

GEOTECHNICAL CHALLENGES FOR ON-SITE WASTEWATER MANAGEMENT IN THE HUNTER REGION

J H Whitehead^{1,2} and P M Geary¹

¹*University of Newcastle, Callaghan, NSW 2308*

²*Whitehead & Associates Environmental Consultants Pty. Ltd., Cardiff Heights, NSW 2285*

ABSTRACT

A large number and growing proportion of both single lot residential and larger scale new developments in the Hunter Region are not serviced by a conventional reticulated sewerage system. In such cases, wastewater treatment, its possible reuse and final disposal, is on-site, where the effluent is generated.

A range of geotechnical factors including the site geology, geomorphology, soils, availability and performance of geo and geosynthetic materials, along with climatic factors, have a bearing on the selection, design, sizing and performance of an on-site wastewater system which will perform adequately and meet regulatory requirements. Geotechnical skills in site and soil assessment are fundamental to and necessary for good on-site wastewater system design and to ensure that the environmental impacts associated with on-site wastewater management are minimised.

The Hunter Region displays a number of challenging geological settings and soil types for wastewater management. These include perched and shallow water tables, sensitive aquifers, floodplains and coastal lake and estuary catchments. Soils include sodic, dispersive and duplex soils and high permeability sandy soils with limited capacities for wastewater assimilation. Hydraulic and nutrient loading capacities of some of the region's soils are limiting and present a challenge to designers.

An understanding of transport and assimilation of nutrients and pathogens through permeable materials is significant in understanding the potential contribution of on-site wastewater management systems to surface and groundwater contamination and the protection of those sensitive receiving bodies by appropriate design.

This paper reviews the geotechnical aspects of on-site wastewater management in the Hunter Region and illustrates, with a number of case studies, both the problems commonly encountered and their possible solutions.

1 INTRODUCTION

1.1 ON-SITE WASTEWATER SERVICING

Outside of the sewered towns, in the smaller villages and rural parts of the Hunter Region, most residential properties and a significant number of other larger scale community and recreational facilities and institutions are serviced by on-site wastewater management systems. These systems both treat the wastewater generated and reuse or dispose of it on the site where the effluent is generated. With continuing development in the region, beyond the reach of the conventional reticulated sewerage system, such on-site systems provide for both an increasing number and growing proportion of developments. Indeed, such systems offer great potential for cost effectively servicing many future developments that will not have access to the sewer. To adequately protect public health and the environment, it is critical that on-site wastewater systems are appropriately selected, designed and sized. Professionals with a range of geotechnical skills are well placed to provide the range of services required for the selection, design and performance monitoring of such on-site wastewater systems (Whitehead & Geary, 1996a).

Traditionally, on-site wastewater servicing has been by primary treatment in a septic tank and subsurface land application of effluent in absorption trenches or transpiration areas. In more recent times secondary treatment by mechanical aerated wastewater treatment systems with surface spray irrigation has provided an alternative. In many cases the performance of these systems has been constrained by site related, geotechnical and climatic factors. A substantial number of existing on-site systems have been found to perform poorly or fail. To address existing problems and satisfactorily plan for future growth, the on-site wastewater industry will increasingly need to rely upon practitioners having higher level scientific and engineering skills. A number of alternative management options, designed to better address the specific challenges presented by many Hunter Region sites, have been developed and these add to the range of options available. Amongst these alternatives are sand filters, mound systems, nutrient removal systems, reed beds and pressurised subsurface irrigation systems.

1.2 THE REGULATORY ENVIRONMENT

Guidance on the design, manufacture and installation of on-site wastewater management systems is provided by the joint Australia-New Zealand Standards AS/NZS1546.1:1998 On-site domestic wastewater treatment units Part 1: Septic tanks (Standards Australia, 1998), AS/NZS1546.2:2001 On-site domestic wastewater treatment units Part 2: Waterless composting toilets (Standards Australia, 2001a), AS/NZS1546.3:2001 On-site domestic wastewater treatment units Part 3: Aerated wastewater treatment systems (Standards Australia, 2001b), and AS/NZS1547:2000 On-site domestic wastewater management (Standards Australia, 2000). AS/NZS1546 outlines the requirements for standard designs of treatment systems and AS/NZS1547:2000 the requirements for a range of land application options, some of which offer an additional element of treatment. AS/NZS1547:2000 outlines relevant terminology and provides guidance on system performance, management of on-site domestic wastewater systems and means of compliance and has 14 technical appendices describing site and soil evaluation, the selection and sizing of land application systems, estimation of design flows and construction of a range of land application system types. Whilst AS/NZS1547:2000 provides detailed coverage of many aspects of on-site wastewater system design and installation, it does not address some key aspects of design, for example, nutrient loads and nutrient assimilation, in detail.

The NSW Environment Health & Protection Guidelines – *On-site Sewage Management for Single Households* (the “Silver Book”) (NSW Department of Local Government, 1998) presents the current State regulatory guideline. This document is primarily a management document, with less emphasis on the technical design elements of on-site wastewater systems. With recent developments in the on-site wastewater industry, best practice has moved beyond some of the guidance provided in this document. The document has recently been subject to a technical review and release of a revised version is awaiting the input of the State government agencies involved; Department of Local Government, Department of Environment and Conservation, NSW Health, Department of Infrastructure, Planning and Natural Resources and the Department of Housing. Domestic on-site wastewater systems are regulated by the Local Government Act (1993) with responsibility for approval to install and approval to operate lying with local Councils.

Larger on-site wastewater systems serving up to 2500 EP (equivalent persons) are regulated under the Protection of the Environment Operations Act (1997), again managed by local Councils. Where they discharge to water or service operations which hold other Environment Protection Authority licences, their operation is overseen by the Department of Environment and Conservation. Guidance for the design of such systems is provided in the now rather dated document Design Criteria for Package Wastewater-Treatment Facilities (SPCC, 1978).

1.3 SITE AND SOIL ASSESSMENT

Guidance on appropriate site and soil assessment procedures for on-site wastewater management systems can be found in AS/NZS 1547:2000 (Standards Australia, 2000). Site and soil assessment should involve consideration of a range of site and soil characteristics including: aspect, slope, landform, slope stability, erosion potential, drainage characteristics, soil landscape, soil texture, structure, colour, mottling, moisture and coarse fragments and their bearing on the selection, location and sizing of the on-site wastewater management system.

1.4 WATER AND NUTRIENT BALANCES

The hydraulic load applied to the chosen land application system element of the on-site wastewater management system will depend on the type and size of facility to be served by the system. Quantification and characterisation of the hydraulic load allows it to be matched with the appropriate application rate for the chosen land application system so that the system can be appropriately sized.

Loading rates are determined using soil textural classification and structural properties. Typical loading rates for weakly structured soils for different types of land application system, as defined by AS/NZS 1547:2000 and the NSW Guidelines, are outlined in Table 1 for a range of soil textural classes. Recent work in the USA and New Zealand (Auckland Regional Council, 2004) has suggested that more conservative rates might be appropriate for secondary treated effluent and in irrigation applications in some circumstances.

The hydraulic performance of any land application system should be checked using a water balance. Various water balance approaches are outlined in the Environment Health & Protection Guidelines – *On-site Sewage Management for Single Households* (NSW Department of Local Government, 1998). Rainfall and evaporation data can be obtained for sites in the Hunter Region from the Bureau of Meteorology website www.bom.gov.au. A Datadrill synthetic data set, which can be of assistance should a design be required for a site some distance from a Bureau of Meteorology station, is also available from www.bom.gov.au. Evaporation data is used, along with appropriate crop factors drawn from the horticultural or agricultural literature, to determine the evapotranspiration data for the chosen land application system.

Nutrient balances are important for land application area design, particularly on sandy soils where nutrient uptake by the soil might be limited. Nutrient assimilation requirements might call for greater land application area than the

hydraulic load and thus be limiting for the design. There are various approaches to nutrient balancing and these must consider the capacity of the vegetation and soil in a land application area to sustainably assimilate the nutrient load of the applied effluent. A simple and conservative approach to nutrient balancing is outlined in the Environment Health & Protection Guidelines – *On-site Sewage Management for Single Households* (NSW Department of Local Government, 1998). More sophisticated nutrient balances are possible and can often be used to optimise design, but they call for higher level understanding of a relatively complex field of study.

Table 1: Typical (conservative) loading rates in mm/day for different types of land application system for a range of soil textural classes (after Standards Australia, 2000 and NSW DLG, 1998).

Land application system type	Absorption trenches and beds	Evapotranspiration beds	Mounds	Irrigation
Primary treated effluent				
Sandy loam	N/A	N/A	24	N/A
Loam	10	15	16	N/A
Clay loam	6	8	8	N/A
Medium clay	*	5	*	N/A
Secondary treated effluent				
Sandy loam	N/A	N/A	24	5
Loam	30	30	16	4
Clay loam	20	20	8	3.5
Medium clay	*	10	*	2

N/A Not applicable, * requires special design consideration

There have been significant advances in both the technologies and management of on-site wastewater systems in recent years and a growing understanding of the underlying scientific and engineering principles, partly as a consequence of research undertaken in the Hunter Region (Geary et al., 1996, 2001; Geary, 2004; Stafford, 2001; Whitehead and Geary, 1996a, 1996b, 2000), yet it takes some time for such advances to become incorporated in regulations and guidelines. Nevertheless, the regulatory framework is performance based, and as a result provides scope for innovation based on recent advances, provided a sound and well argued case can be presented to the regulatory agencies. Recently published technical guidelines developed elsewhere (USEPA, 2002; Auckland Regional Council, 2004) provide extensive coverage of such advances. A range of documents published as part of the NSW Government SepticSafe program (www.dlg.nsw.gov.au), a number of which specifically relate to the Hunter Region (Geary, 2003; Geary et al., 2003), provide useful resources for site and soil evaluators and system designers, as do a number of conference proceedings documents (Lanfax Laboratories, 1999, 2001, 2003).

2 EXISTING ON-SITE SYSTEMS IN THE HUNTER REGION

2.1 THE VARIETY OF SYSTEMS

There are approximately 33,000 on-site systems in the Hunter and Central Coast Region. Table 2 provides an indication of the approximate numbers of systems by Local Government Area and system type, where this data is available. In the main, older systems comprise septic tanks and absorption trenches, with absorption trenches replaced by evapotranspiration/absorption beds for a proportion of the systems in those areas where evaporation approaches or exceeds rainfall and where soils are of low hydraulic conductivity. In recent years a substantial number of aerated wastewater treatment systems have been installed with land application of the treated effluent by surface spray irrigation. Climatic and site related constraints limit the effectiveness of these traditional designs in some parts of the Hunter Region and concerns over the performance of some designs has resulted in alternative approaches being adopted. Thus in areas of poor and shallow soils, shallow water tables and sensitive surface water bodies and aquifers, alternatives such as sand filters, mound systems, nutrient removal systems, composting toilets and reed beds are found in small but growing numbers.

2.2 SYSTEM PERFORMANCE

System manufacture, installation, operation and maintenance are factors which have a significant bearing on long-term performance. System performance is also critically dependent on sound site and soil assessment and appropriate consideration of a range of hydraulic, climatic and nutrient factors for correct system selection, location and sizing.

System performance can be dominated by a single factor or by a complex interaction of factors. The design and operation of a system to meet regulatory expectations and adequately protect both public health and the environment is however rarely straightforward.

Table 2: Approximate numbers of on-site wastewater systems in the Hunter Region by Local Government Area and system type.

Local Government Area	Septic tank and absorption trench or transpiration area	Aerated Wastewater Treatment System	Other on-site systems including pumpout and pump to sewer	Total unsewered premises	Other types of system
Cessnock				5000	Composting toilets
Dungog	~1400	~700	~100	2000	
Gloucester				1200	
Gosford				4345	
Great Lakes	1720	700	480	2900	Sand filters
Lake Macquarie				2242	
Maitland	750	850	300	1900	
Muswellbrook				1167	
Newcastle				600	
Port Stephens	~2848	~1074	~884	4574	Mound systems
Scone				1000	
Singleton	~1750	~720	~130	2800	
Wyong	1860	1240	10	3110	
Total				~32838	

Site and soil assessment should be undertaken prior to and to assist with system selection. In the past this has often not been the case. System selection has often been based on what has traditionally been acceptable to homeowners or regulators, the persuasive promotion of those selling the systems and cost, the combination of which has the potential to result in poor choice. Lack of attention to a range of site and soil related topographic and geomorphological factors can result in inappropriate system location, and as a result, poor performance.

An inadequate understanding of the parameters affecting land application system performance and the application of effluent at excessive loading rates has, in many cases, resulted in premature failure of undersized absorption trenches and transpiration beds. Lack of consideration of simple principles of water balance has resulted in under sizing of transpiration beds and failure to adequately recognise the high hydraulic conductivity and transmissivity of sandy soils in coastal regions has resulted in exposure of surface and ground waters to nutrients and pathogens.

On the other hand, careful consideration of the necessary range of site and soil characteristics can result in a robust design which will deliver good long-term performance.

3 SPECIFIC CHALLENGES IN THE HUNTER REGION

A range of specific challenges for on-site wastewater management system designers exist in the Hunter Region and these include:

- Duplex soils
- Sandy soils
- Sodic and dispersive soils
- Shallow water tables
- Coastal lake and estuarine catchments

3.1 DUPLEX SOILS

Duplex soils with thin sandy or sandy loam upper horizons overlying more clay rich and consequently lower hydraulic conductivity lower horizons, characterise much of the Hunter Region. The Rothbury Soil Landscape soils of the Singleton and Branxton areas (Kovac and Lawrie, 1991) provide a typical example.

Absorption trenches for primary treated effluent are traditionally dug at depths of 450 mm. Where the lower portions of such trenches are dug in the lower hydraulic conductivity horizons, the hydraulic performance of the trench, and hence the acceptable effluent loading rate, is significantly less than the surface horizon. With time, an organic biomat or clogging layer (Beal et al., 2004) develops and the hydraulic performance of the trench may be further constrained by the hydraulic conductivity of this clogging layer. Recognition of this reduced long-term performance has resulted in significant increases in trench length requirements in more recently revised regulatory guidelines.

The more clay-rich lower horizons of duplex soils tend to have higher phosphorus sorption capacities and consequently offer potential for sorption of phosphorus from effluent, albeit that the rates of application must be suitably low in recognition of their lower hydraulic conductivity.

3.2 SANDY SOILS

Sandy soils occur widely in the Hunter Region, both on the alluvial floodplains and in the coastal sand dunes and ridges. Such soils typically have high hydraulic conductivity e.g. 1.4-2.8 m/day as reported by Murphy (1995), while Woolley et al. (1995) report that the range of hydraulic conductivity values for the coastal sands north of Newcastle may be as high as 10-20 m/day. This has, in the past, led to their utilisation for effluent disposal with insufficient consideration being given to their capacity to adequately assimilate the nutrient and pathogen loads so as to avoid adverse impact on sensitive surface and ground water bodies.

By contrast with the relatively high phosphorus sorption of clay soils, sandy soils have negligible or very low capacity for phosphorus sorption. Consequently the potential for phosphorus reaching surface and ground water bodies following application in sandy soils is high. This has implications for nutrient loadings on sensitive receiving waters and can be contributory to unwanted algal blooms. On-site wastewater system designs in such soils require high levels of phosphorus reduction. Whilst this can be achieved by chemical dosing, this approach is commonly costly and inconvenient in smaller scale systems. Successful approaches to phosphorus removal have relied on adsorption in specially constructed amended soil transpiration beds or by amendment of the soil in the irrigation area with highly phosphorus sorptive media.

The other significant nutrient load in treated effluent is nitrogen, most commonly in the form of nitrate by the time the effluent is land applied. Nitrates have the capacity to move quickly in subsurface environments and have potential implications for groundwater quality. Some recent studies (Geary and Whitehead, 2001; Cromer, 2001) suggest that in sandy coastal environments, nitrate levels in effluent plumes attenuate quite quickly. However, Geary (2004) in a detailed study completed in Port Stephens, has noted that both nitrate and orthophosphate were not substantially lost or diluted in shallow groundwaters downgradient from a soil absorption system. The presence of riparian vegetation was shown to be particularly important in limiting the subsurface transport of inorganic nutrients and not attenuation or dilution processes in this sandy coastal location.

3.3 SODIC AND DISPERSIVE SOILS

Sodic and dispersive soils are found widely in the Hunter Region (Charman and Murphy, 2000). Such soils can be significantly affected by application of effluent loads, particularly where the effluent is highly saline (Patterson, 2001). The effect of dispersion of clays in such soils is to cause colloidal particles to be washed down the soil profile causing significant and sometimes rapid reduction in hydraulic conductivity. This results in accelerated clogging of soils in absorption trenches and beds and consequent premature failure. This problem can be addressed by minimising the sodium load in the wastewater by avoidance of, in particular, household cleaning agents rich in sodium. Guidance on the selection of both low phosphorus and low sodium washing products is provided by Patterson (1999). Dispersion in soils might also be addressed by the application of gypsum or lime (Patterson, 2001).

3.4 SHALLOW WATER TABLES

Shallow and perched water tables are found in the Hunter Region, particularly in some alluvial floodplains and coastal lake and estuarine catchments. There is evidence that in some parts of the Hunter Region, shallow groundwater is susceptible to impacts from effluent from on-site wastewater management systems (Whitehead et al., 2001). It is generally considered that in the order of one metre of freely draining soil is required below the point of application of treated effluent, to ensure further in-ground treatment and effectively protect groundwater. Where the water table is less

than one metre below the point of application of treated wastewater, it is generally necessary to increase the separation distance between this point of application and the water table. One particularly effective means by which this separation is achieved is by construction of raised sand beds or mounds (Converse and Tyler, 1987). This approach has been successfully adopted at a number of sites in Port Stephens which exhibit particularly shallow water tables.

3.5 COASTAL LAKE AND ESTUARINE CATCHMENTS

A significant part of the Hunter Region is characterised by coastal lake and estuarine catchments. Coastal waters are of particular significance for recreation and shellfish cultivation. Concern over the sensitivity of the shellfish industry to contamination was raised by the *Hepatitis A* contamination of Wallis Lake oysters in the mid-1990s. Failing on-site wastewater systems are considered a potential source of contamination of coastal lake and estuarine waters and considerable recent research effort has been focused on investigating the contribution of human effluent from failing on-site wastewater systems to the overall contaminant load in such water bodies in the Hunter Region (Geary, 2004). The sensitivity of such environments and the potential cost to the shellfish industry has resulted in the development of a number of tracking techniques applicable to human effluent.

4 CASE STUDIES ADDRESSING SPECIFIC HUNTER REGION ISSUES

4.1 ALTERNATIVE SECONDARY TREATMENT AND SUBSURFACE IRRIGATION AS A MEANS OF ADDRESSING THE LOW LOADING RATES FOR CLAY-RICH LOWER HORIZONS OF DUPLEX SOILS

Table 1 indicates that absorption trenches are not considered suitable for land application of effluent in medium clays. Even for clay loams the acceptable loading rates for primary treated (septic tank) effluent are only 6 mm/day over the basal area of the trench. A loading rate of 6 mm/day equates to 6 Litres per square metre of basal area per day so for a trench of 300 mm width that represents 6 Litres per 3.33 lineal metres of trench, for a trench of 450 mm width 2.22 lineal metres and a trench of 600 mm width 1.67 lineal metres. For a typical household generating a wastewater load of 1000 Litres/day the required trench lengths in a clay loam would therefore be 555 metres, 370 metres or 278 metres, for trench widths of 300 mm, 450 mm and 600 mm respectively. Clearly such trenches would be costly to install, might be too long to fit in the available space on site and would be difficult to load evenly, even if divided into a number of shorter trench lengths to make up the required total length. Where soils at the trench base depth (typically 450 mm) are more clay-rich, effective loading rates would be even lower, so much so that in medium to heavy clay soils trenches are not recommended.

There are many duplex soils in the Hunter Region with thin upper horizons of higher hydraulic conductivity underlain at relatively shallow depths by medium or heavy clays which are of very low hydraulic conductivity. These clays are not receptive to primary treated effluent.

In such cases, to design a land application system of manageable proportions and at reasonable cost it is generally necessary to treat the wastewater to a secondary standard so that it can be applied to the more receptive, higher hydraulic conductivity upper horizon of the duplex soil. Thus, for example, primary treated effluent which could not be land applied via trenches to a medium clay might be secondary treated and land applied by shallow subsurface irrigation (surface irrigation if disinfected) in a loam topsoil at 4 Litres per square metre per day. This lower rate is in recognition of the fact that the effluent is taken up by evapotranspiration rather than absorption. Such alternative secondary treatment can be achieved by use of an aerated wastewater treatment system or, as a passive or lower energy alternative, by a sand filter.

A preliminary site and soil investigation undertaken for a single lot residential site with very low hydraulic conductivity (0.024 m/day) clay soil in Martinsville, NSW, suggested that a total trench length of very close to 2 kilometres would be required to land apply the likely 600 Litres/day primary treated effluent load (Geary et al., 2001). As an alternative, a passive, siphon dosed, single pass sand filter was constructed, with land application again siphon dosed to a shallow subsurface irrigation area of some 150 square metres. Details of the sand filter and a photographic record of construction are provided in the SepticSafe report (Geary et al., 2003).

The opportunity to land apply secondary treated effluent by irrigation has proved popular in the rural residential areas of the Hunter Region where some 5,000 or more aerated wastewater treatment systems have been installed. Although the acceptable loading rates, as defined by the regulatory guidelines, have made the installation of aerated wastewater treatment systems possible, and the strong reuse potential sales pitch for irrigation systems has made them popular, they have not been without problems. Design limitations of some systems, less than satisfactory maintenance and problems with disinfection, have called into question the suitability of such mechanical systems. Quite often, too, although the sites have nominally been large enough to accommodate land application areas as defined by the regulations, the length

of irrigation lines supplied has been insufficient to ensure appropriate even coverage over the required land application area. It might also be the case that the hydraulic load is not limiting, but that the nutrient assimilation capacity of the soil and vegetation results in a larger area requirement for the nutrient content of the same hydraulic load. In such cases it is necessary to complete a nutrient balance for both phosphorus and nitrogen to determine the limiting component of the wastewater and thus the minimum sustainable irrigation area requirement.

4.2 MOUNDS AS ALTERNATIVES FOR SHALLOW WATER TABLE SITES WITH SENSITIVE SURFACE OR SUBSURFACE RECEIVING WATERS

In some parts of the Hunter Region, particularly the coastal areas such as the Tilligerry area of Port Stephens, the seasonal high water table is at depths barely beneath the ground surface and commonly at less than 1 metre below the surface. In such cases, there is insufficient freely draining soil between the point of land application, for absorption trenches or transpiration beds, and the water table. Elsewhere, sites are in close proximity to sensitive surface waters in creeks, coastal lakes and estuaries. In such cases, it is possible for insufficient further treatment to take place in the soil once the effluent is land applied and as a consequence the receiving waters might be at risk of contamination from nutrient or pathogen loads. These contaminants might put at risk the receiving water quality and be contributory to algal blooms, impacts on shellfish (particularly in oyster leases) and groundwater used for a variety of domestic and sometimes potable purposes.

To achieve both greater separation distance between the point of application and the groundwater and higher levels of treatment, due to passage of the primary treated wastewater through a bed of media filter, a raised Wisconsin mound (Converse and Tyler, 1987) might be used. Mounds have the additional benefit of the “clothes line” effect, enhancing evaporation and transpiration from the raised grass-covered bed; consequently they can be loaded at higher rates than subsurface trenches and beds.

Figure 1 illustrates the main features of a Wisconsin mound. Mound design requires careful selection of media for construction and a clear understanding of the hydraulic properties of the medium. Equally, aspects of mound design relating to loading rates, basal loading rates and mound sizing for construction on sloping ground, require high level expertise.

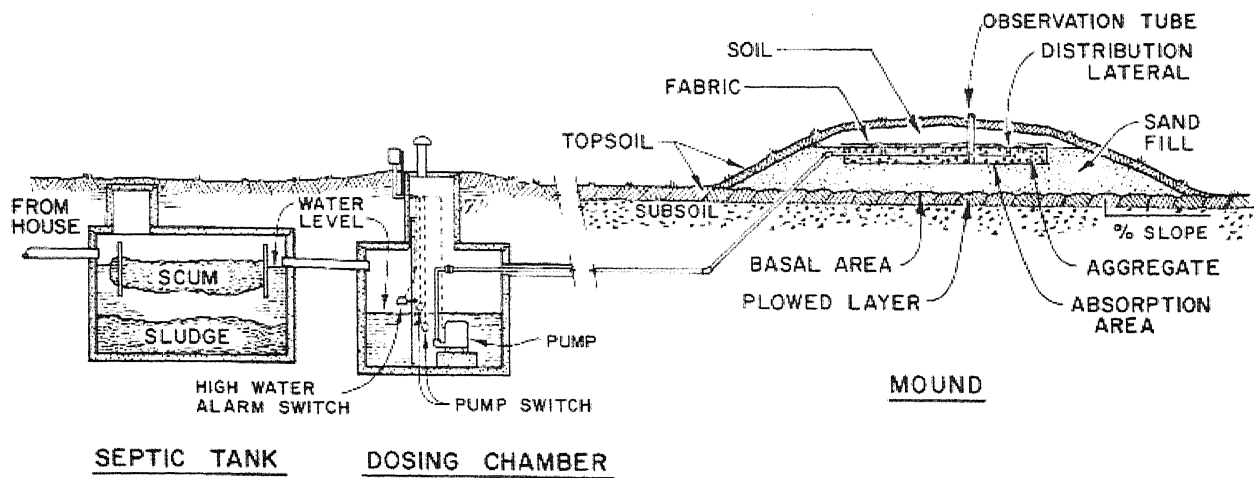


Figure 1: Schematic drawing of a Wisconsin mound system (Converse and Tyler, 1987).

A number of mounds have been constructed in the Hunter Region to address the limitations of shallow water table sites, particularly in Port Stephens, where they have proved effective in cases where other land application systems are not satisfactory. One such system, installed at Marsh Road, Bobs Farm, NSW (Port Stephens Council, 2004) has been monitored for a period of time and, despite some initial problems with construction and overloading, has demonstrated that suitably high levels of treatment can be attained and, in that particular case, that shallow groundwater can be better protected.

4.3 NUTRIENT REMOVAL SYSTEMS

Where the nutrient load of treated effluent has potential to adversely impact on the groundwater or surface water, additional nutrient removal might be necessary prior to land application of the effluent. Nutrients of concern are nitrogen and phosphorus. Typical nutrient loads of primary treated effluent are 50-60 mg/L Total Nitrogen and 10-15

mg/L Total Phosphorus. Secondary treatment in an aerated wastewater treatment system might be expected to reduce the Total Nitrogen to 25-50 mg/L but have little effect on the Total Phosphorus (NSW Department of Local Government, 1998). A single pass intermittent sand filter might be expected to remove some 18-33% of the Total Nitrogen, whilst a recirculating sand filter, with recirculation of the filtered wastewater back to the anaerobic septic tank, might remove 70-80% of the Total Nitrogen. Neither type of sand filter would remove an appreciable proportion of the Total Phosphorus.

Sandy soils, typical of coastal beach ridges and dunes in the Hunter Region, have little capacity to adsorb phosphorus in the way in which many clay rich soils do. Consequently, in sandy soils, it might be necessary to remove phosphorus as part of the treatment process to avoid nutrient impacts on receiving waters. Chemical removal of phosphorus by dosing is generally considered too complex, labour intensive and costly for domestic on-site wastewater systems. An alternative means of phosphorus removal is by adsorption onto a highly phosphorus-sorbing medium, either in the treatment system or land application area. Amendment of the soil in the land application area with either a highly phosphorus-sorbing natural soil or a highly phosphorus-sorbing waste product such as red mud (a waste product of bauxite refining which is available in some other parts of Australia) or blast furnace slag (which is available in NSW) is possible.

Another option is to incorporate the highly phosphorus-sorbing medium into a mound and remove the phosphorus from the effluent by sorption whilst it is passing through the mound. A commercially available mound system incorporating a blend of sand and blast furnace slag (Ecomax) (Bowman, 1997), is available in NSW. Figure 2 shows a schematic drawing of an Ecomax system. This system has proven effective in achieving high levels of effluent treatment with very low levels of residual phosphorus and has ample phosphorus-sorptive capacity for a sustained effective service life of several tens of years. Such a system is installed at Salt Ash School, Port Stephens.

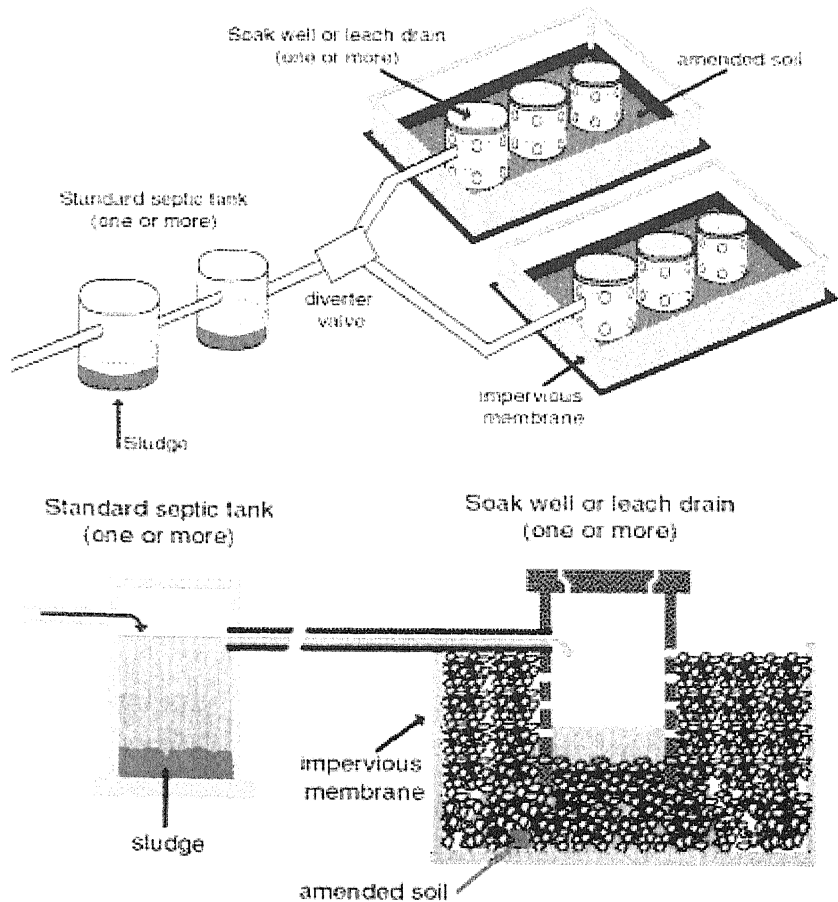


Figure 2: Schematic drawing of an Ecomax nutrient removal system (after Bowman, 1997).

4.4 CONTAMINANT MIGRATION AND ATTENUATION IN SANDY SOILS

A monitoring project at one individual property near Salt Ash was undertaken by Geary (2004) to examine the migration and attenuation of contaminants from a domestic septic system in 2002. The Tomago Sandbeds as previously reported have high hydraulic conductivities and the area is characterised by a rainfall responsive shallow groundwater table. The septic tank effluent absorption field at the property was instrumented with suction lysimeters and piezometers and monitoring undertaken to determine the plume boundaries and the subsurface fate of the effluent, in particular nitrate nitrogen and orthophosphate. A tracer was also added to the wastewater system to determine the direction and rate of effluent movement from the absorption field, into the groundwater and potentially towards an adjacent dish drain. A cross-section of the disposal field with locations and depths of several samplers is shown in Figure 3.

The soil at the site was typical of the freely draining sandy soils found along the Hunter coastline; it was acidic with low electrical conductivity, very low cation exchange capability and also low in total and organic carbon, nitrogen and phosphorus indicating a leached and nutrient deficient soil. The phosphorus sorption of the soil was low (15 mg/kg) suggesting there was little possibility that phosphorus from effluent disposal would be found on site in sub-surface soils. Samples of septic tank effluent were regularly taken in the study and the subsurface plume boundaries identified by pore and groundwater sampling.

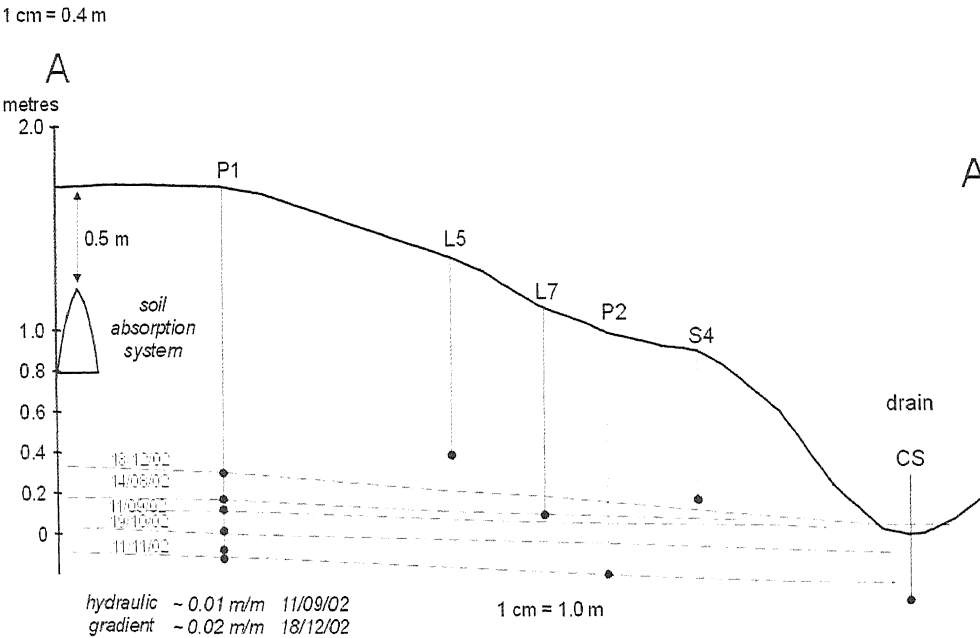


Figure 3: Cross-section of drainfield A-A' (vertical exaggeration 2.5) and groundwater level variations.

The effluent pH entering the soil absorption field (and groundwater) was typically neutral with the dissolved solids relatively consistent around 900 – 950 mg/L. Almost all of the nitrogen present in the tank was ammonium and organic nitrogen (total Kjeldahl nitrogen) with little free oxygen being available. Nitrite and nitrate nitrogen concentrations were negligible. After the effluent was discharged to the infiltrative surface of the absorption system, the ammonium was rapidly oxidized in the vadose zone to nitrate and moved away from the absorption system at a velocity estimated (using the tracer results) at 0.4 m/day. Based on the Darcy equation and the groundwater hydraulic gradient, the saturated hydraulic conductivity of the soil was calculated as 14 m/day, which is typical for a medium to coarse-grained sand. Concentrations of nitrate and orthophosphate at all samplers downgradient from the disposal area were typically high (with the exception of Sampler CS) as shown in Table 3.

Further detailed analysis of the data from these samplers and the other locations within the drainfield suggested that both nitrate and orthophosphate were transported towards the adjacent dish drain and were not significantly attenuated or diluted in transport in the groundwater. To examine the effect of nutrient removal from dilution processes, loss was examined by evaluating ratios of the various nutrient concentrations in relation to conservative ion concentration patterns. While this examination supported the observation that both nitrate and orthophosphate were not lost downgradient from the disposal field, the importance of riparian zones was highlighted by examination of the data collected from the dish drain (Sampler CS, Table 3). At this site in the drain there were still elevated levels of ammonium but nitrate nitrogen and orthophosphate were substantially reduced suggesting that a riparian zone (consisting of a line of large paperbark trees (*Melaleuca quinquernervia*) between Samplers S4 and CS) was responsible for nitrate removal. It was however difficult to assess whether denitrification or simply plant uptake contributed to this observed nitrate loss. A similar analysis demonstrated that orthophosphate (which is highly mobile in sandy soils) was

also not attenuated in groundwater transport from the soil absorption system. It was also substantially reduced possibly by plant uptake after passing through the root zone of the riparian zone.

Table 3: Septic tank (ST) and effluent plume quality at septic tank, samplers L7, S4 and CS.

		pH	EC (uS/cm)	DO (mg/L)	PO ₄ -P (mg/L)	NH ₄ -N (mg/L)	NO ₃ -N (mg/L)	TIN (mg/L)	Na (mg/L)
ST	Mean	7.44	1480	1.20	15.0	108.0	0.20	108.2	108.3
	Std Dev	0.23	131	0.61	1.76	15.7	0.15	15.7	23.9
	N	17	17	8	16	14	10	14	16
L7	Mean	5.20	968	5.17	16.1	30.6	60.4	96.2	86.2
	Std Dev	0.82	255	1.21	3.79	15.2	18.8	24.2	23.9
	N	16	16	6	16	15	16	15	16
S4	Mean	4.79	1130	4.76	17.2	32.1	75.2	108.7	100.0
	Std Dev	1.19	178	0.44	2.62	21.7	25.1	17.9	25.4
	N	25	25	8	25	22	25	22	25
CS	Mean	4.85	432	4.28	3.29	12.2	2.83	15.1	51.9
	Std Dev	0.09	93	0.81	0.61	1.36	1.16	2.0	18.2
	N	8	8	7	8	4	4	4	8

This case study in a sandy soil highlights a common concern in the Hunter Region with respect to on-site wastewater disposal systems where there are shallow groundwater tables. Under these conditions, the potential exists for the subsurface off-site transport of inorganic nutrients (and pathogenic microorganisms) in groundwater. In terms of managing and reducing the risk associated with the environmental and public health impacts of on-site wastewater systems in coastal locations, the presence and maintenance of riparian vegetation is therefore very important in limiting the subsurface transport of contaminants where there are shallow groundwater tables and inadequate vertical and horizontal set-back distances in place. The adoption of an alternative design involving an above ground mound will also substantially reduce the risk associated with on-site wastewater disposal in sandy soils.

5 CONCLUSIONS

A range of issues relating to the effective site and soil assessment for design, sizing, installation and maintenance of on-site wastewater management systems arise in the Hunter Region. Many of these issues can be resolved, in whole or in part, by the application of higher level geotechnical skills.

Effective solutions to the geotechnical challenges posed for on-site wastewater management systems in the Hunter Region have been developed, in many cases by research completed in the region. These are increasingly available to and used by geotechnical professionals and are reported in a substantial body of literature. This paper seeks to make this information more readily accessible and provide designers with the opportunity to offer a range of innovative designs in this increasingly important environmental area.

6 REFERENCES

Auckland Regional Council (2004). *TP58 On-site Wastewater Systems: Design and Management Manual*. Auckland Regional Council Technical Publication TP58, Auckland Regional Council, Auckland, New Zealand.

Beal, C., Gardner, T., Menzies, N.W., Rassam, D. and Vieritz, A. *Prediction of steady-state flux through variably saturated zones within a septic absorption trench*. SuperSoil 2004, 3rd Australian New Zealand Soils Conference, University of Sydney, Australia. 5 – 9 December 2004. The Regional Institute Ltd., Sydney.

Bowman, M. (1997). www.ecomax.com.au/un.html

Charman, P.E.V. and Murphy, B.W. (eds.) (2000). *Soils - Their Properties and Management* (2nd edition). Oxford University Press, South Melbourne.

Converse, J.C. and Tyler, E.J. (1987). *On-Site Wastewater Treatment Using Wisconsin Mounds on Difficult Sites*. Transactions of the ASAE. 1987. American Society of Agricultural Engineers. Vol. 30. No. 2. pp 362-368.

Cromer, W.C. (2001). *Treating Domestic Wastewater in a Shallow Coastal Sand Aquifer near Hobart*. In Patterson, R.A. and Jones, M.J. eds. *On-site '01 Advancing On-site Wastewater Systems*. Lanfax Laboratories, Armidale. September 2001.

Geary, P.M., Whitehead, J.H. and Gardner, E.A. (1996). *Soil Assessment and Domestic Effluent Disposal Systems*. Australian and New Zealand National Soils Conference, Melbourne, July 1996.

- Geary, P.M., Spinks, A., Stafford, D. and Whitehead, J.H. (2001). *The Use of Clinoptilolite as Filter Media in a Low Cost Sand Filter for Treating Domestic Effluent*. In Patterson, R.A. and Jones, M.J. eds. On-site '01 Advancing On-site Wastewater Systems. Lanfax Laboratories, Armidale. September 2001.
- Geary, P.M. and Whitehead, J.H. (2001). *Groundwater Contamination from On-site Domestic Wastewater Management Systems in a Coastal Catchment*, In 9th International Conference on Individual and Small Community Sewage Systems, Proceedings, American Society of Agricultural Engineers, Dallas/Fort Worth, Texas.
- Geary, P.M. (2003). *On-site Treatment System Failure and Shellfish Contamination in Port Stephens, NSW*. Local Council OSM Strategy Enhancement Project, NSW Department of Local Government, SepticSafe Program. NSW Department of Local Government, Nowra, NSW.
- Geary, P.M., Stafford, D.J. and Spinks, A.T. (2003). *Performance Monitoring of a Low Cost Alternative On-site Effluent Treatment System*. Research Grant Project R13, NSW Department of Local Government, SepticSafe Program. NSW Department of Local Government, Nowra, NSW.
- Geary, P.M. (2004). *On-Site System Effluent Tracing in a Coastal Catchment*, 10th National Symposium on Individual and Small Community Sewage Systems Proceedings, American Society of Agricultural Engineers, St. Joseph, Michigan, pp 722-732.
- Kovac, M. and Lawrie, J.W. (1991). *Soil Landscapes of the Singleton 1:250,000 Sheet*. Soil Conservation Service of NSW, Sydney.
- Lanfax Laboratories (1999). Patterson, R.A. ed. On-site '99 Meeting the Challenge. Lanfax Laboratories, Armidale. July 1999.
- Lanfax Laboratories (2001). Patterson R.A. and Jones, M.J. eds. On-site '01 Advancing On-site Wastewater Systems. Lanfax Laboratories, Armidale. September 2001.
- Lanfax Laboratories (2003). Patterson, R.A. and Jones, M.J. eds. On-site '03 Future Directions for On-site Systems: Best Management Practice. Lanfax Laboratories, Armidale. September 2003.
- Murphy, C.L. (1995). *Soil Landscapes of the Port Stephens 1:250,000 Sheet*. Department of Land and Water Conservation, Sydney.
- NSW Department of Local Government (1998). Environment Health & Protection Guidelines – *On-site Sewage Management for Single Households*. NSW Department of Local Government, Nowra, NSW.
- NSW Department of Local Government (1998). <http://www.dlg.nsw.gov.au>
- NSW Government (1993). Local Government Act (1993).
- NSW Government (1997). Protection of the Environment Operations Act (1997).
- Patterson, R.A. (1999). Laundry Products Research. www.lanfaxlabs.com.au
- Patterson, R.A. (2001). *Consideration of soil sodicity when assessing land application of effluent*. SepticSafe Technical Reference Sheet 01/7, NSW Department of Local Government. Nowra, NSW.
- Port Stephens Council (2004). Wisconsin Mound Project, Marsh Road, Bobs Farm, New South Wales. SepticSafe Enhancement Project Grant E031, NSW Department of Local Government, Nowra, NSW.
- SepticSafe website. <http://www.dlg.nsw.gov.au>
- Stafford, D. (2001). *Automatic Dosing Siphon Optimisation and Use: A Non Theoretical Approach*. In Patterson, R.A. and Jones, M.J. eds. On-site '01 Advancing On-site Wastewater Systems. Lanfax Laboratories, Armidale. September 2001.
- Standards Australia (1998). AS/NZS1546.1:1998 On-site domestic wastewater treatment units Part 1: Septic tanks. Standards Australia, Strathfield, NSW.
- Standards Australia (2000). AS/NZS1547:2000 On-site domestic-wastewater management. Standards Australia, Strathfield, NSW.
- Standards Australia (2001a). AS/NZS1546.2:2001 On-site domestic wastewater treatment units Part 2: Waterless composting toilets. Standards Australia, Strathfield, NSW.
- Standards Australia (2001b). AS/NZS1546.3:2001 On-site domestic wastewater treatment units Part 3: Aerated wastewater treatment systems. Standards Australia, Strathfield, NSW.
- State Pollution Control Commission (1978). *Design Criteria for Package Wastewater-Treatment Facilities*. SPCC, Sydney.
- USEPA (2002). *On-site Wastewater Treatment Systems Manual*, Office of Water, USEPA, EPA/625/R-00/008, February 2002.
- Whitehead, J.H. and Geary, P.M. (1996a). *Geoscience and the Design of Effluent Disposal Systems*. 13th Australian Geological Convention, Canberra, February 1996.
- Whitehead, J.H. and Geary, P.M. (1996b). *Geotechnical Aspects of Land Capability Assessment for On-site Wastewater Disposal in the Hunter Region*. 30th Newcastle Symposium - Advances in the Study of the Sydney Basin. University of Newcastle, March 1996.
- Whitehead, J.H. and Geary, P.M. (2000). *Geotechnical Aspects of Domestic On-site Effluent Management Systems*. Australian Journal of Earth Sciences, **47**, pp 75-82.

- Whitehead, J.H., Geary, P.M., and Saunders, M. 2001. *Towards a Better Understanding of Sustainable Lot Density - Evidence from Five Australian Case Studies*. In Patterson, R.A. and Jones, M.J. eds. *On-site '01 Advancing On-site Wastewater Systems*. Lanfax Laboratories, Armidale. September 2001.
- Woolley, D., Mount, T. and Gill, J. (1995). *Tomago Tomaree Stockton Groundwater Technical Review*, NSW Department of Water Resources, Parramatta.