AUSTRALIAN ON-SITE WASTEWATER STRATEGIES: A CASE STUDY OF SCOTLAND ISLAND, SYDNEY, Australia

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Abstract

Australian urban centres are primarily situated along wetter and more humid coastal areas, with much of the dry continental parts of the country remaining relatively undeveloped. Approximately 12 % of the population, in excess of 2 million persons, are not serviced by reticulated sewerage facilities and rely solely on on-site management for the treatment and disposal of domestic wastewaters. A relatively prescriptive Australian Standard is currently in place which provides guidance for the design and installation of domestic wastewater management systems. A new joint Australian and New Zealand performance based standard is in the final stages of revision and should provide for improved management of domestic wastewater management systems. A description of this new code is included elsewhere in these proceedings.

A case study of Scotland Island, in Sydney's Pittwater Bay on the lower Hawkesbury River estuary is cited. The unsewered island has a population of approximately 1100 and represents a microcosm of the nation at large. A major environmental study conducted in 1996 indicated that many of the existing conventional septic tank / drainfield installations were failing and causing very high levels of nutrient and bacterial pollution in local streams.

Since the study, wastewater issues have been addressed through more rigorous application of the existing Standard and the anticipated implementation of the new performance based Standard. All new homes and modifications to existing homes (where domestic effluent loads are likely to increase) are now required to meet the Standards criteria. This has resulted in significantly improved wastewater management on the Island and reduced potential public health risks. Whether improved environmental amenity also follows still remains to be seen.

Keywords

on-site, Scotland Island, sewage treatment, soil studies standards,

1 On-site Wastewater Management in Australia

Australia is one of the most urbanised countries in the world. The majority of its population of 18 million resides in large urban areas which have developed over the last 200 years of European settlement along its extensive coastline. As a result, a very large proportion of the population is served by reticulated sewerage systems with ocean disposal of effluent being typical. Approximately 12% of the population, or in excess of 2 million people, relies on on-site wastewater treatment systems for domestic wastewater management. In comparison, approximately 25% of the population of the United States relies on on-site systems, reflecting the much more dispersed population across rural America.

Within New South Wales (NSW) alone, the most populated state, there are approximately 250,000 on-site systems utilising septic tanks. It has been estimated that 130,000 of these dwellings connected to reticulated mains water rely on septic tanks to treat their domestic wastewater while a further 120,000 septic systems rely on rainwater inputs (Patterson, 1993). There will continue to be a reliance on these systems in locations such as in small rural communities, in rural/residential developments and in coastal vacation communities where the cost of sewerage infrastructure remains high.

The conventional domestic system in use in Australia is, as elsewhere, a septic tank, which provides partial treatment of raw waste, and a disposal field, where final treatment and disposal of the liquid discharged from the septic tank takes place. Disposal fields are typically lengths of aggregate filled sub-surface trench, from where effluent is leached to unsaturated soil underneath. A common variation to the trench is a large rectangular transpiration bed (usually unlined) which contains aggregate. Effluent is distributed within the bed and transpired by vegetation grown on the surface and leached to the subsurface through the base of the bed. In a number of places in Australia, the use of such a bed takes advantage of the often dry, hot climate and these systems perform better than trench based systems.

Small aerated wastewater treatment (AWT) systems are becoming increasingly popular in unsewered areas, particularly where difficult site and soil conditions are encountered. These self-contained proprietary biological treatment systems rely on mechanical devices to provide mixing, aeration and pumping of effluent. There are at least 25,000 of these systems in NSW alone, and their number is increasing rapidly due to the typically poor performance of conventional [septic] systems in some areas. Treated effluent from these systems is, following disinfection (typically chlorination), usually land applied using surface irrigation techniques to appropriately landscaped areas.

Apart from effluent removal by tanker, the use of different or alternative on-site systems to those described above is not particularly common in NSW or Australia. There are specific instances of composting toilets being used in combination with reed bed systems for greywaters, and some designs for mounds and sand filters, but such systems have only been installed where there have been particularly difficult situations or where there has been a specific desire by the home-owner to utilise different technologies. While cost is also an inhibiting factor to the adoption of alternative systems, the regulatory requirements for on-site systems have not conceded that systems, other than prescribed standard systems, had a role to play in on-site wastewater management.

The performance of both conventional soil absorption and AWT systems in a number of small unsewered communities in eastern Australia has been reported by Rawlinson (1994) and Martens and Warner (1995), while recent developments in the on-site industry in Australia were reported at a previous conference of the American Society of Agricultural Engineers (Geary, 1994). The results of these surveys clearly indicate that many systems are performing poorly and that failures result from poor public awareness, poor local authority guidance, and the adoption of inadequate design standards, procedures and guidelines.

It is generally recognised that the poor performance of on-site systems is contributing, in part, to on-going water management problems in Australia. Poor system performance is due to the inadequate regulation and management of domestic wastewater systems which have been permitted in many areas. While there has been significant growth in the industry over the last 10 years, including the development of newer plant applications and designs, the fragmented administration and the low profile of the regulators have not been able to manage this growth, let alone manage systems properly which are already in the ground and which are performing poorly.

2 Standards and Compliance Requirements

2.1 Current Standards and Requirements

Within Australia, domestic wastewater disposal in unsewered areas is generally administered by local government authorities, although guidance in terms of policy and the final approval of prescribed systems has typically rested with each State Department of Health (DOH). This is currently the situation in NSW where the non-urban and rural local authorities administer the approval and management of individual on-site systems, while the DOH is responsible for the testing and approval of new systems (treatment only and not disposal systems)..

Design requirements for septic tanks were provided by the N.S.W. Department of Public Health in the 1960's, while in the early 1970's an Australian Standard was developed which dealt with the disposal of effluent from small septic tanks (AS1547, 1973). This Standard was recently revised (AS1547, 1994) and is currently available for use in the design of on-site systems. It represents a substantial improvement on the earlier document. However its prescriptive approach has led to the belief that a scientifically exact approach to septic tank land application field design and implementation is possible. Time and experience have shown this belief to be erroneous and such a prescriptive approach has not achieved sound environmental outcomes. The Standard only briefly refers to the importance of land capability criteria in siting disposal areas, and the characteristics of the soil type such as texture and permeability are not adequately considered in the design of the disposal system. No reference is made in the standard to the use of alternative system designs for problem soils.

As a result of this situation, many local government bodies have developed their own requirements for on-site wastewater disposal systems, in particular, the absorption/transpiration area required for their particular localities. Some local authorities have only recently prepared quite detailed policies on domestic wastewater disposal for unsewered subdivisions and rural residential areas after environmental problems have become apparent. The NSW DOH has also prepared a domestic wastewater disposal policy for proposed subdivisions. However, in the main, many authorities have not adequately addressed the problem of domestic wastewater disposal for unsewered communities in planning or practice.

Although the use of local knowledge is important with respect to soils and system performance, the lack of a standardised procedure has led to many inconsistencies in approaches and system sizing and, consequently, performance. One of the reasons for this general lack of guidance is that there has been very little empirical work dealing with on-site systems in Australia and the particular characteristics of Australian soils. This is currently the case where funding to undertake research in this area is difficult to obtain as land management agencies see this as an urban problem and the water and wastewater service providers dealing mainly with urban sewered areas regard the problem as an agricultural one.

2.2 Joint Australian/New Zealand Standard

Over the last three years an intensive effort has been made to develop a new standard which focuses on the performance of on-site treatment systems and the processes needed to achieve desired outcomes. The new performance based Standard will supersede AS1547 (1994) and incorporate provisions related to the treatment function of septic tanks contained in New Zealand Standard 4610 (1992). The Joint Australian and New Zealand Standard, the subject of recently presented paper (Gunn, 1998) is likely to be published in early 1998.

The objective of the Standard is to provide guidance to all persons and agencies involved with on-site domestic wastewater management in Australia and New Zealand. It will cover matters related to site investigation, land application system design, installation, and operation and maintenance to achieve sustainable outcomes and public health performance. It has been developed by a range of experts from both countries and is more all-embracing offering a holistic approach to the entire on-site management problem rather than just effluent disposal. It is anticipated that many local authorities which are currently finding difficulty in managing all aspects of on-site systems will defer to this document and adopt it as policy. The provision of a uniform approach based on performance related outcomes will attempt to address the many inconsistencies in relation to new systems which are evident at the moment.

3 Scotland Island: An Example of Improving Management

3.1 Background

Sydney, the NSW state capital and Australia's most populated and well known city, still maintains several areas to its north, west and southern boundaries which are presently unsewered and are likely to remain so for the next 10-20 years. Scotland Island, located in the far northern suburbs (Figure 1), is unique in that represents an entire physically isolated Sydney community which remains unconnected to reticulated sewers. The Island measures approximately 950 m in both north-south and east-west dimensions and is located approximately 30 minutes north of the central business district. Approximately 1100 people reside on the Island and some 350 houses have already been built with some 100 vacant lots remaining on the Island. The site represents a unique opportunity to evaluate the implications of current and past management practices against the revised joint Australian / New Zealand Standards within a relatively dense city urban setting.

3.2 Physical Characteristics

Physiographically, Scotland Island is a steep bedrock Island located in Pittwater in the lower estuary of the Hawkesbury-Nepean river. Site conditions for domestic wastewater disposal are generally very poor. Topography is steep, with 85 % of the island being steeper than 1:10 and 30 % being steeper than 1:5 (Figure 1).

Soils are predominantly shallow (< 1 m deep) yellow podzolics developed on predominantly Hawkesbury Sandstone strata. Topsoils are thin (< 50 cm), highly unstructured permeable (K_{sat} > 800 mm/day), sandy loams derived from both *in situ* and colluvial materials. Topsoil offers little retention for applied domestic effluent. Subsoils are generally highly impermeable (K_{sat} < 20 mm/day), medium plasticity, residual clays which offer limited potential for effluent application by way of traditional septic tank drainfields.

Phosphorus sorption capacity is low in the topsoil (163 mg P /kg soil) and moderate in subsoils (237 mg P /kg soil). Soil data are summarised in Table 1.

Vegetation is characterised by predominantly partly disturbed open dry sclerophyll forest (*Eucalyptus spp*. and shrub understorey) with small patches of depauperate closed rainforest found in the steeper gullies of catchments 7 and 8 (Figure 1) on the island's southern side.

Table 1: Summary of Scotland Island soil properties with errors representing standard deviations.

Parameter	Topsoil	Subsoil
Depth (m)	0.46 ± 0.24	0.54 ± 0.24
Texture	LS-SL	SCL-C
K_{sat} (mm/day)	952 ± 608	< 20
pH (1:5 susp.)	4.10 ± 0.24	4.00 ± 0.34
EC (dS/m, 1:5 susp.)	0.05 ± 0.02	0.09 ± 0.05
CEC (cmol(+)/kg)	3.69 ± 1.62	4.77 ± 1.41
Sodicity (ESP%)	6.7 ± 3.4	12.6 ± 5.9
Oxidised N (mg/kg)	3.8 ± 3.0	2.5 ± 0.0
Total N (%)	0.14 ± 0.07	0.07 ± 0.02
Bray-P (mg/kg)	4.3 ± 4.3	3.8 ± 1.8
P-sorption (mg/kg)	163.2 ± 58.5	237.1 ± 13.7

Fifteen small water catchments, ranging in total area between 0.58 - 7.15 ha, drain radially from the elongated central rise (100 m ASL) and flow rapidly to Pittwater. Streams are ephemeral, requiring some 2-5 mm/hour rainfall to generate runoff. Stream catchment areas are complicated by the existing unsealed road network which circumnavigates the island in two primary ring-roads. Where sufficient catchment area provides, short streams develop (catchments 1, 5, 7, 8, 9 and 12) with steep grades and quick response to rainfall.

Some 1225 mm of rainfall falls annually (Table 2), although there is considerable variation in rain intensity between seasons and individual months. Summer months are wetter than winter, though intense high rainfall events can occur at any time of the year in association with off-shore extra-tropical cyclonic activity.

Annual evaporation (Class A Pan) is 1790 mm and exceeds rainfall in all months except May and June.

Depending on the type of crop cover available, there is an excess in water over effluent application areas for 4 to 5 months (March through to July) of the year (Table 2).

3.3 Urban Characteristics

Urban development is generally confined to the lower parts of the Island [below 65 m ASL], and average house block size is small, ranging between 800 - 1000 m^2. Apart from the roads, urban infrastructure is restricted to several parks, including Catherine Park, Patilda Reserve, Harold Reserve, and land above 65 m ASL.

Water supply is generally restricted to on-site rainwater tanks which maintain holding capacities of 30 000 - 40 000 litres. A recent water survey conducted by the island residents indicated that mean daily water consumption is approximately 110 L/person/day. Household occupation is approximately 3.5 EP/household. Recently, an emergency water supply line maintained by the local water authority (Sydney Water) has been provided on a 'user pay' system.

Table 2: Mean monthly rainfall (P), Class A Pan Evaporation (E), Evapotranspiration (ET, crop factor = 0.80), and water balance (ET-P). Shaded cells indicate negative water balance.

Month	Mean P (mm)	E (mm)	ET (mm)	ET-P (mm)
Jan	120	217	173.6	53.6
Feb	125	176	140.8	15.8
Mar	141	164	131.2	-9.8
Apr	116	123	98.4	-17.6
May	110	87	69.6	-40.4
Jun	132	78	62.4	-69.6
Jul	75	84	67.2	-7.8
Aug	84	115	92	8
Sep	66	141	112.8	46.8
Oct	82	177	141.6	59.6
Nov	92	195	156	64
Dec	82	233	186.4	104.4
Total	1225	1790	1432	207

3.4 Existing On-site Wastewater Management

On-site Facilities

A survey of island residents revealed that conventional septic tanks and drainfields accounted for 91 % of domestic wastewater management. Of these systems, 21 % received only black water, while 79 % received both grey and black water wastes. An additional 8 % have AWT systems, with the remaining 1 % comprising of either composting toilets or no on-site wastewater management facility.

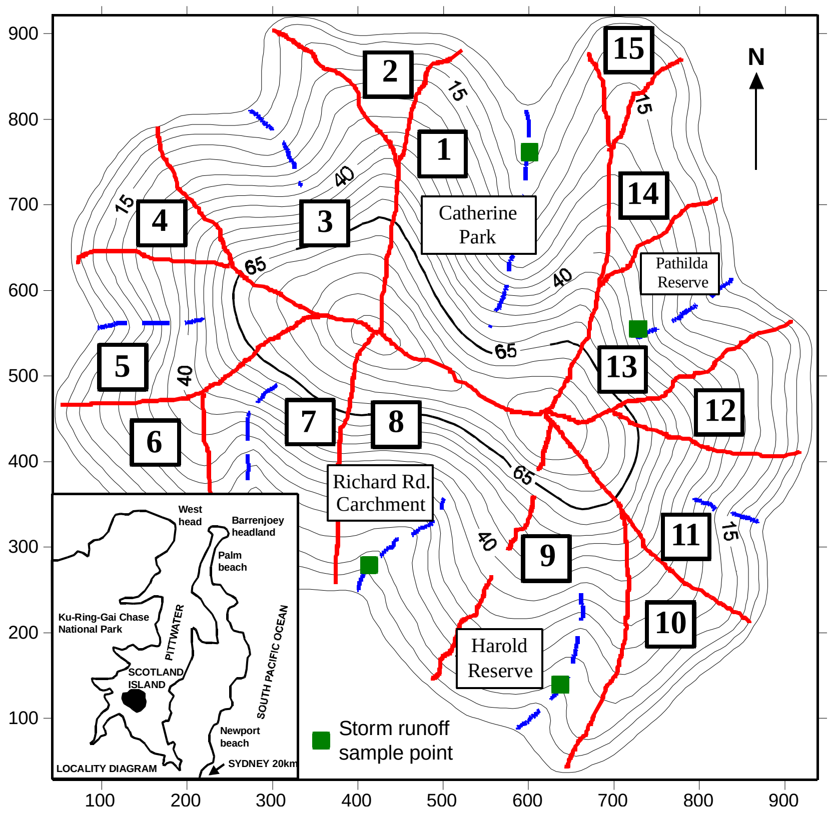

Figure 1: Scotland Island catchments and stream networks including locations of storm event water sampling. Scale is in metres.

The majority of the island utilises soil drainfields for the disposal of domestic wastewater from septic tanks. Generally, these are poorly designed due both to incorrect engineering practice, but also due to the difficulty of providing building materials to the island.

Drainfields are generally very small, maintaining total surface areas of 10 - 30 m^2, although smaller drainfields exist. These are typically excavated well into the impermeable subsoils. As a result, many trenches are hydraulically overloaded and fail. Drainfield failure is evident in many locations as seepage from effluent disposal areas to streets downslope of the disposal area.

Where greywater and blackwater wastes are separated, only two areas are typically used, each approximately 10 m^2 in total surface area.

The ready availability of an additional [emergency] water supply provides residents with access to much larger quantities of water. This has placed further hydraulic stresses on existing drainfields.

Past Management Practices

In the past, the lack of any centralised management system or performance based design standard, has meant that the problems with on-site domestic wastewater management on the island have remained unchecked. Existing wastewater management installations have continued to perform poorly, and the local authority (Pittwater Council) has relied on the experience of plumbers and drainage contractors for the design of drainfields on the Island.
There has been no requirement for a performance based assessment of individual house lots to accommodate domestic wastewaters, either for the purposes of constructing a septic tank drainfield, or to accept treated effluent from an AWT system to a surface irrigation field.

3.5 Environmental Quality

In response to the general concern of both residents and local Council for potential public health risks of domestic wastewater management practices and degraded environmental quality on the island, an environmental study was commissioned during 1996-1997 to determine the impacts of existing practices on public health and environmental amenity. Several monitoring programmes were initiated including: stream water quality (Figure 1); runoff from unsealed roads; on-site system performance; and drainfield performance.

Island surface water quality data were collected from the local streams (Table 3). Five storm events were monitored. In an attempt to accurately describe storm pollutant concentrations, two samples were taken from streams: 15 minutes after rainfall began, and a second sample being taken approximately 1 hour after the first. Samples were collected manually and placed 'on ice' during transit to the laboratory for analysis.

Results indicate that storm generated runoff on the Island is generally contaminated with both nutrients and bacteria, indicative of severe sewage runoff pollution. Nutrient levels are comparable with other unsewered urban areas (Martens, 1996). Bacterial levels are extremely high, exceeding ANZECC (1992) guidelines for surface waters (primary contact < 150 FC CFU/100mL and < 35 Enterococci organisms/100mL) and saltwater estuaries (secondary contact < 1500 FC CFU/100mL and < 230 Enterococci organisms/100mL).

Table 3: Summary of surface water quality monitoring programme data with errors representing standard deviations.

Parameter	Stream Concentration
Nox-N	1.19 ± 0.97
Amm-N	0.08 ± 0.05
TN	3.93 ± 1.56
TP	0.28 ± 0.07
FC	96850 ± 58475
E	91207 ± 51869
SS	4353 ± 3790

Note: Nox-N = Oxidised Nitrogen (mg/L), Amm-N = Ammonia Nitrogen (mg/L), TN = Total Nitrogen (mg/L), TP = Total Phosphorus (mg/L), FC = Faecal Coliforms (colony forming units / 100mL), E = Enterococci (organisms / 100mL), Turbidity (NTU), SS = Suspended Solids (mg/L).

In an effort to determine the performance of existing drainfield disposal systems, ten absorption trench samples were collected during the study from five separate drainfields (Table 4). Results were variable but on the whole indicated very high nutrient and sodium levels, and high sodium absorption ratios (SAR). Total nitrogen was some 300 % higher than that found by Martens (1996) in septic drainfields with similar soil characteristics in the Sydney region. Total phosphorus (TP) levels were extremely high with one site maintaining trench water concentrations of 153 mg/L. These are approximately three orders of magnitude higher than levels previously reported by Martens (1996) and indicates that large amounts of soluble rather than sorbed [to soil] phosphorus are present in the drainfield.

Trench water quality data indicate that drainfields have become saturated with contaminants (nutrients and bacteria). Limited potential now exists for existing trenches to renovate effluent prior to discharge to the local environment. There is, therefore, a general net export of contaminants to the local environment. Based on modelling of phosphorus sorption to soil particles, the expected life period for phosphorus ranges between 2 - 10 years at most sites before phosphorus migrates away from the drainfield.

Table 4: Summary of drainfield water quality data with errors representing standard deviations.

Parameter	Drainfield Concentration
Nox-N	2.2 ± 3.6
Amm-N	91.1 ± 60.9
TN	108.4 ± 64.0
TP	33.5 ± 58.3
K	54.3 ± 26.3
Na	95.0 ± 68.0
Ca	18.6 ± 8.3
Mg	13.2 ± 4.0
SAR	> 20
EC	144 ± 61

Note: Nox-N = Oxidised Nitrogen (mg/L), Amm-N = Ammonia Nitrogen (mg/L), TN = Total Nitrogen (mg/L), TP = Total Phosphorus (mg/L), K = Potassium (mg/L), Na = Sodium (mg/L), Ca = Calcium (mg/L), Mg = Magnesium (mg/L), SAR = Sodium Absorption Ratio, EC = Electrical Conductivity (dS/m)

4 Impacts of Domestic Current Wastewater Management Practices

There have been several impacts associated with the existing domestic wastewater management practices. Environmental amenity has been substantially degraded on the island. Soils are locally saturated with nutrients such as nitrogen and phosphorus, far beyond levels of uptake capable by *Eucalyptus* vegetation. In many parts of the island, tree dieback has occurred in association with locally saturated soils and phosphorus toxicity effects. High soil phosphorus concentration is notably toxic to a number of native Australian flora.

Water quality in the ephemeral streams has been significantly affected by sewage entering from the undersized septic tank drainfields. The mechanism of transport is primarily during heavier rainfall events by sub-surface flow through highly permeable topsoils and over relatively impermeable subsoils. Low contaminant retention capabilities of the topsoils indicates that rapid pollutant transport to waterways is possible. This is aided by the generally hydraulically and chemically overloaded nature of the drainfields.

Rapid transport of relatively untreated domestic wastewater to streams has resulted in bacterial concentrations several orders of magnitude above acceptable limits for primary or secondary contact (ANZECC, 1992).

5 Implementing New Management Practices

In response to the environmental study, the local authority has embraced the existing Standard AS1547 (1994) and shall take on board the new recommendations of the ensuing joint Australian / New Zealand Standard for domestic wastewater management. All building applications, including both those for new houses and modifications to existing facilities, are now required to be evaluated and meet Standards requirements.

What this has meant is a general improvement to many of the existing septic tank drainfields, but ensured significantly improved wastewater management facilities on all new constructions. Drainfields are now sized according to site specific requirements such as soil depth, texture, structure, and drainage. On the whole, drainfields are significantly larger and located to minimise the potential for runoff, rather than on an ad-hoc basis.

To the community, this has meant some additional establishment costs, including [in some cases] site evaluation fees, preparation of on-site wastewater management reports, and increased costs for the improved domestic wastewater management facility. However, on an island wide basis, a reduction in potential risks to public health has resulted due to the enforcement of larger effluent application areas and properly designed soil absorption trenches and surface irrigation fields. The improvements to environmental amenity are yet to be seen.

6 Conclusions

6.1 Implications of Improved Management

The benefits of improved on-site domestic wastewater management are immediately manifested in reduced risks to public health, and in the long-term, reduced environmental impact of the disposal process.

Drawbacks of an improved management philosophy are the added complexities associated with domestic wastewater management, including site evaluation procedures and design and location of the treatment / disposal facility. In a society already overloaded with information, new performance based standards again call for additional data.

6.2 Future directions

There is a clear need to improve on-site system performance in small communities. The development of a new joint Australian/New Zealand Standard will assist in relation to new developments. However, this is long overdue. The design of disposal areas needs to be soundly based on:

a) the results of soil survey (including textural and structural analyses);

b) land capability assessment; and

c) a knowledge of the long-term performance of on-site systems

These are general criteria required to overcome many of the environmental problems currently being experienced from failing systems. Excess nutrients in water bodies from poorly performing on-site systems represent only part of the diffuse water pollution problem being experienced at the moment. The improved performance of new domestic wastewater systems can be achieved by the application of sound, yet basic environmental management principles. Scotland Island is but an example of these areas.

The problem of dealing with the many thousands of installed systems still remains. As local authorities have responsibilities in this area, they need to be more responsible in requiring communities and individuals to improve system performance and be more vigilant than they have been. The attitude of neglect resulting from the view that septic tank systems are an inappropriate technology suited only as a temporary short-term solution until sewers are installed is outdated. Achieving improvements in system performance and revisions to current arrangements for managing on-site systems should be major priorities to assist in water management strategies throughout NSW and Australia, and New Zealand.

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