Evaporation data for Gunnedah, nearest recording location

The estimated area required and the wet weather storage requirements are presented in Appendices 3 to 5.

5. System recommendation

Based on the site and soil limitations, practicality and cost considerations the following recommendations are made for the treatment and application of effluent.

The recommended effluent system for red earth soil is:

- **Surface irrigation with an irrigation area of 537m²** and secondary treatment system accredited by NSW Health.

- Other innovative systems such as an amended sand mound and composting toilets may be suitable.

The recommended effluent system for earthy sand soil is:

- **Surface irrigation with an irrigation area of 723m²** and secondary treatment system accredited by NSW Health.

- Other innovative systems such as an amended sand mound and composting toilets may be suitable.

The recommendations are made using the available data and should be considered as being generalised for the site as a whole. Assumptions have been made in the soil description and more detailed assessment is required to make recommendations of locations and suitable systems for individual lots.

6. System management

Wastewater should be evenly applied over the application area.

Access to the application area by people and stock should be restricted as recommended in AS1547:2012 and summarised in Appendix 7.

The topsoil on the site is capable of supporting plant growth that will optimise evapotranspiration and wastewater usage.

A maintained grass sward is the recommended vegetation over the irrigation area. Appendix 7 is a checklist of do's and don'ts to ensure correct operation of the wastewater system. Periodic application of gypsum is recommended.

Construction and maintenance of systems should comply with AS/NZ 1547:2012. The system including both the treatment system and application area, should be inspected by Dubbo City Council following installation to ensure correct construction techniques and location of the system. The system requires quarterly maintenance by a qualified person, to ensure it is satisfying environmental performance criteria. Dubbo City Council should be provided with a copy of the maintenance report.

7. References

AS/NZS 1547:2012 On-site domestic-wastewater management. (Standards Australia, Strathfield)

Colour: Munsell (2000) In 'Munsell Soil Color Charts' (Gretag Macbeth: NY)

DUAP (1998) *On-site Sewage Management for Single Households.* (Department of Urban Affairs and Planning: Sydney)

Emerson: AS 1289.3.8.1-1997 Method of testing soil for engineering purposes- Soil classification tests- Dispersion- Determination of Emerson Class number of a soil analysis (Standards Australia: Homebush)

Murphy BW and Lawrie JW (1998) *Soil Landscapes of the Dubbo 1:250 000 Sheet Report,* Department of Land and Water Conservation of NSW, Sydney

Figures

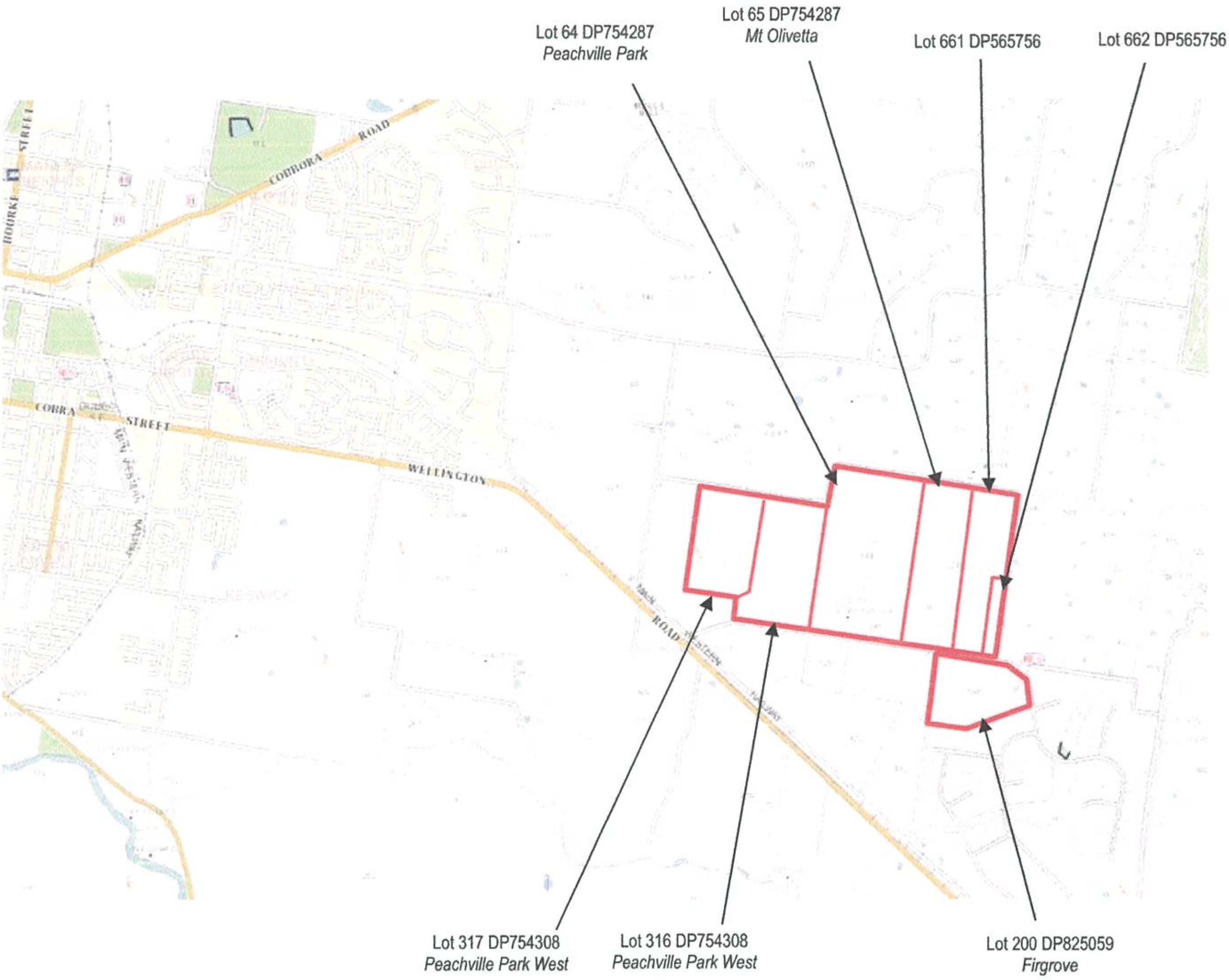


Figure 1. Locality plan

Daisy Hill Estate Eulomogo Road, Dubbo NSW

Envirowest Consulting Pty Ltd

Job – R13365e.1	Drawn by: LD	Date: 3/10/2013

North

Legend

Lot boundary

Approximate Scale 1: 17,800

0 178 356 712m

Figure 2. Aerial photograph of the site		
Daisy Hill Estate, Eulomogo Road, Dubbo NSW		
	Envirowest Consulting Pty Ltd	
Job – R13365e.1	Drawn by: LD	Date: 16/10/2013

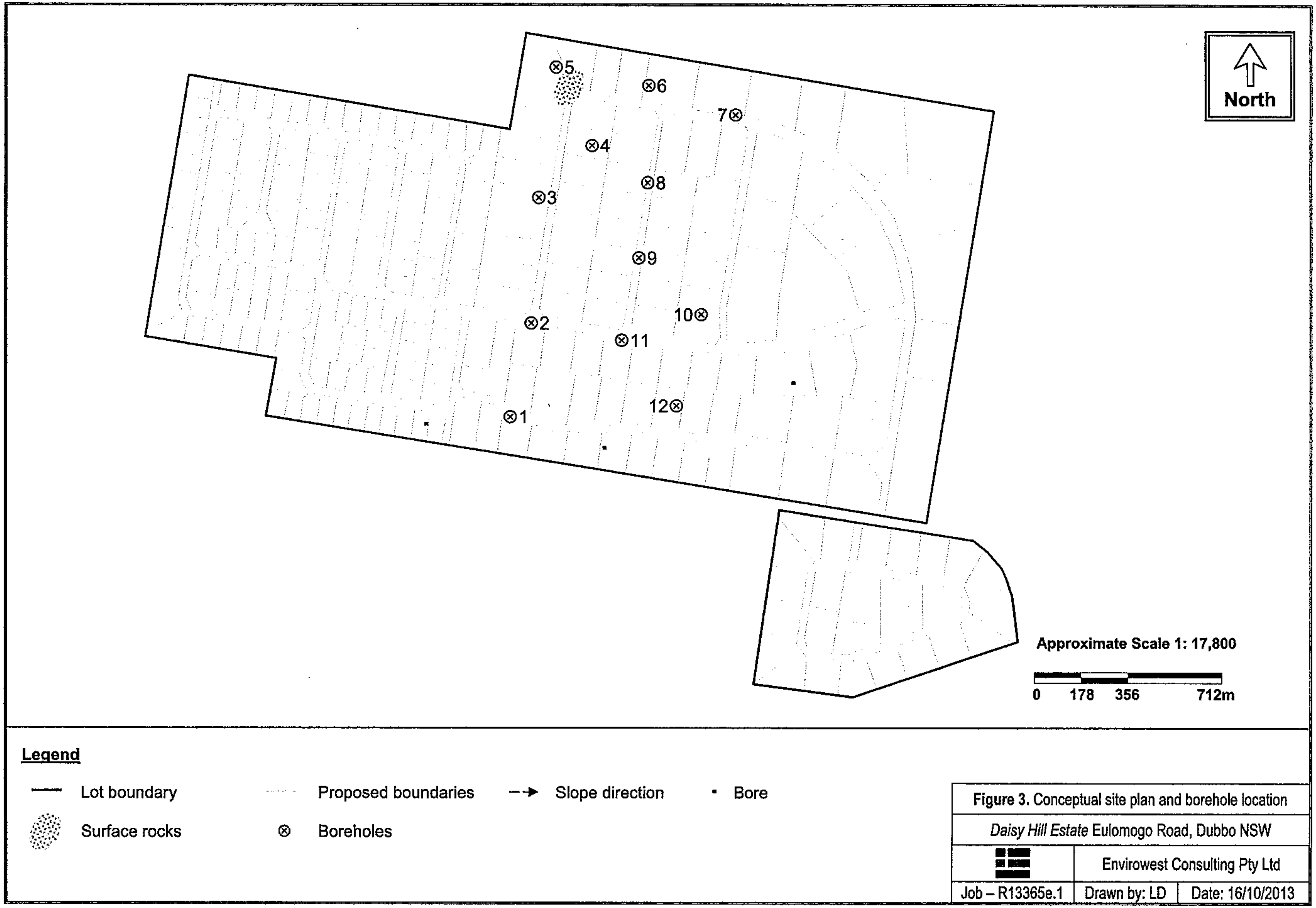
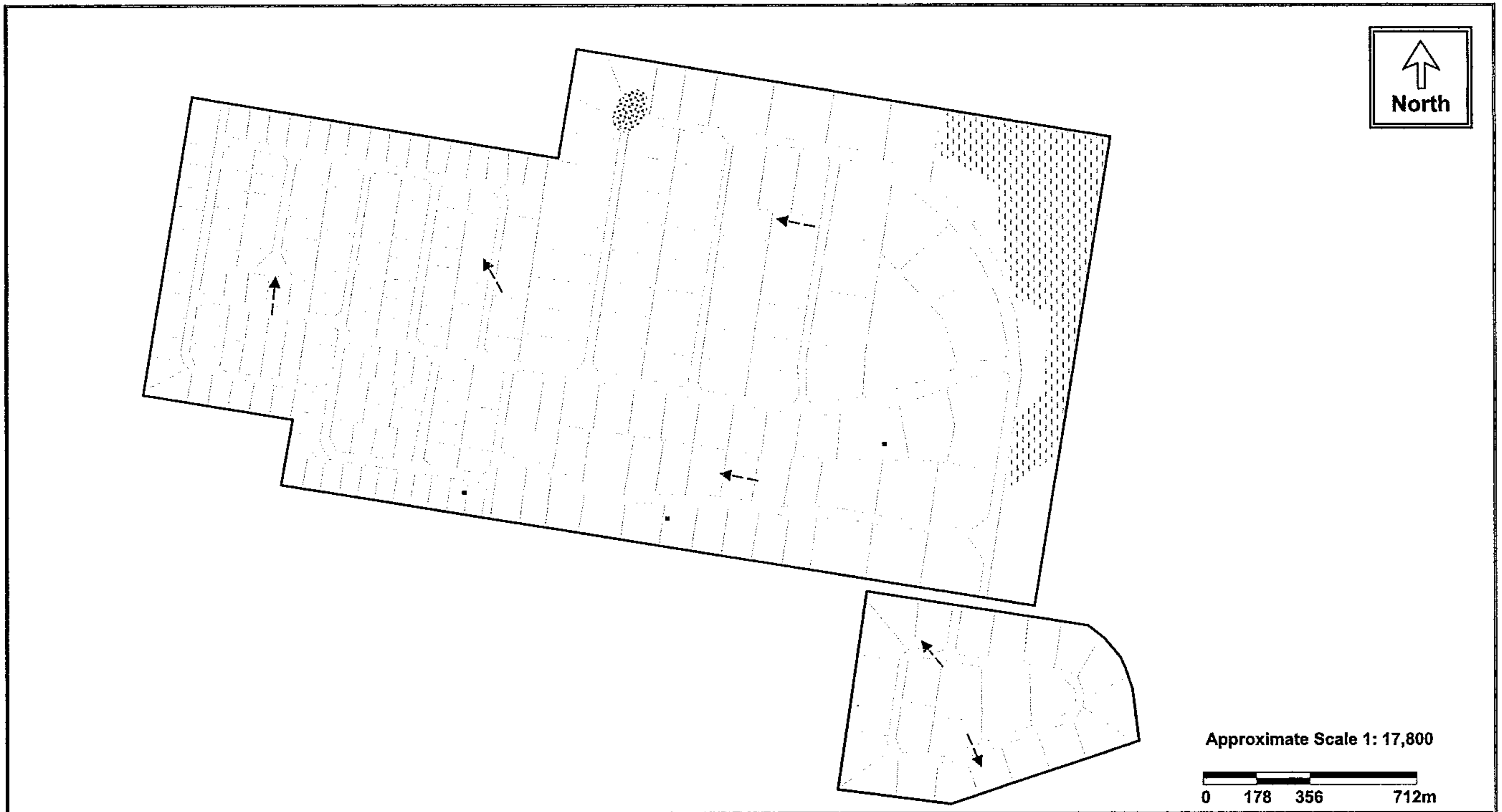


Figure 3. Conceptual site plan and borehole location

Daisy Hill Estate Eulomogo Road, Dubbo NSW

	Envirowest Consulting Pty Ltd	
Job – R13365e.1	Drawn by: LD	Date: 16/10/2013



Legend

- Lot boundary
- Surface rocks
- Proposed boundaries
- Red earths
- Slope direction
- Earthy sands
- Bore

Figure 4. Approximate location of soil types

Daisy Hill Estate Eulomogo Road, Dubbo NSW

Envirowest Consulting Pty Ltd

Job – R13365e.1 | Drawn by: LD | Date: 3/10/2013

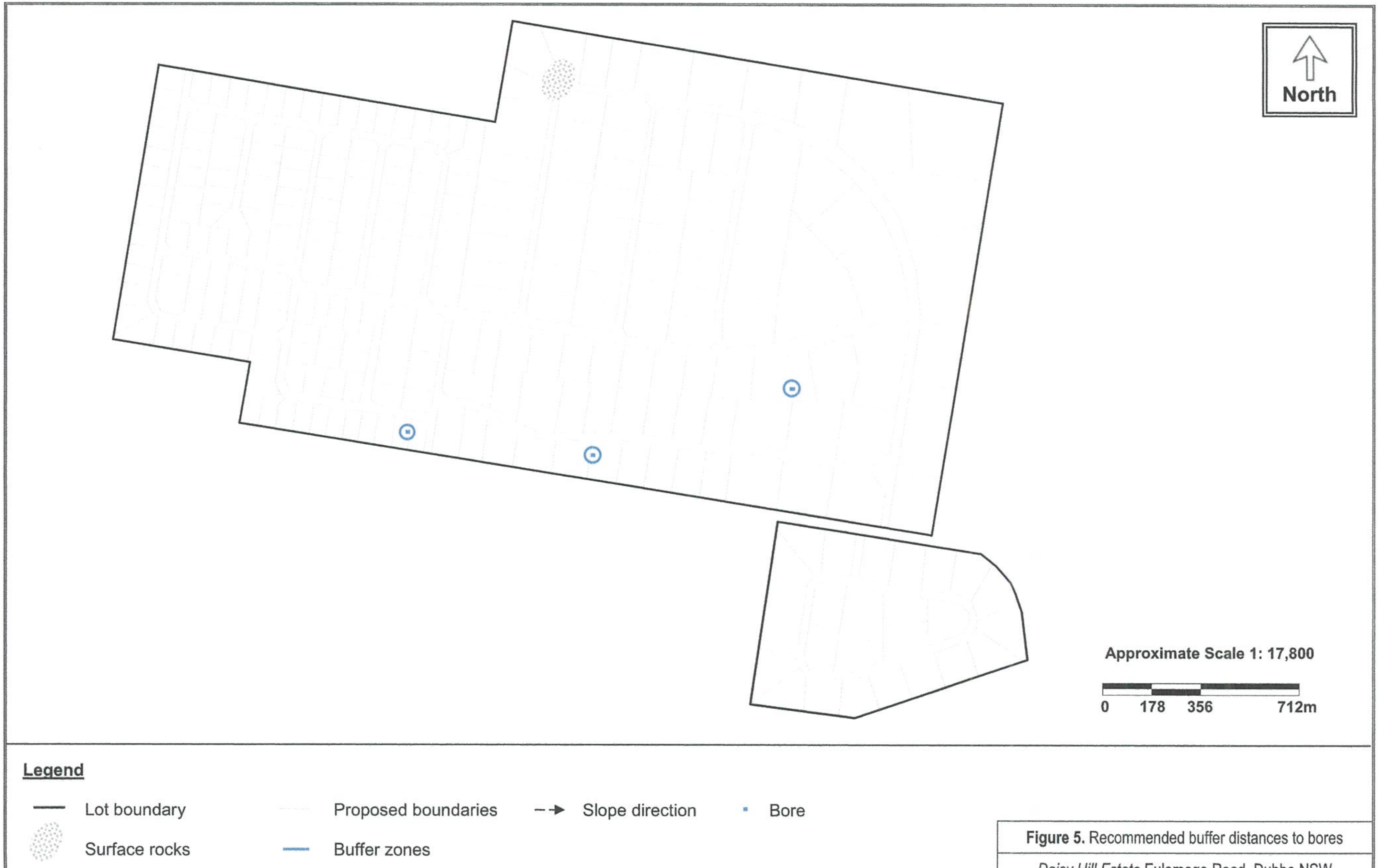


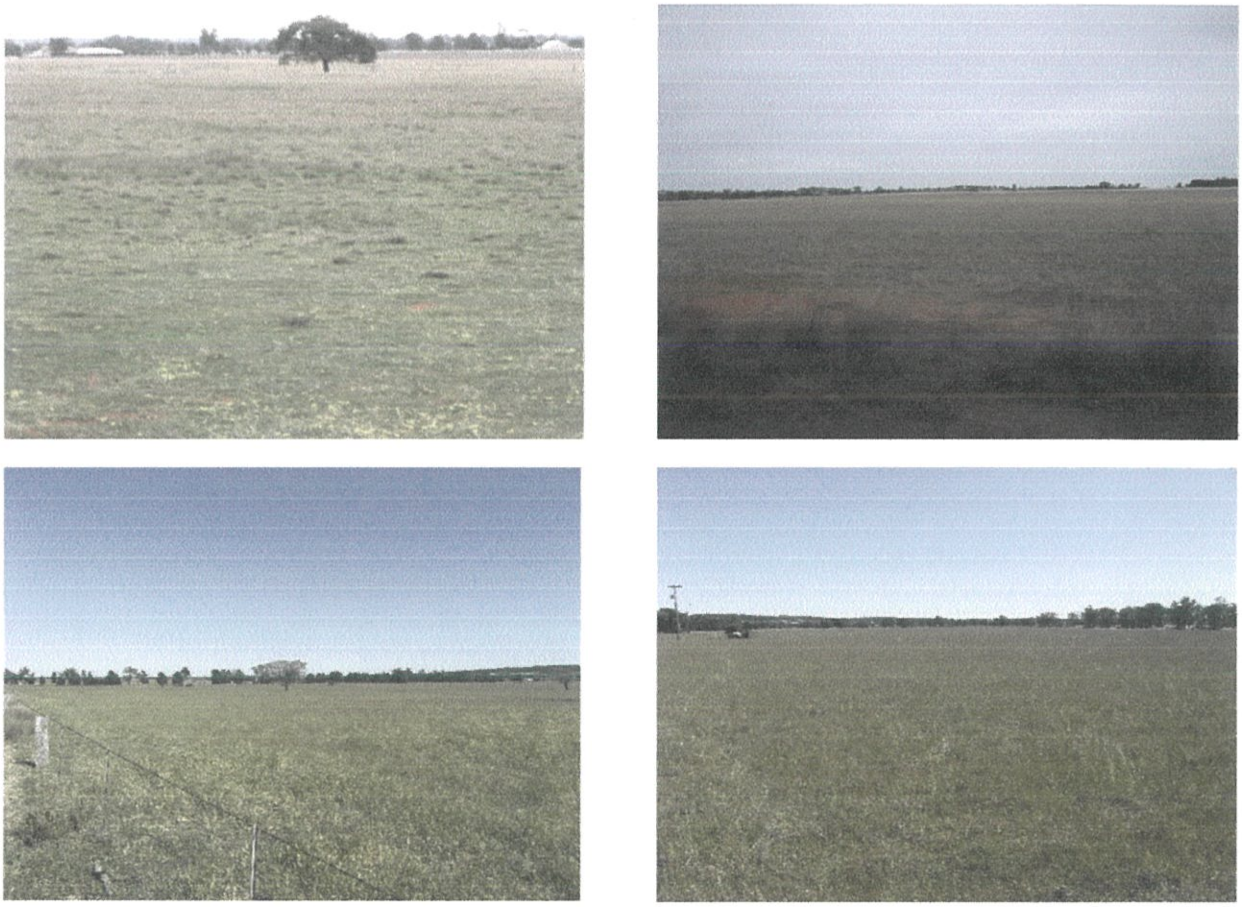
Figure 5. Recommended buffer distances to bores

Daisy Hill Estate Eulomogo Road, Dubbo NSW

Envirowest Consulting Pty Ltd

Job – R13365e.1	Drawn by: LD	Date: 3/10/2013

Figure 6. Representative photographs of the site



Appendices

Appendix 1. Bore logs and laboratory results

Depth (mm)	Description	Sampled (X)	Texture group	Moisture	Emerson aggregate test*	pH (1:5 water)	EC 1:5	ECe dS/m
Test hole 1								
0-700	Brown sandy loam to dark brown	X	SL	M	3	5.4	0.02	0.08
	sandy clay loam	X	SCL	M	3	5.2	0.02	0.19
700-1500	Reddish brown sandy clay	X	SC	M	3	5.9	0.05	0.37
1500	End of hole							
Test hole 2								
0-300	Brown sandy loam	X	SL	M	3	5.7	0.02	0.28
300-700	Red sandy clay loam	X	SCL	M	5	5.8	0.19	0.19
700-1500	Red sandy clay	X	SC	M	5	5.7	0.23	0.23
1500	End of hole							
Test hole 3								
0-200	Dark reddish brown loamy sand with silt	X	LS	M	3	5.7	0.02	0.46
200-700	Yellowish red sandy loam	X	SL	M	2	5.6	0.01	0.15
700-1400	Yellowish red sandy clay	X	SC	M	1	6.7	0.06	0.45
1400-1500	Reddish brown sandy clay		SC	M				
1500	End of hole							
Test hole 4								
0-400	Dark reddish brown sandy clay loam	X	SCL	M	2	5.7	0.04	0.38
400-900	Reddish brown sandy clay	X	SC	M	2	7.1	0.11	1.05
900-1500	Strong brown medium clay with sand	X	MC	M	2	7.8	0.36	2.09
1500	End of hole							
Test hole 5								
0-200	Dark reddish brown sandy clay loam	X	SCL	M	2	5.6	0.03	0.29
200-1000	Yellowish red medium clay with sand	X	MC	M	1	6.9	0.14	0.81
1000-1500	Brown sandy clay with gravel	X	SC	M	2	8.2	0.54	4.05
1500	End of hole							
Test hole 6								
0-150	Reddish brown sandy loam	X	SL	M	3	5.9	0.04	0.56
150-700	Reddish brown sandy clay loam	X	SCL	M	5	5.9	0.02	0.15
700-1500	Yellowish red sandy clay	X	SC	M	3	5.5	0.05	0.38
1500	End of hole							
Test hole 7								
0-150	Reddish brown sandy loam	X	SL	M	3	5.3	0.02	0.28
150-1100	Yellowish red sandy clay loam	X	SCL	M	3	5.5	0.01	0.10
1100-1500	Red sandy clay	X	SC	M	5	6.0	0.04	0.30
1500	End of hole							

M=Moist, D=Dry

*1= highly dispersive (slakes, complete dispersion), 2= moderately dispersive (slakes, some dispersion), 3= slightly dispersive (slakes, some dispersion after remoulding), 4= non-dispersive (slakes, carbonate or gypsum present), 5= non-dispersive (slakes, dispersion in shaken suspension) 6= non-dispersive (slakes, flocculates in shaken suspension), 7= non-dispersive (no slaking, swells in water), 8= non-dispersive (no slaking, does not swell in water).

Depth (mm)	Description	Sampled (X)	Texture group	Moisture	Emerson aggregate test*	pH (1:5 water)	EC 1:5	ECe dS/m
Test hole 8								
0-150	Dark reddish brown sandy loam	X	SL	M	3	4.8	0.02	0.28
150-900	Yellowish red sandy clay loam	X	SCL	M	2	5.4	0.02	0.19
900-1500	Strong brown medium clay with sand	X	MC	M	2	7.2	0.08	0.46
1500	End of hole							
Test hole 9								
0-250	Reddish brown sandy clay loam	X	SCL	M	2	5.0	0.03	0.29
250-600	Yellowish red sandy clay loam	X	SCL	M	3	5.4	0.02	0.19
600-1200	Red sandy clay	X	SC	M	5	5.8	0.07	0.53
1200-1500	Red medium clay with sand		MC	M				
1500	End of hole							
Test hole 10								
0-350	Reddish brown sandy clay loam	X	SCL	M	3	6.1	0.07	0.67
350-1300	Yellowish red sandy clay	X	SC	M	2	6.7	0.05	0.38
		X			5	7.2	0.13	0.98
1300-1500	Yellowish red medium clay with sand		MC	M				
1500	End of hole							
Test hole 11								
0-150	Yellowish red sandy loam	X	SL	M	3	6.2	0.01	0.14
150-250	Yellowish red sandy clay loam		SCL	M				
250-800	Red sandy clay loam	X	SCL	M	3	5.6	0.02	0.19
800-1500	Red sandy clay	X	SC	M	5	5.8	0.02	0.15
1500	End of hole							
Test hole 12								
0-100	Reddish brown sandy loam	X	SL	M	3	5.6	0.02	0.28
100-1500	Red sandy clay	X	SC	M	5	5.4	0.02	0.15
		X	SC	M	5	5.7	0.03	0.23
1500	End of hole							

M=Moist, D=Dry

*1= highly dispersive (slakes, complete dispersion), 2= moderately dispersive (slakes, some dispersion), 3= slightly dispersive (slakes, some dispersion after remoulding), 4= non-dispersive (slakes, carbonate or gypsum present), 5= non-dispersive (slakes, dispersion in shaken suspension) 6= non-dispersive (slakes, flocculates in shaken suspension), 7= non-dispersive (no slaking, swells in water), 8= non-dispersive (no slaking, does not swell in water).

Appendix 2. Recommended buffer distances for on-site systems (*On-site Sewage Management for Single Households* (1998) Dept of Urban Affairs and Planning)

Feature	**System and buffer distance (m)**			
	Surface spray irrigation	Surface drip	Subsurface irrigation	Absorption systems
Permanent streams	100	100	100	100
Domestic groundwater wells	250	250	250	250
Intermittent streams	40	40	40	40
Property boundaries	6 (upslope) 3 (down slope)	6 (upslope) 3 (down slope)	6 (upslope) 3 (down slope)	12 (upslope) 6 (down slope)
Dwelling/ buildings	15	6 (upslope) 3 (down slope)	6 (upslope) 3 (down slope)	6 (upslope) 3 (down slope)
Swimming pools	6	6 (upslope) 3 (down slope)	6 (upslope) 3 (down slope)	6 (upslope) 3 (down slope)
Paths and walkways	3	-	-	-
Driveways	6 (upslope) 3 (down slope)	6 (upslope) 3 (down slope)	6 (upslope) 3 (down slope)	6 (upslope) 3 (down slope)

Appendix 3. Monthly water balance determine the wastewater application area required (irrigation systems) – Red earths and earthy sands

Design wastewater flow	Q	L/day	725	145	L/person/day	5	persons
Design percolation rate	R	mm/wk	0	0	mm/day		
Land area	L	m2	308				
Effective precipitation	EP		0.9	(10% runoff)			

Parameter	Symbol	Formula	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	total
days in month	D		days	31	28	31	30	31	30	31	31	30	31	30	31	365
Precipitation	P		mm/month	61	54	48	45	48	49	45	45	43	49	51	50	587
Evaporation	E		mm/month	216	157	137	94	51	41	38	51	81	114	152	203	1335
Crop factor	C		-	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	10.8
Inputs																
Effective Precipitation	EP		mm/month	54.81	48.24	43.29	40.23	42.93	43.83	40.32	40.5	38.97	44.01	45.63	45.09	528
Effluent irrigation	W	QXD/L	mm/month	73.0	65.9	73.0	70.6	73.0	70.6	73.0	73.0	70.6	73.0	70.6	73.0	859
Inputs		P+W	mm/month	127.8	114.1	116.3	110.8	115.9	114.4	113.3	113.5	109.6	117.0	116.2	118.1	1387
Outputs																
Evaportranspiration	ET	ExC	mm/month	194.4	141.3	123.3	84.6	45.9	36.9	34.2	45.9	72.9	102.6	136.8	182.7	1202
Percolation	B	R/7xD	mm/month	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Outputs		ET+B	mm/month	194.4	141.3	123.3	84.6	45.9	36.9	34.2	45.9	72.9	102.6	136.8	182.7	1202
Storage	S	(EP+W)-(ET+B)	mm/month	-66.6	-27.2	-7.0	26.2	70.0	77.5	79.1	67.6	36.7	14.4	-20.6	-64.6	
Cumulative storage	M		mm	0.0	0.0	0.0	26.2	96.2	173.8	252.9	320.5	357.1	371.5	351.0	286.3	
Storage	V	largest M	mm	371.5												
		Soil storage	mm	372.0												
		Storage required	mm	-0.5												
		VxL/1000	m^3	-0.1												
Irrigation area			m^2	308												

	water holding capacity	depth (mm)	Totals(mm)
Topsoil	34%	200	68
Subsoil	38%	800	304
			372

Appendix 4. Estimation area requirement from organic matter and nutrient balances (irrigation systems) – Red earths

Estimated effluent flow	(Q)	725	L/day
Soil depth		1	m

Organic matter balance

BOD (C)	20	mg/L
treated wastewater flow rate (Q)	725	L/day
critical loading rate of BOD (Lx)	3000	mg/m²/day
land area required (A)	**4.8**	m²

Nitrogen balance

nutrient concentration	37	mg/L
treated wastewater flow rate	725	L/day
critical loading rate of nutrient	50	mg/m²/day
land area required (A)	**537**	m²

Determination of nitrogen critical loading rate

Nitrogen load (kg/year)	9.8	kg/year			
Loss 20% denitrification	7.8	kg/year			
Load to soil	146.0	kg/ha/year	assumed irr. area	537	m2
Vegetation usage	200.0	kg/ha/year	from table		
Residual (potential leaching)	-54.0	kg/ha/year			

Typical nitrogen uptake (Myers et al. 1984)

Pastures	300 kg/ha/year	82 mg/m2/day
Pine	350 kg/ha/year	96 mg/m2/day
Eucalypts	180 kg/ha/year	49 mg/m2/day

Phosphorus balance

Phosphorus sorption capacity per metre=		9,000	kg/ha	
Phosphorus sorption capacity of profile=		9,000	kg/ha	
Soil factor		0.33		
Critical loading=		3 mg/m²/day		
P concentration*=		12	mg/L	
P adsorbed=	phosphorus sorption capacity x soil factor			
	2970			
	0.297	kg/m²		
Puptake=	critical loading x days/year x	50	years	
	54750			
	0.0548	kg/m²		
Pgenerated=	total phosphorus concentration x wastewater volume in		50	years
	1.59E+08			
	159	kg		
	Pgenerated / (Padsorbed + Puptake)			
Land area required	**451.4**	m²		

Phosphorus sorption

High- 14,400 (900 mg/kg)
Medium- 9,600 (600 mg/kg)
Low- 4,800 (300 mg/kg)

Appendix 5. Estimation area requirement from organic matter and nutrient balances (irrigation systems) – Earthy sands

Estimated effluent flow	(Q)	725	L/day
Soil depth		1	m

Organic matter balance

BOD (C)	20	mg/L
treated wastewater flow rate (Q)	725	L/day
critical loading rate of BOD (Lx)	3000	mg/m²/day
land area required (A)	**4.8**	m²

Nitrogen balance

nutrient concentration	37	mg/L
treated wastewater flow rate	725	L/day
critical loading rate of nutrient	50	mg/m²/day
land area required (A)	**537**	m²

Determination of nitrogen critical loading rate

Nitrogen load (kg/year)	9.8	kg/year			
Loss 20% denitrification	7.8	kg/year			
Load to soil	146.0	kg/ha/year	assumed irr. area	537	m2
Vegetation usage	200.0	kg/ha/year	from table		
Residual (potential leaching)	-54.0	kg/ha/year			

Typical nitrogen uptake (Myers et al. 1984)

Pastures	300 kg/ha/year	82 mg/m2/day
Pine	350 kg/ha/year	96 mg/m2/day
Eucalypts	180 kg/ha/year	49 mg/m2/day

Phosphorus balance

Phosphorus sorption capacity per metre=		5,000	kg/ha
Phosphorus sorption capacity of profile=		5,000	kg/ha
Soil factor		0.33	
Critical loading=		3 mg/m²/day	
P concentration*=		12	mg/L
P adsorbed=	phosphorus sorption capacity x soil factor		
	1650		
	0.165	kg/m²	
Puptake=	critical loading x days/year x	50	years
	54750		
	0.0548	kg/m²	
Pgenerated=	total phosphorus concentration x wastewater volume in	50	years
	1.59E+08		
	159	kg	
	Pgenerated / (Padsorbed + Puptake)		
Land area required	**722.5**	**m²**	

Phosphorus sorption

High- 14,400 (900 mg/kg)
Medium- 9,600 (600 mg/kg)
Low- 4,800 (300 mg/kg)

Appendix 6. Buffer distances for bores

The recommended buffer distance for on-site effluent management systems to groundwater wells is 250m. Three domestic bores are located at less than 250m from potential recommended application areas. The bores may potentially be located down-slope of recommended application areas. The size of the buffer distance from the bores can be reduced by determining the separation distance required between the bores and an on-site application system.

The separation distance is the distance required between a bore and a land application system to prevent contamination of the bore with effluent that may enter the bore. The separation distance is determined from the radius of influence of a bore plus the setback distance.

The radius of influence of a bore can be calculated from the aquifer and bore hydraulic characteristics as an application of the viral die-off method of Cromer *et al.* (2004). The viral die-off method estimates the time required for viruses in the contaminated water to be inactivated (reduced to acceptable number by natural mortality processes) as they move down gradient in the groundwater. The distance travelled during the travel time is the setback distance. Darcy's law is used to estimate the travel time.

The model for estimating the setback distance is:

$$dg = (t - dv.P/K) / (P/K.\ i)$$

where:
d_g = setback distance (m)
t = time (days)
d_v = vertical distance to watertable (m)
P = porosity of fraction (decimal)
K = hydraulic conductivity (m/day)
i = groundwater gradient (fraction)

The model for estimating the radius of influence of a water bore is:

$r = 1.5[(KHt/S)^{0.5}]$ *which is reasonably valid for* $t = Kt/SH \geq 1$

where:
r= radius of influence
K= aquifer permeability (m/day)
H= initial thickness of the water (m) in the fully-penetrating bore
t= time of pumping (t, days)
S= specific yield (S fraction, dimensionless)

A land application system should not be located within the maximum radius of influence of a bore. Additionally, the appropriate separation distance is the radius of influence of the bore plus the setback distance for viral die-off when application systems are located up gradient of the bore. Application systems will potentially be located up gradient of the bore, therefore the radius of influence and setback distance is a sufficient buffer distance.

No impact from the application of effluent is expected on the domestic bores. Bores surrounding the site are confined aquifers.

An assessment of potential impacts on non-confined aquifers was undertaken by modelling. The viral die-off method of Cromer *et al.* (2004) was used to calculate the radius of influence and subsequently the minimum separation distance required to the well.

Viral die off time was estimated to be a reduction in order of magnitude of 7 at a groundwater temperature of 15˚C equivalent to 50 days. This is expected to be a conservative estimate in viral die-off.

Mt Olivetta

The model parameters for estimating the setback distance of the water bore on *Mt Olivetta* was;

t = time (days) = 50
d_v = vertical distance to watertable (m) = 50.8
P = porosity of fraction (decimal) = 0.1
K = hydraulic conductivity (m/day) = 0.12
i = groundwater gradient (fraction) = 0.01

The setback distance was subsequently calculated to be 0.1 metres.

The model parameters for estimating the radius of influence of the water bore was:

K= aquifer permeability (m/day) = 1
H= initial thickness of the water (m) in the fully-penetrating bore= distance to WBZ – SWL = 15
t= time of pumping (t, days) = 31
S= specific yield (S fraction, dimensionless) = 2

The radius of influence was subsequently calculated to be 22.9 metres.

A buffer distance of 23 metres is therefore required around the southern bore.

Peachville Park

The model parameters for estimating the setback distance of the water bore on *Peachville Park* was;

t = time (days) = 50
d_v = vertical distance to watertable (m) = 29.2
P = porosity of fraction (decimal) = 0.1
K = hydraulic conductivity (m/day) = 0.12
i = groundwater gradient (fraction) = 0.01

The setback distance was subsequently calculated to be 0.3 metres.

The model parameters for estimating the radius of influence of the water bore was:

K= aquifer permeability (m/day) = 1
H= initial thickness of the water (m) in the fully-penetrating bore= distance to WBZ – SWL = 16.8
t= time of pumping (t, days) = 5

S= specific yield (S fraction, dimensionless) = 0.25

The radius of influence was subsequently calculated to be 27.5 metres.

A buffer distance of 28 metres is therefore required around the southern bore.

Peachville Park West
The model parameters for estimating the setback distance of the water bore on *Peachville Park West* was;

t = time (days) = 50
d_v = vertical distance to watertable (m) = 46.6
P = porosity of fraction (decimal) = 0.1
K = hydraulic conductivity (m/day) = 0.12
i = groundwater gradient (fraction) = 0.01

The setback distance was subsequently calculated to be 0.1 metres.

The model parameters for estimating the radius of influence of the water bore was:

K= aquifer permeability (m/day) = 1
H= initial thickness of the water (m) in the fully-penetrating bore= distance to WBZ – SWL = 5.2
t= time of pumping (t, days) = 10
S= specific yield (S fraction, dimensionless) = 1.5

The radius of influence was subsequently calculated to be 8.8 metres.

A buffer distance of 9 metres is therefore required around the southern bore.

Appendix 7. Checklist for effective management of wastewater systems

Domestic wastewater system

DO

- Check household products for suitability of use with a septic tank.
- Conserve water, prolonged period of high water use can lead to application area failure. For optimum operation, avoid daily and weekly surges in water flows. Spas are not recommended.
- Scrape cooking dishes and plates prior to washing to reduce solid load.
- Maintain the system with regular servicing as per the manufacturers instructions.

DON'T

- Dispose excessive solid material, fats, lint or large water volumes into drains.

Land application area

DO

- Construct and maintain diversion drains around the top-side of the application area to divert surface water.
- The application area should be a grassed area, which is maintained at 10-30cm height.
- The area around the perimeter can be planted with small shrubs to aid transpiration of the wastewater.
- Ensure run-off from the roof or driveway are directed away from the application area.
- Periodic application of gypsum may be necessary to maintain the absorptive capacity of the soil.

DON'T

- Don't erect any structures or paths on the land application area.
- Don't graze animals on the land application area.
- Don't drive over the land application area.
- Don't plant large trees that shade the land application area thereby reducing transpiration of water.
- Don't let children or pets play on the land application area.
- Don't extract untreated groundwater for potable use.