SEPTIC ABSORPTION TRENCHES: ARE THEY SUSTAINABLE?

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Introduction

The most common on-site wastewater treatment system (OWTS) in Australia is the septic tank - soil absorption system (SAS). In this paper, an introduction of some management issues and public perceptions of SAS is followed by a description of the key mechanisms and hydrology of SAS. This paper also discusses the performance of SAS, particularly in terms of the current and future role of SAS in *sustainable* management of domestic wastewater in Australia.

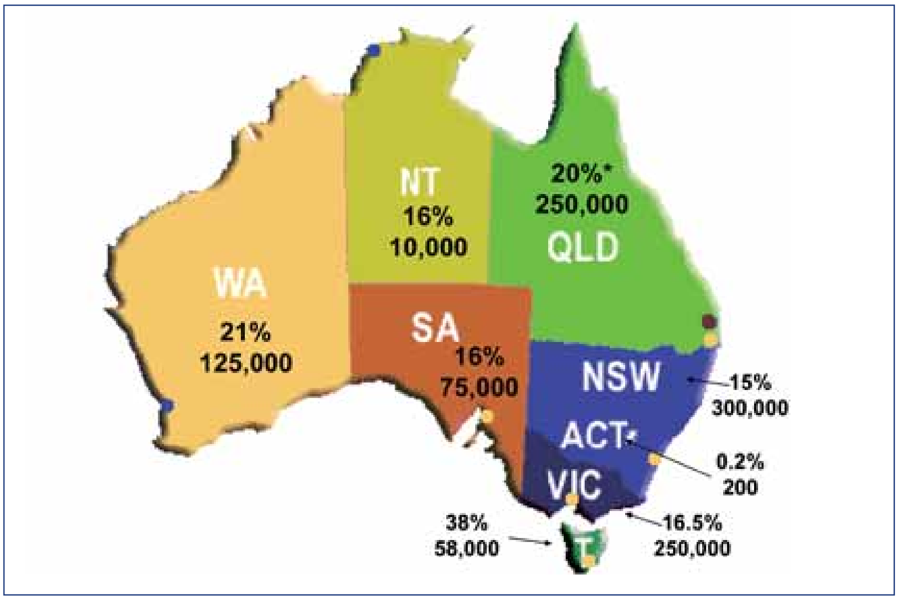

Figure 1. Distribution of on-site wastewater systems in Australia based on figures presented in O'Keefe (2001). Percentages indicate the proportion of non-sewered properties in each state. *Updated Queensland statistics from recent studies by N. Diatloff (pers. comm.) and Beal *et al.* (2003a).

How Many Systems are there in Australia/United States

The distribution of OWTS in Australia in 2001 is presented in Figure 1 based on figures reported by O'Keefe (2001). Over 1 million systems were in operation over Australia in 2001 with the greatest number in NSW (300,000), Victoria (250,000) and Queensland (250,000). The most common (>80%) OWTS in Australia is the septic tank - soil absorption system (SAS). Assuming a daily consumption of 200L per person, at an average of 2.6 person/house, 700ML of effluent may be generated daily. That is around 31,500 kg of nitrogen, 8,400 kg of phosphorus and 70 x 10^{10} faecal coliform organisms: on-site wastewater treatment is a serious water management issue.

In the United States 25% of households (≈ 60 million people) use OWTS (predominantly SAS), with an estimated one-third of new developments to be non-sewered (USEPA, 2002). The percentage of non-sewered sites in the US has not decreased for the last 3 decades, rather they are considered a permanent and viable alternative to reticulated sewerage.

Why are Septic Systems 'On the Nose' in Australia, Yet Accepted in America ?

The USEPA response to Congress on the long-term viability of OWTS draws on the accumulated knowledge gathered from decades of investigation across many states: "Adequately managed decentralized wastewater treatment systems are a cost-effective and long-term option for meeting public health and water quality goals, particularly in less densely populated areas." (USEPA, 1997). Despite this, SAS continue to have a mixed reputation both with the Australian public and local authorities. Unpredictable and variable performance, together with limited scientific investigation, have perpetuated the belief that the SAS is a sub-standard and out-dated means of on-site wastewater treatment. This is somewhat puzzling given that the evidence to support the argument that SAS cause widespread and serious pollution is by no means conclusive.

> *The evidence that septic tank - soil absorption systems cause widespread and serious pollution is by no means conclusive.*

On-site System Regulation in Australia

Regulatory guidelines for OWTS Management is fragmented in Australia, with many states opting to adopt their own OWTS management framework. The relevant Australian Standard is AS/NZS 1547:2000. The publication of it's predecessor, AS1547:1994, signified a positive shift toward improved on-site system management. Prior to AS1547:1994, trench design was loosely based on technical concepts and largely based on local knowledge and 'rule of thumb'. AS15747:1994 was a prescriptive guide to designing not only SAS but also surface irrigation areas for aerated wastewater treatment systems and sand filters. In 2000, a revised Standard, incorporating Standards New Zealand was published. AS/NZS 1547:2000 is a more performance-based approach to the design and management of on-site systems. This has been received with mixed response by the industry.

A Recent Audit of Septic Systems in SEQ

Recently, a review of OWTS management practices in south-east Queensland was carried out by the Qld

Department of Natural Resources and Mines for the Moreton Bay Waterways and Catchments Partnership. Key management issues were notably the frequency of greywater failure and inappropriate greywater discharge. Most early SAS were split greywater/blackwater systems where blackwater, usually less than 20% of the total internal household water use, is dispersed into separate trenches. The majority of SAS (>70%) were installed pre-1994 which preceded the release of Australian Standard AS1547: 1994, so these early systems were not being designed as a function of soil type and effluent volume but rather using a 'rule of thumb'. Failures were reported in poorly designed older trenches, and the newer combined septic systems. Nonetheless, reported SAS failures were low (Figure 2), for example Gold Coast reported up to 200/year - only 2.2% of all their SAS. Despite the low reported failures, there was widespread opinion by local authorities that this was a substantial under-reporting of the real situation.

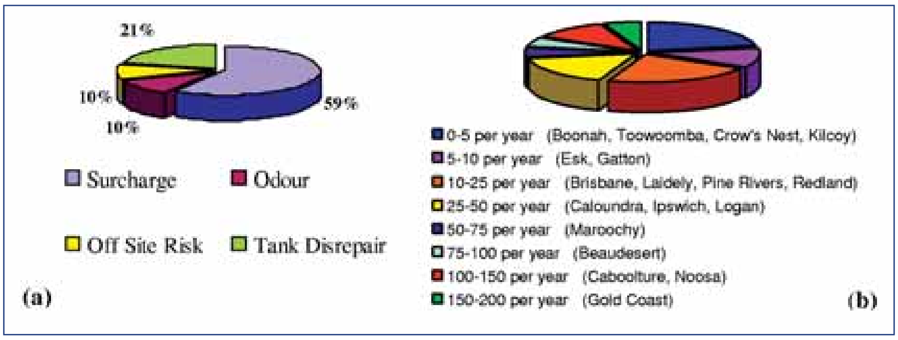

Figure 2. (a) Classification of major septic system failure as identified by SEQ Local Authorities (% = % of responses from Local Authorities); (b) Number of reported failures per year for septic systems (Beal *et al*, 2003a), note: pie slice = % of total septic systems in SEQ.

How Do Soil Absorption Systems Work? It's More Complex than you Think!

Wastewater undergoes primary treatment in the septic tank via sedimentation and anaerobic digestion. Secondary treatment of the septic tank effluent occurs within the trenches and surrounding soil (Figure 3). The mechanisms governing purification and hydraulic performance of SAS have been shown to be highly influenced by a biological zone at the interface of the bottom of the trench and the soil, termed the *biomat* (Figure 3c). The biomat zone is made up of amoebas, rotifers, protozoans, filamentous bacteria and inorganic particulates. The biomat zone is 'fed' by the suspended solids (SS) and organic matter (BOD) in the septic tank effluent and becomes increasingly impermeable to flow as it develops. The flux through the biomat zone is less than the saturated hydraulic conductivity of the underlying soil and therefore creates unsaturated flow conditions in the soil (Figure 4). The secondary treatment process in a SAS, much like sand filters and biological trickling filters, relies on prolonged contact with media in an aerobic environment to treat effluent pollutants (nutrients, SS, BOD and pathogens). In the case of a SAS, this aerobic environment is provided by the unsaturated soil zone created by the hydraulically resistant biomat zone. The relatively long hydraulic retention time in the unsaturated soil provides opportunity for treatment processes such as oxidation, adsorption, die-off, and ion exchange.

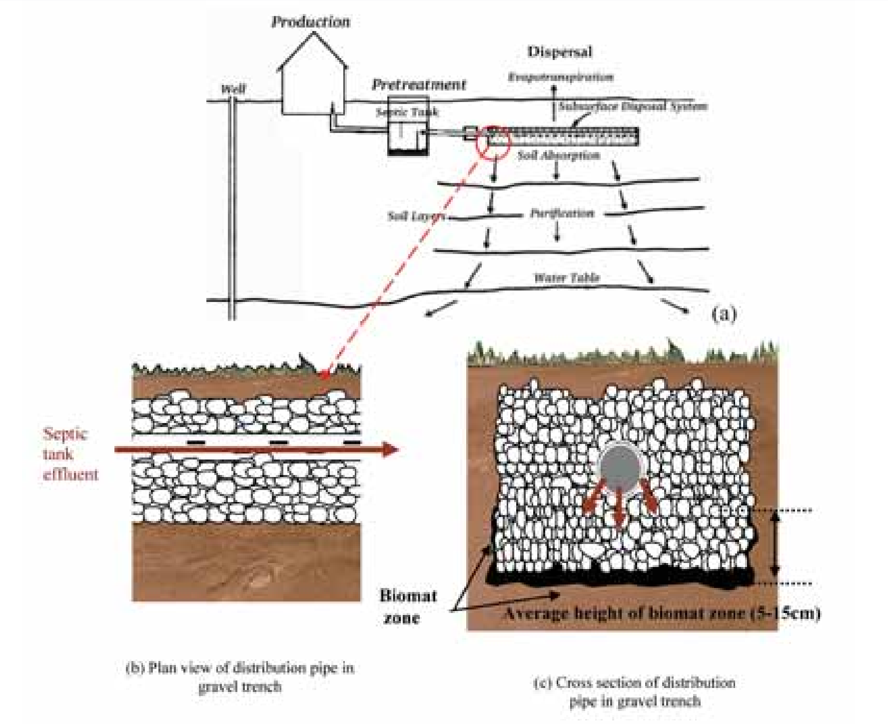

Figure 3. Schematic of layout and main processes (a); plan and cross section view of the trenches in a septic absorption system (b & c).

What is the Role of Soil in the Septic System Process - Do Differences in Soil Type Really Matter?

Although unsaturated flow characteristics vary between soils, studies have indicated that the biomat zone acts to regulate the long term acceptance rate (LTAR) to a narrow range, regardless of soil type (Bouma, 1975). This was also found by Beal *et al.* (2003b) where a four order of magnitude variation in saturated hydraulic conductivities between soils collapsed to a one to two order of magnitude LTAR under the influence of low permeable biomat zone (Figure 5).

Soil hydraulic conductivity characteristics are important for hydraulics in SAS but are they as important for effluent treatment? Several investigators report that soil chemical properties are a key in effluent treatment (Dawes and Goonetilleke, 2003; McCardell and Davison, 2003) suggesting that finer-grained (clay) soils are particularly effective in treatment. However, the efficiency of sand media in the reduction of BOD, SS and pathogens is also well documented (Crites and Tchobanoglous, 1998), despite the relatively low physico-chemical activity of sand. A SAS acts much like a sand filter when unsaturated conditions are present below the biomat zone and there is sufficient depth to groundwater. Soil type may not be as important as the *depth of unsaturated* soil for effective effluent treatment.

What are Main Types of Septic System Failure?

Hydraulic failure occurs if the effluent loading rate into the trench is greater than the infiltration rate through the biomat zone. This will result in ponding of water within the trench and surface surcharging of effluent above the trench (Figure 6). Hydraulic failure can be separated into 'catastrophic' and 'periodic' failure. Catastrophic failure occurs from solids carry-over in the septic tank combined with the natural biomat zone, thus clogging infiltrative surfaces and inhibiting flow into the subsoil. This is usually an irrevocable failure. Episodic failure is a temporary condition where peak loadings into the trench occur from increased water use or prolonged rainfall. In this situation, the water may pond to the surface, however infiltration, particularly through the trench sidewall, will still continue, resulting in eventual draining of water. Sidewall exfiltration above the biomat zone has shown to be a key pathway for excess water in permeable soils (Beal *et al.*, 2004).

Treatment failure relates to insufficient hydraulic retention time within the soil matrix thus precluding adequate treatment of effluent before entering the groundwater. This can occur through a poorly designed SAS, a shallow water table or saturated flow from the trench (poor development of biomat zone).

Treatment Efficiencies - How Much Soil do you Need?

Effluent passage through the biomat zone and the upper unsaturated soil of a SAS significantly reduces BOD and SS. Soil column experiments and field monitoring suggests that, with the exception of nitrate, adequate treatment of effluent can occur within 60cm-200cm of unsaturated soil depth (Gerritse *et al.*, 1995; Cromer, 2001; Van Cuyk *et al.*, 2001). Table 1 provides a snapshot on average removal efficiencies of key pollutants in SAS, whilst Figure 7 shows the distribution of faecal coliforms with depth from SAS in a sandy soil (Whelan and Parker, 1981).

Evidence For and Against Sustainable Performance of Septic Systems...Is There a Smoking Gun?

Surfacing effluent can lead to the export of pathogens into streams, presenting potential health risks, including waterborne-disease outbreaks. Nitrate contamination of groundwaters and nutrient enrichment of receiving surface waters are also potential impacts. Nitrate has been detected at high concentrations in sandy aquifers below non-sewered areas in the United States (Robertson *et al.*, 1991) although evidence of direct surface water contamination from failing SAS is more ambiguous. Nitrogen export from OWTS via groundwater pathways has been predicted to contribute up to 20% (~20 t/yr) of the overall nitrogen catchment load in the Pine Rivers Shire, Queensland (Neumann *et al.*, 2004).

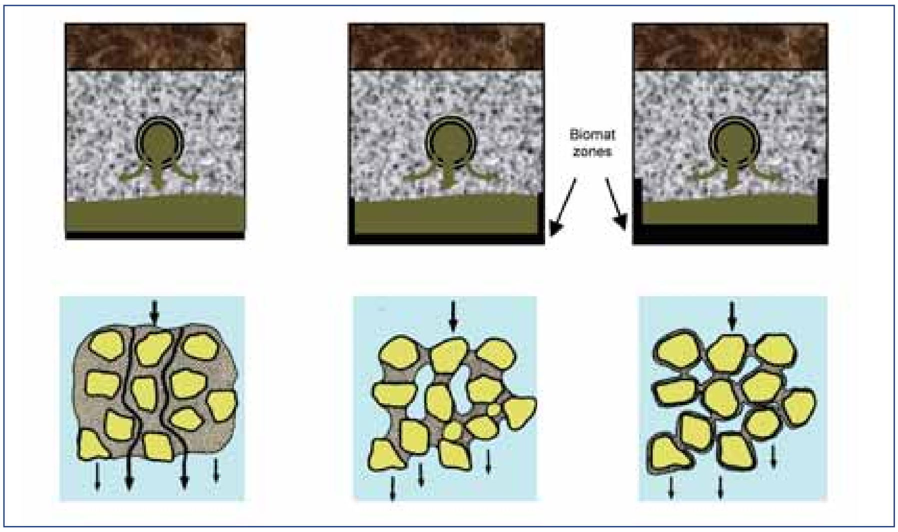

Figure 4. Cross section of trench with increasingly resistance biomat zone (top) resulting in increasingly unsaturated flow (below).

There was a case in 1997 where over 400 people contracted Hepatitis A from eating sewage-contaminated oysters from Wallis Lake (Ryan v Great Lakes Council, 1999). The source of the contamination was not directly from a failing SAS, but reported to be from a caravan site discharging septic tank effluent directly into Wallis Lake. This incident triggered the formation of the Septic Safe programme, co-ordinated by the NSW Department of Local Government, which has funded hundreds of projects aiming to improve research and management of OWTS. To date, a few Australian investigations have demonstrated conclusive evidence of OWTS-sourced pollution, and these have utilised tracers to track the contaminant plume originating from the effluent dispersal zone (Gerritse *et al.*, 1995; Whitehead and Geary, 2000; Geary, 2004).

There is also evidence demonstrating a low impact from SAS. Whitehead and Geary (2000) reported elevated nitrate concentrations but found faecal coliforms to be almost undetectable in groundwater from a non-sewered community in Tasmania. Cromer (2001) found greatly reduced concentration of nitrate and faecal coliforms in a sandy aquifer 10m from a SAS. Gerritse (1995) reported high reductions in nitrate concentration 10m from a SAS and concluded agricultural practices contribute the bulk of nutrients to waterways. There was very little documented evidence of surface and groundwater contamination from on-site systems in the south-east Queensland septic system survey (Beal *et al.* 2003a).

Is it the poorly maintained septic tanks and subsequent solids carry-over into the trench that results in failure, rather than the inability of the soil to treat and percolate the effluent? And is the surprisingly common practice of discharging effluent into streams, gutters and drains (Jelliffe

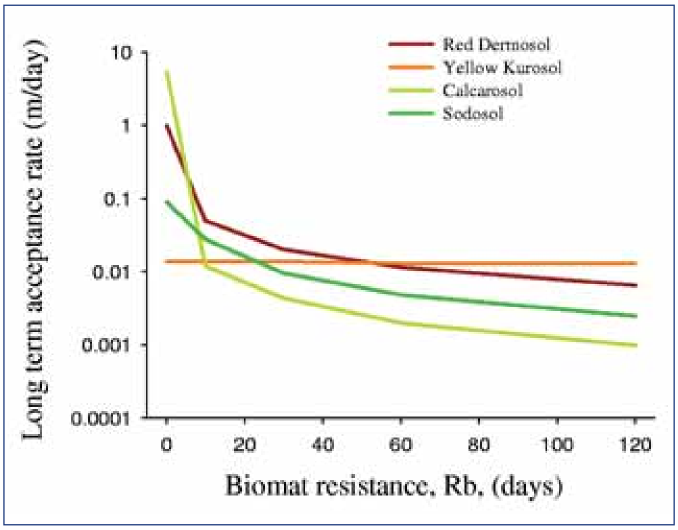

Figure 5. Influence of biomat zone resistance on long term acceptance rate for some Australian soils (Beal *et al.* 2003b).

Figure 6. Examples of surface surcharging of septic tank effluent due to hydraulically failing septic absorption system.

et al., 1995; Beal *et al.*, 2003a) making the greatest contribution to OWTS-related water quality impacts? To date, no 'smoking gun' of poor water quality from non-sewered catchments have been clearly identified. However, absence of evidence is not evidence of absence. There remains a gap between desk top studies/circumstantial evidence and actual field measurement. Further, distinguishing animal from human -sourced pathogens, using methods like faecal sterol markers (Leeming *et al.*, 1996), needs to be incorporated into field measurement. This will help eliminate ambiguity surrounding the nature and extent of impacts from OWTS.

Sustainable Management of Septic Absorption Systems

The density of systems in non-sewered subdivisions can be controlled by Local Authorities through the planning process. A key factor in sustainable OWTS management is providing sufficient lot area for pollution reduction. This means increasing lot size and thus reducing the densities of allotments in non-sewered subdivisions. Therefore a compromise is required between sustainable OWTS densities and economic return for subdivision developers - never an easy balancing act.

Regulations for setback distances from waterbodies, boundaries etc are explicit in state OWTS guidelines, but not the Australian Standard. Beavers and Gardner (1993) developed a model to calculate setback distances based on virus travel times in the groundwater. Jelliffe (1998) suggested that setback distances to contain surface exports should vary with soil type and the target receiving water quality objectives, and proposed a relatively simple biophysical model to calculate sufficient nutrient assimilation area. The answer to sustainable SAS may be very simple: filters and pumps! Installation of septic tank filters prevent solids carry-over to the trench. Pressure dosing effluent into trenches will allow uniform application, which has been repeatedly demonstrated to improve the performance and lifetime of the trenches by creating an even biomat zone and regulating peak flows.

The increasing trend is to address the issue of setback distances and lot densities based on a risk management protocols. For example, research is underway in the Sydney Catchment (Charles *et al.*, 2003) and Queensland (Carroll *et al.*, 2004) to develop risk-based OWTS management models. An allotment-scale Development Assessment Model (DAM) has been developed for the Sydney Catchment Authority (McGuiness and Martens, 2003) to facilitate their decision-making on non-sewered allotment size and location of the on-site system. The Onsite Sewage Risk Assessment System (OSRAS) (Department of Local Government, 2001) is a catchment-scale model that identifies the areas at greatest risk and therefore directing management to these 'hotspot' areas (Figure 8).

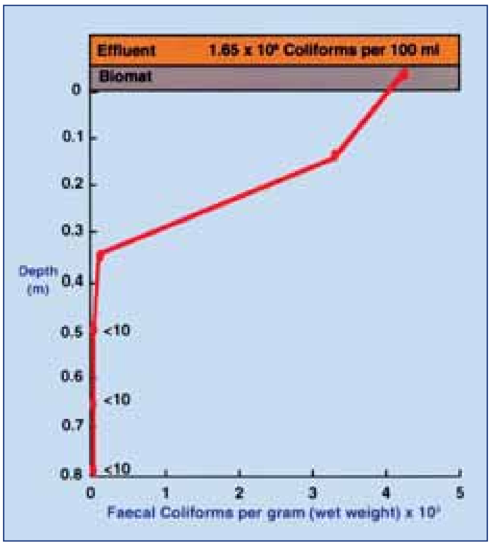

Figure 7. The distribution of faecal coliforms with depth from SAS in a sandy soil based on (adapted from Whelan and Parker, 1981).

Areas of Current and Future Research to Improve Sustainability of Septic Systems

The development of the biomat zone and its interaction with the unsaturated soil in hydraulic and treatment function has yet to be fully recognised. Specifically, lateral flow of effluent and its relationship with biomat zone height and saturated hydraulic conductivity of the A horizon. Modelling SAS using Hydrus-2D can provide significant insight into the hydraulic pathways in SAS and prediction of surcharge events (Beal *et al.*, 2004).

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Table 1. A snapshot on average removal efficiencies of key pollutants in septic absorption systems.

Effluent pollutant	Treatment efficiency	Reference
Pathogens	>99% bacteria and 2-3 log virus reduction in 60-90cm soil	(Van Cuyk *et al.*, 2004)
Nutrients	Almost complete nitrification <20cm soil.	(Gerritse *et al.*, 1995)
	83% P removal in~75cm unsaturated sand	(Pell and Nyberg, 1989)
Organics	91% COD removal in 15cm unsaturated sand	(Pell and Nyberg, 1989)

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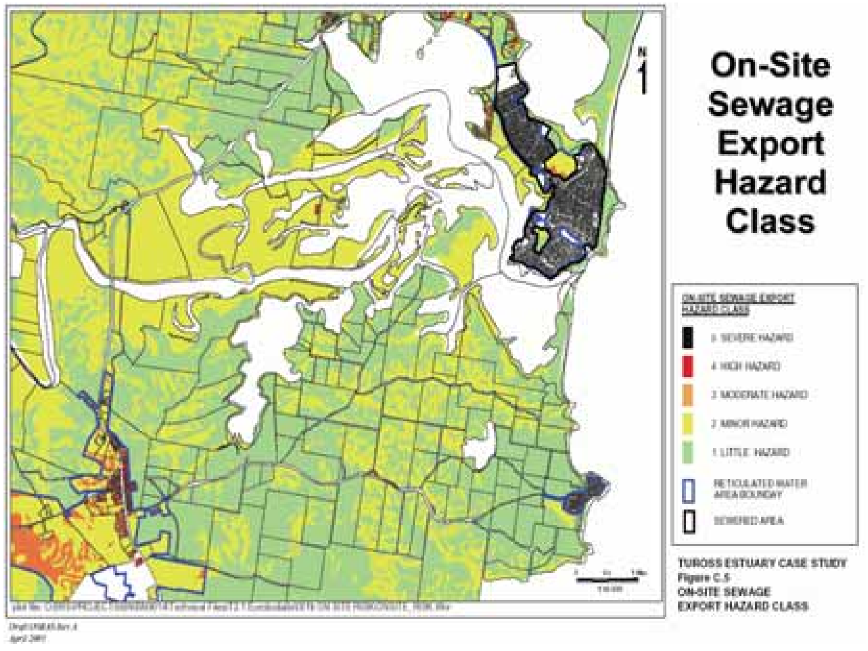

Figure 8. Example of OSRAS graphical output for on-site sewage export hazard class the for Tuross Estuary case study (Department of Local Government, 2001).