ON-SITE SYSTEMS AND CATCHMENT MANAGEMENT

P.M. Geary[1], G. Robertson[2] & J.H. Whitehead[3]
[1] The University of Newcastle, NSW, [2] Sorell Council, Tasmania,
[3] Whitehead and Associates Environmental Consultants, NSW.

Abstract

In 1998 a three-stage catchment management and groundwater monitoring program commenced in several small unserviced communities in and around Dodges Ferry, approximately 35 km south east of Hobart, Tasmania. Domestic wastewater disposal in these communities (where lot sizes are typically less than 800 m^2) is on-site where the absorption systems are in sandy soils. Sorell Council commenced the program because of the potential for ground and surface water contamination and the increase in the density of the systems associated with development. The area is along the coastal zone and is commonly used for primary contact recreational activities such as swimming and surfing, particularly in the summer months.

In this paper, part of the catchment management program and project methodology is discussed and the results from the groundwater monitoring program are presented. The initial survey results revealed low levels of bacterial indicators in bore water. However, some high nitrate concentrations were recorded, usually associated with clusters of houses and, from this, several high-risk areas could be identified. It does appear as though the failure of on-site systems is affecting, to a limited degree, the quality of shallow groundwater in the area.

In 1988 the first Code of Practice: *Site Assessment for Septic Tank Absorption Trenches* (AIEH, 1988) was developed in Tasmania by the Australian Institute of Environmental Health (AIEH) for use by all professionals making decisions on site suitability for septic tank systems. In 1996 the Tasmanian Division of the Institute resolved to update the Code and a draft, *Site Assessment and System Design for Disposal of Wastewater from Septic Tanks and Sullage Water* (AIEH, 1998) was released for comment in December 1998. This development coincides with other major State based revisions to guidelines and the finalisation of Australian Standard 1547 (Standards Australia / Standards New Zealand, 1999). The introduction of the new codes will result in amendments to planning and development guidelines that will ensure that new on-site systems perform satisfactorily.

Keywords

Groundwater, contamination, septic systems, nitrate, bacteria.

1 Introduction

The aim of the study was to identify any impacts arising from on-site wastewater disposal systems in relation to groundwater and surface drainage. Dodges Ferry and Carlton are holiday shack areas that have recently become more permanently occupied. The properties have traditionally used septic tanks with on-site disposal. The performance of such systems is variable, with some giving the appearance of working well while some clearly require upgrading. Sorell Council is concerned that with shallow water tables and permeable soils in some areas, there is potential for groundwater and surface water contamination. A recent survey of recreational water quality at swimming beaches around Dodges Ferry reported higher than desirable levels of indicator organisms, not always associated with rainfall events (Robertson, 1998). The survey examined the microbiology of nearshore beach water quality after three rainfall events of between 11 and 15 mm and found indicator levels per 100 mL of between 4500 - 8000 faecal coliforms and 800 – 64000 faecal streptococci, however, the source of the microbiological contamination was unclear.

As part of this study it was necessary to review recent literature on environmental impacts of failing on-site systems and undertake both a desk study and field investigation. Information on the geology, topography, soils and hydrogeology of the study area was collated and the results of field investigations presented in a report to Council (Whitehead & Associates Environmental Consultants, 1998). One of the most important factors influencing groundwater contamination by on-site systems is the density of systems. Catchment scale studies have recorded groundwater contamination in aquifers underlying permeable soils where the density of on-site systems exceeds $15/km^2$ for potable groundwater protection (Hoxley and Dudding, 1994; Yates, 1985). While Gardner et al, (1997) also made recommendations with respect to the sustainable density of on-site systems, the degree to which groundwater contamination is acceptable appears ultimately to depend on the beneficial long-term use of the aquifer, given that contamination, particularly by nitrate, is likely.

2 Study Methodology

The desk study comprised a collation and review of available geological, topographical, hydrogeological and groundwater data, records of bores and wells, existing water quality data, University research and local knowledge. Some relevant data on bores and wells in the area were also gathered from the Tasmanian Department of Mines.

The field investigation involved locating and visiting some 26 bores and wells in the study area. In discussion with property owners, information on bore history, usage, performance and water quality was gathered and recorded on a database for use in the later stages of this study. Where possible, bores were sampled and field and laboratory testing for a number of physical, chemical and microbiological water quality parameters was conducted.

2.1 Water quality parameters

Some water quality parameters were tested at the time of sample collection, while other samples were stored for later analysis, always within 24 hours of collection. Water samples for chemical analysis were collected in clean polyethylene sample bottles from the bores with pumps after approximately five minutes of continuous pumping. The water samples for microbiological examination were collected in sterile glass bottles according to standard procedures and techniques for this type of testing and transported to a microbiological testing laboratory on the day of collection. On several occasions, shallow wells without pumps had to be sampled with hand bailers. The same procedures were followed for these samples as for the pumped bore samples.

Water quality parameters which were tested in the field with a Horiba multiprobe were; pH, electrical conductivity, turbidity and temperature. Collected samples from each location were later analysed for nitrate (NO_3^-) using the Cadmium Reduction Method and a HACH DR/2000 spectrophotometer, while microbiological analyses for faecal coliforms and *Escherichia coli* were conducted by the Public Health Laboratory at Royal Hobart Hospital.

3 Results

3.1 Desk study

The desk study reviewed data from a variety of published and unpublished sources. The study area is largely underlain by Triassic sandstone, comprising well-bedded quartzitic sandstone with minor mudstone horizons. The Triassic rocks have been intruded by Jurassic dolerite which is harder and more resistant to weathering and hence forms headlands such as Tiger Head and Spectacle Head. The gently sloping coastal plain is draped with a mantle of Quaternary windblown sand. One borehole located approximately 1 km east of Valleyfield Hill indicated a thickness of 11m of Quaternary sands. Vegetation stabilised sand dunes are apparent in the Quaternary deposits in the Tiger Head Beach and Okines Beach area. The dunes are oriented parallel to Carlton Beach and reflect the prevailing wind direction in Quaternary times. Recent river alluvium and spit deposits occur along Carlton, Red Ochre, Tiger Head and Okines Beaches.

The soils of the area reflect the underlying geology and the drainage regime. Deep sandy soils occur on the recent windblown sand deposits. Podzols, comprising a deep sand horizon with an iron or humus accumulation at depth and a clay accumulation below, develop on the Triassic sandstone. More clayey soils develop on dolerite. In areas of poor drainage, such as the lagoon area behind Carlton Beach and the low lying area inland from Okines Beach, the soils are typically clayey.

Data from available records of bores indicate that, in some areas of Dodges Ferry and Carlton Beach, spear bores access shallow aquifers in the windblown Quaternary sands at depths of only a few metres. This shallow aquifer is of variable depth and yield reflecting the variable thickness of the windblown sands. The bores accessing the shallow aquifer are typically located near to the coast. This aquifer is unconfined and recharges directly from rainfall and surface runoff and hence has the potential to be contaminated from surface and near surface sources. Some bore users indicate that yield diminishes in drier periods. These aquifers may be perched on less permeable sandy clay horizons.

A deeper aquifer exists in the Triassic sandstone, where bores of in excess of 30 metres and up to 60 metres in depth access more saline waters. In places bores penetrate the Quaternary sands to access this aquifer. On the higher ground there is commonly only a thin veneer of superficial deposits overlying the Triassic sandstone.

3.2 Field results

The broad distribution of bores in the study areas and the bores/spear points sampled are shown on Figure 1. Individual locations are not identified at this stage because of the need for confidentiality. Groundwater samples were taken over a three-day period in February 1998 at 26 bores and wells located within the study area. Water quality data collected are presented in Table 1.

4 Discussion

4.1 Geology

The windblown Quaternary sands define the areas of shallow and often perched aquifers. Immediately below, unconsolidated sands the upper horizons of the Triassic sandstone are, in places, weathered to a depth of some few metres. Beneath, the Triassic sandstone extends under most of the area, and in some places is intruded by igneous sills. Jointing in the sandstone and the presence of shale horizons and the igneous intrusions all have a bearing on transmissivity and are commonly identified in borehole logs at or about the depths at which high yields are realised.

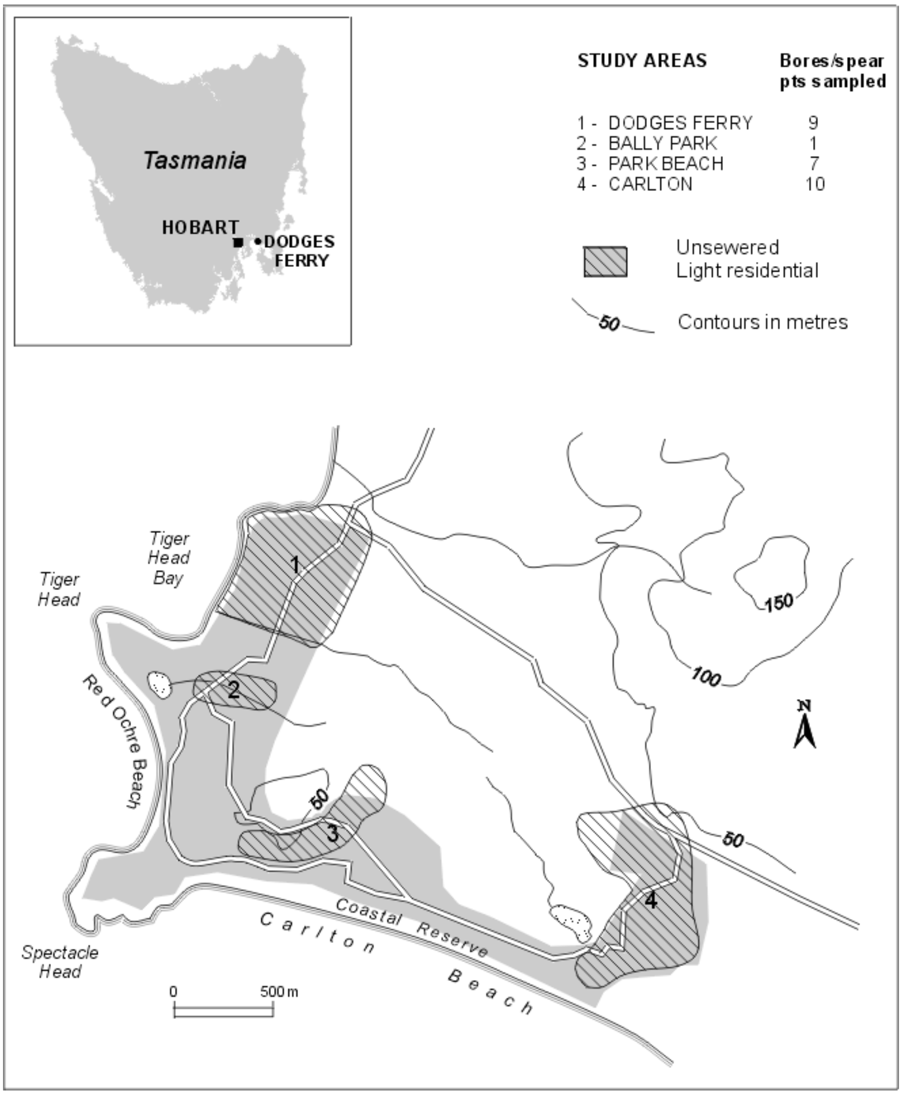

Figure 1 Location of Study Areas

4.2 Hydrogeology

Unconfined shallow aquifers in the Quaternary windblown sand deposits recharge from rainfall and surface waters and are susceptible to contamination from a number of potential sources. Amongst the potential contaminant sources are poorly performing septic trenches, particularly if overloaded by heavy usage at peak periods, if inundated by heavy rain, or where present in high density, the latter resulting in locally elevated effluent loading.

The deeper aquifer in the Triassic sandstone is less variable in yield but is appreciably more saline than the shallow aquifer. This aquifer provides a plentiful supply for some bore users, but usage is limited to toilet flushing, occasional laundry use and for garden watering of the more salt tolerant plant species.

Occasional seeps and springs were noted, in particular along the coast, where clay and sandy clay horizons hold up perched water tables. There is evidence that overpumping and pumping for prolonged periods in bores located close to the coast, results in saltwater ingress and deterioration of bore water quality with time.

Table 1 Groundwater Quality Data

Site No. Locality Area	**Bore Depth (m)**	**pH**	**EC (uS/cm)**	**Turb (NTU)**	**Temp (ºC)**	**NO_3^- (mg/L)**	**FC (cfu/ 100mL)**	**E coli (cfu/ 100mL)**
1 (DF)	60	7.32	4220	1	16.8	<0.44	<2	<2
2 (DF)	54	7.18	3430	0	16.1	<0.44	<2	<2
5 (DF)	14	6.98	2300	0	17.2	253	<2	<2
6 (DF)		6.34	5860	0	16.8	50.6	<2	<2
7 (BP)		4.77	13600	350	16.0	0.88	<2	<2
9 (DF)		6.67	2290	0	18.0	30.8	<2	<2
10 (C)	40	6.62	1940	0	15.6	0.44	<2	<2
11 (C)		6.04	2030	10	14.7	7.92	<2	<2
12 (C)	4	6.71	1930	10	16.0	19.8	12 (est)	12 (est)
13 (C)		6.16	2440	0	15.1	2.2	<2	<2
14 (C)	60	6.37	920	0	14.4	2.2	<2	<2
15 (DF)	36	5.51	410	81	19.5	46.2	<2	<2
17 (C)		5.60	1310	0	16.6	0.44	<2	<2
18 (C)	30	5.82	1750	0	15.5	0.88	<2	<2
19 (C)	60	6.92	3920	0	15.3	0.44	<2	<2
20 (C)	65	5.70	3080	0	16.6	0.44	<2	<2
21 (C)	19	5.40	2860	0	16.9	0.44	<2	<2
22 (PB)	9	6.51	1170	83	15.2	6.6	<2	<2
23 (DF)	30	6.30	4600	0	16.7	1.32	<2	<2
24 (PB)	41	6.48	2400	0	15.4	1.76	<2	<2
25 (PB)	8	6.43	1380	10	14.7	9.68	<2	<2
26 (PB)		6.51	1130	11	19.5	3.96	<2	<2
27 (PB)	40	5.25	11300	59	15.2	4.4	<2	<2
28 (PB)	90	4.48	10500	0	17.5	3.08	<2	<2
29 (PB)		6.56	1350	52	15.5	3.52	<2	<2
32 (DF)		6.52	1400	14	16.2	14.08	<2	<2

Area 1. (DF) Dodges Ferry, **Area 2. (BP)** Bally Park, **Area 3. (PB)** Park Beach, **Area 4. (C)** Carlton

4.3 Water quality results

In the interpretation of water quality data, the proposed use of the water should be considered, as relevant use criteria may differ. Water obtained from bores and wells in the Dodges Ferry/Carlton area is not used for potable purposes. While it is primarily used for irrigation purposes, there is a small risk that, on occasions, people will come in contact with the groundwater. It is, therefore, appropriate that the water quality be examined in relation to criteria which exist for potable uses (NH&MRC, 1996).

The groundwater quality of samples collected is variable and obviously related to the local geology. The variability is due to the aquifer depth and the residence or contact time of groundwater with the parent material. The most obvious feature of the groundwater is the high electrical conductivity (salinity) of some of the samples. While there are no health effects associated with high salt concentrations (taste usually determines whether it is acceptable), these high concentrations will affect the suitability of the groundwater for irrigation. Only one sample met the criteria of Class 2 (medium salinity water), with the majority of waters in Classes 3 and 4 (high and very high salinity water respectively). Four samples (Sites 6, 7, 27 and 28) could be classified as extremely high salinity water which would cause an impact on vegetation if used for irrigation. Several residents at these sites reported this impact on vegetation.

The pH for drinking water should be between 6.5 and 8.5 (NH&MRC, 1996). Lower pH values are to be expected for groundwaters and this is in fact the case for most of the samples. Several of the samples have pH values less than 6.0 and two samples (Sites 7 and 28) have values between 4.0 and 5.0. These waters would be expected to be corrosive under certain circumstances. The turbidity of the majority of the samples was also low, as expected. These water samples are typically clear, containing no suspended matter when collected. One sample (Site 7) recorded a high turbidity which is unusual given the high salinity of the sample. Some samples, particularly those sampled from shallow wells (Sites 11, 12, 13, 25, 26 and 29) were lightly coloured presumably from the leaching of soil organic matter, while two samples (Sites 6 and 15) were highly coloured. Some samples were odorous indicative of low dissolved oxygen concentrations (Sites 11, 12, 13 and 22).

As discussed previously, the presence of nitrate in waters, particularly groundwaters, can be used as an indicator of contamination by sewage effluents. Prior to this investigation there had been concern expressed that failing on-site systems may be contributing to groundwater contamination. The most obvious indicator is usually the presence of odorous, black organic seeps and saturated conditions where systems are failing. Apparently this is more common during winter in the Dodges Ferry/Carlton area, although one seep was identified in this study which was conducted during the dry summer months. Given the porous nature of the sediments in the area, it is logical to assume that effluent may reach the shallow aquifers when systems fail. The water samples which were collected from bores and wells were analysed for nitrate (NO_3^-) because it is a useful indicator of the presence of human waste. Aerobic activity in unsaturated soils results in the almost total conversion of ammonium in human wastewater to nitrate. This ion is highly mobile due to its solubility and low adsorption capacity.

In general, the majority of bore waters exhibited low or background concentrations of nitrate. Nitrate was recorded at a number of sites however, usually associated with small clusters of residences. One sample (Site 5) contained 253 mg/L which is considered to be a very high concentration by any standards. This sample was from a shallow well approximately 14 m deep above which was sited the on-site disposal system. The water sample was contaminated by effluent which may have either reached the aquifer by percolation through the porous media below the on-site system or, if the bore was poorly sealed, by leakage down the side of the casing.

The water sample collected at Site 6 also contained a nitrate concentration which exceeded the NH&MRC Drinking Water Guideline of 50 mg-NO_3/L. Other elevated (above background) nitrate concentrations were recorded at Sites 9, 11, 12, 15, 22, 25 and 32. Testing undertaken by Sorell Council also indicated high concentrations at Site 6 (twice) and Site 9 (once). These higher than background concentrations appear to be associated with the shallower bores.

Coliform organisms are also used as indicators of faecal contamination of water supplies. The test results for this study for Faecal Coliforms and *Escherichia coli* are shown in Table 1. At all locations with the exception of Site 12 the results have been reported as less than 2 cfu/100 mL for both bacteriological indicators. These results indicate that the organisms were not found according to the method of detection for all sites, with the exception of Site 12 where an estimate of 12 cfu/100 mL is given. At this site a shallow (4 m) well was sampled in which the water was highly coloured and odorous. A higher than background nitrate concentration was also recorded for this sample. Of interest is the fact that high numbers of the bacteriological indicators were not recorded at the sites with the highest nitrate concentrations (Sites 5, 6, 9 and 15). The use of pathogens as indicators in groundwaters is somewhat problematic in deep bores due to the substantial residence time of these waters and the potential for bacterial die-off. *E. coli* has also been recorded at one shallow site (Site 26) according to the test results obtained by Sorell Council. On the basis of these results, bacterial contamination of groundwaters is not regarded as a serious problem.

4.4 Areas at risk of groundwater pollution

The preliminary testing of groundwaters has indicated that there are several areas at risk of groundwater pollution from failing on-site systems in the Dodges Ferry/Carlton area. It is not possible, however, on the basis of the limited results, to quantify the nature of the risk. There appears to be a connection between the quality of shallow groundwater aquifers in specific areas and the practice of disposing of domestic wastewaters on-site, particularly where houses are in close proximity to each other.

There are three clusters of residences where there is, or appears to be, contamination of shallow aquifers. The area near the surface drainage divide between the Third Avenue/Jetty Road catchments at Dodges Ferry (Sites 5, 6, 9, 15 and 32) is at risk of groundwater contamination if not already contaminated. This observation is also supported by data collected by Sorell Council. This is an area where there is a high density of residences with typically small lots and the groundwater samples contained the highest nitrate concentrations.

Significantly lower (but above background) nitrate concentrations were recorded from bores in the Gully Road catchment at Carlton (Sites 22, 25 and 26). Shallow groundwaters in this general area appeared to be highly coloured with particularly high iron concentrations. The third cluster of residences is further along Carlton Beach in the Lloyd/Meethanar Street catchment (Sites 11, 12 and 13) where shallow groundwater contains some bacteria and nitrate and is highly coloured and sometimes odorous. The other bores sampled from the more elevated areas in the Dodges Ferry/Carlton area did not indicate any contamination or significant problems with groundwater quality, with the exception of high salinity. This is dependent upon the local geology, rather than waste disposal practices. It does appear that both surface and subsurface drainage is towards each of the three clusters where elevated concentrations were recorded. They are all located at the bottom of drainage areas and the catchments above them each contain high densities of residences and on-site systems.

5 Conclusions

In this study a limited number of samples have been collected. An attempt has been made to ensure that the results could be interpreted and considered to be representative of the conditions in the Dodges Ferry/Carlton area. The results appear to show that there is a connection between the shallow aquifer quality, the number of residences and their domestic wastewater disposal practices. The quantification of risk to the community is, however, difficult as the groundwater is not used for potable purposes. Clearly the density of on-site systems has a significant bearing on the potential for groundwater contamination. Loadings, dependent upon occupancy and number of occupants, are of importance, however, further sampling and analysis, particularly under wetter conditions, is required.

In some parts of the Dodges Ferry/Carlton area there are substantial numbers of undeveloped lots and development of these lots with on-site wastewater disposal increases the potential for groundwater and surface water impacts, particularly in those areas where water quality impacts have already been identified. Other subcatchments which have not been so rigorously investigated by this preliminary study may be subject to similar impacts given that, in some cases, their topographical, geological and soils characteristics are similar.

It is important that existing guidelines be enforced in the case of new and existing developments and that landowners and developers continue to be afforded high quality guidance and technical support to ensure effective installation and maintenance of on-site wastewater systems. As a result of this study and the introduction of new codes regulating on-site systems, Council intends working toward a longer term planning framework to protect groundwater quality in the Dodges Ferry/Carlton area.

6 References

Australian Institute of Environmental Health, 1988, Code of Practice*: Site Assessment for Septic Tank Absorption Trenches*. AIEH, Tasmania.

Australian Institute of Environmental Health, 1998, Code of Practice*: Site Assessment and System Design for Disposal of Wastewater from Septic Tanks and Sullage Water.* AIEH, Tasmania.

Gardner, E., Geary, P. and Gordon, I., 1997, Ecological Sustainability & On-Site Effluent Treatment Systems, *Aust. J. Env. Man*., 4, 2, 144-156.

Hoxley, G. and Dudding, M., 1994, Groundwater Contamination by Septic Tank Effluent: Two Case Studies in Victoria, Australia, *paper presented to Water Down Under '94: Proceedings of 25th Congress of International Association of Hydrogeologists, Adelaide*, 1994, 145-152.

National Medical & Health Research Council, 1996, *Australian Drinking Water Guidelines*, Commonwealth of Australia, Canberra.

Robertson, G., 1998, *Recreational Water Quality Monitoring – Tigerhead Beach*, Unpublished report, Sorell Council, Tasmania.

Standards Australia / Standards New Zealand, 1999, AS/NZS 1547 *Domestic On-site Wastewater Management,* Standards Australia, Homebush.

Whitehead & Associates Environmental Consultants, 1998, *Dodges Ferry Catchment Management and Groundwater Monitoring Programme*, Report prepared for Sorell Council, Tasmania.

Yates, M., 1985, Septic Tank Density and Groundwater Contamination, *Groundwater*, 23, 586-591.