TREATING DOMESTIC WASTEWATER IN A SHALLOW COASTAL SAND AQUIFER NEAR HOBART

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Abstract

At Lauderdale near Hobart, 500 houses discharge domestic wastewater to a coastal sand aquifer. Testing for bacteria, nutrients, metals, organics and pesticides, shows no significant effects on the groundwater or marine environment.

This result was explained by detailed sampling near a septic tank absorption trench. After 1 m of wastewater infiltration through unsaturated sand to the water table, bacteria were reduced to non-detectable levels, total nitrogen (TN) reduced by 90%, nitrogen as ammonia (NH_3-N; 140 mg/L) reduced to around 1 mg/L, and nitrogen as nitrate (NO_3-N) increased from about 0.01 mg/L to 10 to 30 mg/L. Importantly, downgradient from the trench, NO_3-N decreased with distance, so that after 10 to 20 m it was reduced to 1 mg/L. Orthophosphate (PO_4-P) at 15 mg/L in the trench decreased to 5 mg/L beneath the trench, to 1 mg/L after 10 – 20 m of groundwater travel, and to 0.1 mg/L after 50 m.

It is contrary to current environmental dogma that a high septic tank density (500+ per km^2) could result in relatively minor changes in groundwater quality. Furthermore, the environmental and economic benefits of such wastewater disposal outweigh the beneficial uses of the groundwater.

Keywords

Absorption trench, groundwater, nutrients, sand aquifer, wastewater treatment

1 Introduction

Clarence City Council commissioned investigations into shallow groundwater quality at Lauderdale, a coastal town on a sandy spit near Hobart (Figure 1). About 500 houses have reticulated mains water, septic tanks and absorption trenches. The lot density approaches 500 per km^2. The spit comprises Quaternary beach sand with a capping of wind-blown sand. Sand permeability is about 1 to 5 m/day. The sands extend vertically to a clay basement about 8 to 10 m below sea level. Unconfined groundwater at depths of 1 to 2 m is moving coastwards at 5 to 15 m per year. There is no significant groundwater use.

Investigations were in two parts:

- Stage 1, the *Town Survey*, involved sampling from twelve shallow groundwater bores and six surface waters (Figure 1).
- Stage 2, the *Detailed Survey*, sampled seven water bores, a well, and effluent from an absorption trench, at a selected house (Figures 1 and 2).

Water samples were collected in June and December 1997, and in May 1998.

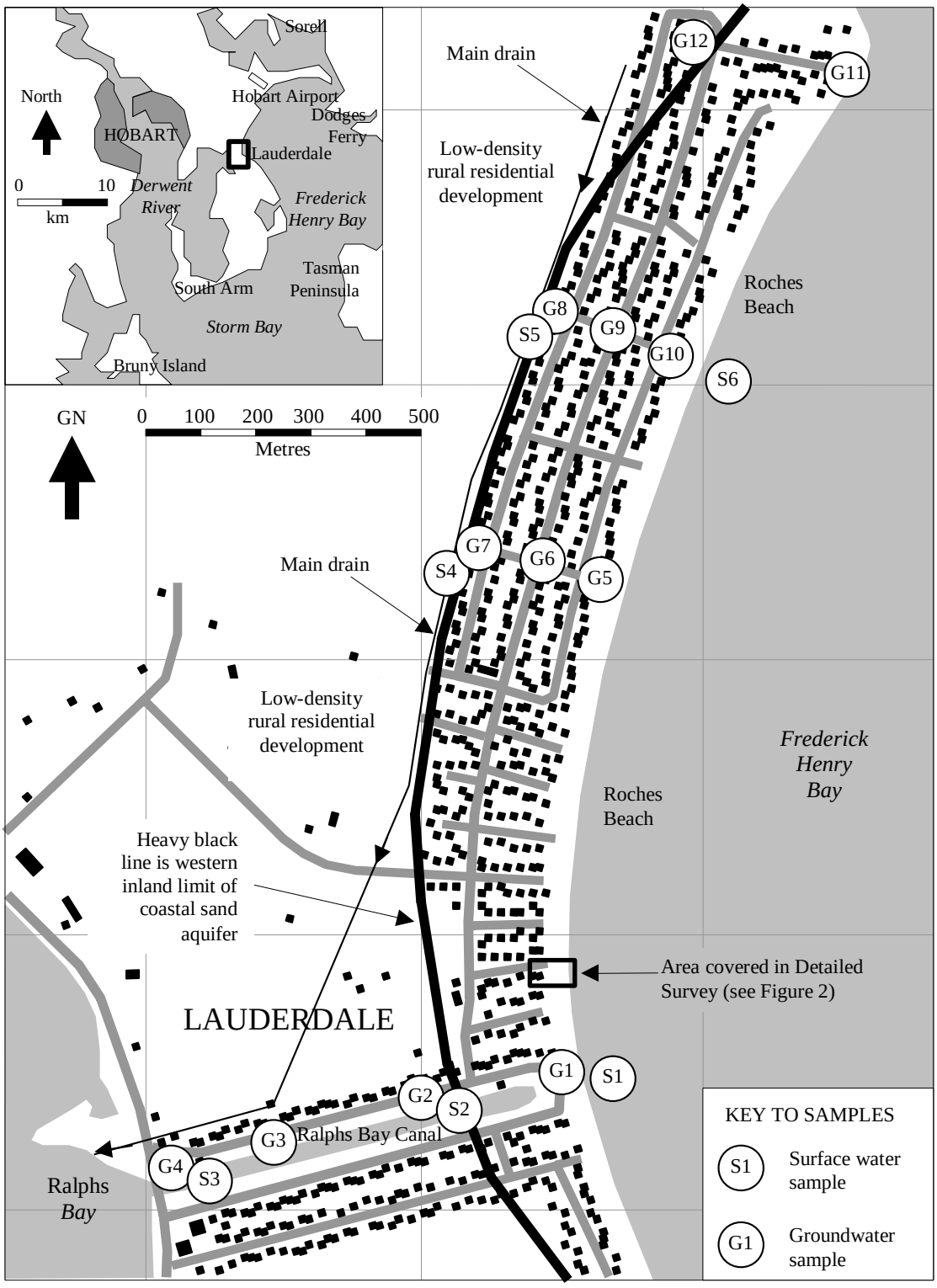

Figure 1. Sample locations for the Town Survey at Lauderdale, southeastern Tasmania. The location of the Detailed Survey is indicated.

2 Sampling Results from the Town Survey

2.1 General Comments

The main results from the Town Survey sampling programme were as follows:

- Pesticides, and a range of fifty volatile organic compounds, were undetected.
- In seawater and canal water, cadmium, chromium, cobalt and nickel were undetected. Other metals were close to detection limits. Iron and aluminium were mainly

undetected, but were elevated at 420 μg/L and 115-180 μg/L in the drain samples. Zinc (<10-99 μg/L) was also elevated.

- In groundwater, cadmium, chromium, cobalt and copper were undetected. Other metals were very close to detection limits, except for iron (<20 to 2,000 μg/L), manganese (<5 to 300 μg/L), zinc (<10 to 650 μg/L), aluminium (<50 to 800 μg/L) and mercury (<0.01 to 0.1 μg/L).

Table 1. Nutrients and Bacteria in Surface Waters in the Town Survey

	Sample	S1 sea	S2 canal	S3 canal	S4 drain	S5 drain	S6 sea
Nutrients (mg/L)							
TN	Jun-97	0.250	0.20	0.34	5.3	14.7	0.14
	Dec-97	0.170	0.27	0.19	3.2	19.6	0.19
	Mar-98	0.350	0.26	0.16		35.0	0.33
NO_2-N	Jun-97	0.002	0.002	0.002	0.01	0.10	0.002
	Dec-97	0.002	0.002	0.002	0.002	0.28	0.003
	Mar-98	0.002	0.002	0.002		0.00	0.002
NO_3-N	Jun-97	0.002	0.002	0.002	0.03	1.5	0.003
	Dec-97	0.009	0.018	0.011	0.03	2.5	0.026
	Mar-98	0.002	0.021	0.004		0.02	0.003
NH_3-N	Jun-97	0.110	0.032	0.021	0.41	6.8	0.018
	Dec-97	0.032	0.033	0.024	0.01	0.30	0.061
	Mar-98	0.030	0.029	0.033		21.0	0.026
TP	Jun-97	0.033	0.023	0.054	1.3	6.2	0.017
	Dec-97	0.022	0.025	0.022	0.87	9.9	0.025
	Mar-98	0.041	0.13	0.082		7.4	0.046
PO_4-P	Jun-97	0.008	0.009	0.010	0.51	5.2	0.007
	Dec-97	0.008	0.010	0.007	0.32	8.9	0.017
	Mar-98	0.009	0.13	0.078		5.6	0.009
Bacteria (cfu/100mL)							
Faecal coli (FC)	Jun-97	<1	9	4	10,000	400	<1
	Dec-97	<10	10	<10	9,400	180,000	20
	Mar-98	530	800	160		<1,000	170
Faecal strep (FS)	Jun-97	4	6	3	1,100	4,700	<1
	Dec-97	<10	10	60	29,000	30,000	<10
	Mar-98	700	30	160		50	170
E. coli	Jun-97	<1	9	4	5,000	400	<1
	Dec-97	<10	10	<10	9,400	120,000	20
	Mar-98	450	800	160		<1,000	170
C. perfringens	Jun-97	2	18	19	4,300	1,400	2
	Dec-97	<10	220	30	6,000	1,500	10
	Mar-98						

TN = Total Nitrogen TP = Total Phosphorus

2.2 Nutrients and bacteria in surface waters

The main results (Table 1) were:

- Seawater and canal water averaged about 0.25 mg/L Total Nitrogen (TN). Globally, seawater averages about 0.7 mg/L (Hem, 1989).
- Seawater and canal water averaged about 0.04 mg/L Total Phosphorus (TP, mostly organic). Globally, seawater averages about 0.1 mg/L (Hem, 1989).
- Stormwater from the drains is strongly elevated in nutrients.
- Bacteria were present in almost all samples in each of the three sampling runs.
- Seawater and canal water show the lowest bacterial concentrations.
- The two drain waters returned variable but generally high bacterial counts.

Table 2. Nutrients and Bacteria in Groundwater in the Town Survey

	Sample	G1 bore	G2 bore	G3 bore	G4 bore	G5 bore	G6 bore	G7 bore	G8 bore	G9 bore	G10 bore	G11 bore	G12 bore
Nutrients (mg/L)													
TN	Jun-97	10.7	6.8	4.4	0.98	3.0	0.35	1.0	4.8	0.31	0.31	1.9	0.21
	Dec-97	4.4	3.3	2.4	0.50	3.0	0.37	1.3	4.8	0.60	0.23	2.6	
	Mar-98	1.8	2.6	2.5	0.58	0.77	0.47	1.7	5.7	0.59	0.26	3.4	0.36
NO_2-N	Jun-97	0.16	0.002	0.005	<0.002	0.11	<0.002	<0.002	0.063	0.008	<0.002	<0.002	0.004
	Dec-97	0.060	0.004	0.005	<0.002	0.14	<0.002	0.003	0.072	<0.002	<0.002	0.003	
	Mar-98	0.020	0.002	0.006	<0.002	0.032	<0.002	0.004	0.12	<0.002	<0.002	<0.002	0.002
NO_3-N	Jun-97	7.4	0.010	0.008	0.016	1.8	0.022	0.007	3.3	0.15	0.009	0.002	0.018
	Dec-97	4.0	0.43	0.060	0.033	2.8	0.33	0.042	3.5	0.52	0.012	0.011	
	Mar-98	1.7	0.026	0.014	0.017	0.28	0.041	0.12	4.0	0.51	0.022	0.032	0.094
NH_3-N	Jun-97	0.025	0.45	0.21	0.083	0.008	0.018	0.13	0.28	0.005	0.089	1.5	0.029
	Dec-97	0.016	0.087	0.20	0.066	0.029	0.031	0.24	0.23	0.009	0.076	0.51	
	Mar-98	0.017	0.41	0.15	0.083	0.034	0.034	0.35	0.067	0.006	0.089	2.4	0.034
TP	Jun-97	0.035	0.13	0.11	0.11	0.069	0.058	0.073	0.048	0.045	0.12	0.20	0.015
	Dec-97	0.048	0.15	0.045	0.061	0.068	0.044	0.042	0.037	0.046	0.14	0.18	
	Mar-98	0.12	0.22	0.33	0.15	0.15	0.29	0.91	1.2	0.041	0.15	0.40	0.37
PO_4-P	Jun-97	0.018	0.010	0.007	0.029	0.046	0.020	<0.002	0.013	0.019	0.082	0.043	0.010
	Dec-97	0.028	0.006	0.013	0.036	0.031	0.026	<0.002	0.007	0.021	0.12	0.018	
	Mar-98	0.11	0.20	0.28	0.14	0.14	0.22	0.46	0.94	0.036	0.13	0.28	0.36
Bacteria (cfu/100mL)													
Faecal coli (FC)	Jun-97	2	<100	<100	<10	1	<1	<100	<1,000	1	<1	3	100
	Dec-97	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	
	Mar-98	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Faecal strep (FS)	Jun-97	1	<100	<100	<10	<1	<1	<10	2	<1	<1	<1	<10
	Dec-97	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	
	Mar-98	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	100
E. coli	Jun-97	2	<100	<100	<10	1	<1	<100	<1,000	<1	<1	<1	<100
	Dec-97	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	
	Mar-98	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
C. perfringens	Jun-97	<1	<100	800	70	4	4	20	<1	<1	5	8	100
	Dec-97	<10	50	20	<10	<10	10	<10	20	<10	<10	20	
	Mar-98												

TN = Total Nitrogen TP = Total Phosphorus

2.3 Nutrients and Bacteria in Groundwater

The main observations (Table 2) about nutrients and bacteria in groundwater are:

- TN ranged from 0.2 to about 11 mg/L in groundwater. Exceptions were the groundwater from bores 1, 5, 8 and 9. Bore 1 is close to public toilets, and bore 8 to the main drain. These might explain their high total nitrogen and nitrate levels.
- High TN or nitrate levels are not mirrored by high TP or phosphate levels. TP ranges from about 0.05 to 0.1 mg/L in the first two sampling runs.
- Phosphate levels in groundwater are lower than in seawater/canal waters.
- Generally, the groundwater contains no detectable bacteria. The 800/100 mL of *C. perfringens* in bore 3 is unexplained.

3 Description of the Detailed Survey

Stage 2 - the Detailed Survey - at Lauderdale investigated whether high-level treatment of wastewater was occurring during infiltration from absorption trenches to the water table, or via lateral groundwater movement, or both. A single two-storeyed brick residence was selected (Figure 2). Average mains water use was 1,200 L/day for domestic purposes. The septic tank trench is 10 m long, 1 m wide and 0.7 m deep, with its base a metre above the water table. The sullage trench is 7 m long, and 0.6 m wide and deep.

4 Sampling Results from the Detailed Survey

4.1 Nutrients

Nitrogen in the Effluent

TN in the effluent trench was 125 mg/L in December 1997 and 170 mg/L in March 1998 (Table 3). About 85% was NH_3-N in March 1998. Nitrite and nitrate were present in negligible proportions.

Table 3. Nutrients in the Detailed Survey

		Effluent trench	Groundwater bore	bore	bore	bore	well	bore	bore	bore	Surface Water
Sample		1	2	3	4	5	6	7	8	9	(Roof
Distance (m) from HWM		55	54	53	52	42	36	32	20	3	runoff
Distance (m) from trench		*0*	*1*	*2*	*3*	*13*	*19*	*23*	*35*	*52*	to well)
Nutrients (mg/L)											
TN	Dec-97	125	32.4	7.7		8.3	1.03	1.26	0.31	0.30	2.30
	Mar-98	170	11.1	4.3	0.45	12.7	2.1	2.7	0.29	0.75	
NO_2-N	Dec-97	<0.01	0.01	<0.10		0.07	<0.01	0.03	<0.01	<0.01	<0.01
	Mar-98	<0.01	0.07	0.25	<0.10	0.11	<0.01	0.02	<0.01	0.01	
NO_3-N	Dec-97	0.01	29.4	7.3		7.8	0.03	0.42	0.03	0.04	0.01
	Mar-98	0.02	8.9	3.6	0.01	1.3	0.02	1.1	0.01	0.40	
NH_3-N	Dec-97	Too coloured	0.02	0.02		0.01	0.15	0.37	0.03	0.01	0.06
	Mar-98	146	0.02	0.01	0.15	0.02	0.68	1.0	0.03	0.03	
TP	Dec-97	16.3	2.9	4.9		6.5	0.61	2.1	0.20	0.04	0.50
	Mar-98	18.3	3.9	5.1	0.18	8.5	1.0	2.2	0.42	0.14	
PO_4-P	Dec-97	14.7	2.9	4.8		2.8	0.33	1.9	0.10	0.02	0.04
	Mar-98	16.3	3.2	4.6	0.18	7.1	0.75	2.1	0.38	0.12	

TN = Total Nitrogen TP = Total Phosphorus

Nitrogen in the Groundwater

In both sampling runs, TN in groundwater in bores 2 and 3 decreased by an order of magnitude (to less than 10 mg/L) compared to TN in the effluent trench. Downgradient, TN further fell to values between 0.3 and 0.8 mg/L (Figure 3). In the second sampling run, NH_3-N decreased by more than three orders of magnitude (from 146 mg/L to 0.01 mg/L) within two metres of the trench. It increased to 0.7 mg/L in the well, and decreased again to about 0.03 mg/L in bores 8 and 9.

NO_3-N increased by more than three orders of magnitude (from about 0.02 mg/L in the trench, to 30 mg/L and 9 mg/L in the adjacent groundwater). It then decreased with increasing distance, to about 0.01 to 0.4 mg/L. Over about 50 m, this is an average NO_3-N reduction of about 0.5 mg/L/m of groundwater travel, or, if groundwater is moving coastwards at rates of (say) 10 m/year, a reduction rate of 5 mg/L/year.

Phosphorus in the Effluent

TP in the effluent was about 16 mg/L and 18 mg/L in the two sampling runs (Table 3). These levels are probably fairly typical of septic tank effluent. PO_4-P accounted for 90% of the total in both cases.

Phosphorus in the Groundwater

TP in groundwater in bores 2 and 3 decreased four times (to about 5 mg/L) compared to TP in the trench. The levels increased slightly at bore 5, then decreased with increasing distance to 0.04 to 0.14 mg/L (Figure 3). This is a phosphate removal rate of 0.1 mg/L/m of groundwater travel, or about 1 mg/L/year.

Vertical Distribution of Nutrients in Groundwater

Bore 4 was installed about one metre deeper than the others, and its March 1998 results (Table 3) compared to nutrient concentrations in bore 3 reveal TN 10 times lower, NH_3-N 20 times higher, NO_3-N 35 times lower, NO_2-N 125 times lower, and TP (all as PO_4-P) 28 times lower.

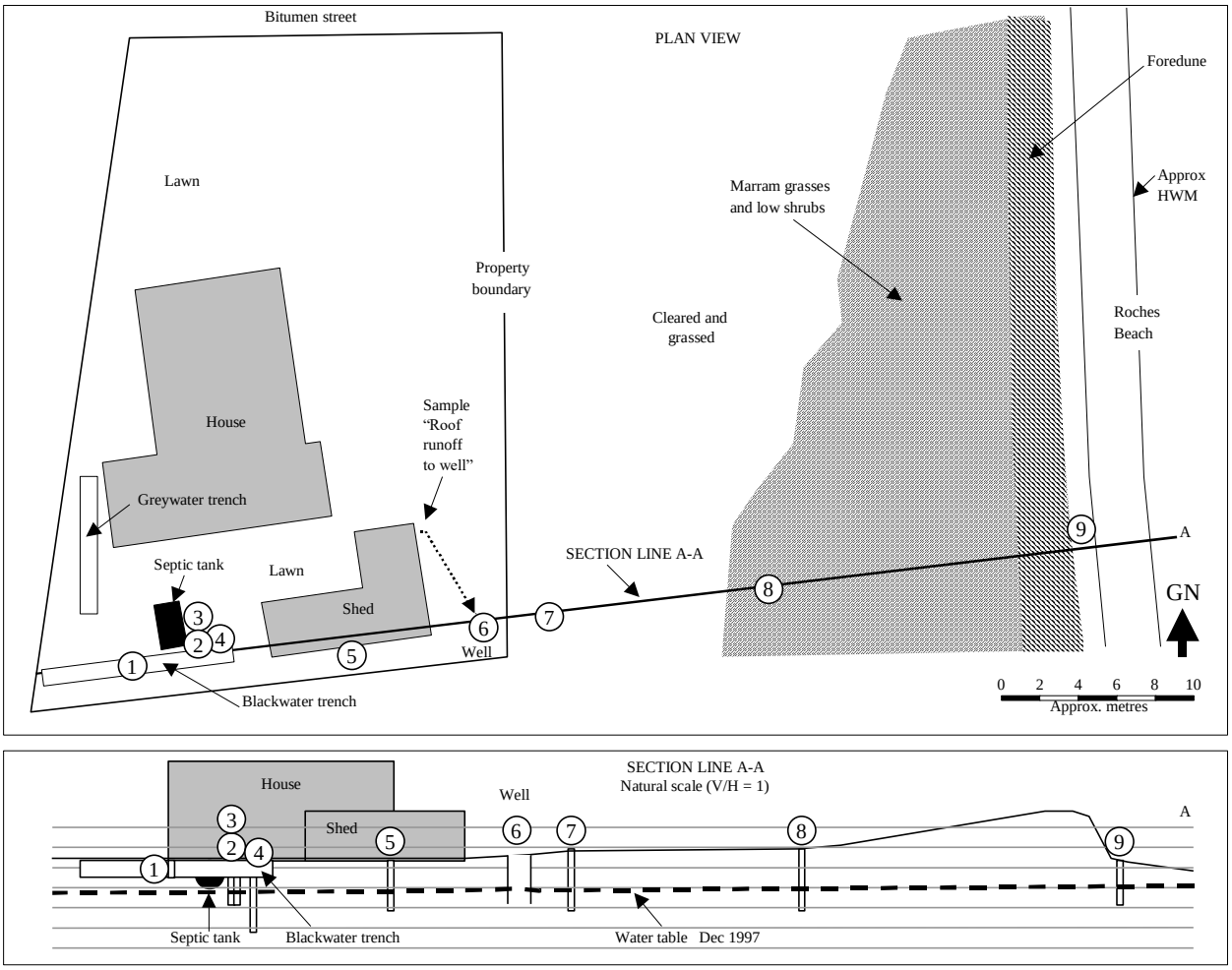

Figure 2. Location of Sampling Bores for the Detailed Survey at Lauderdale.

4.2 Bacteria

Bacterial Levels in the Septic Tank Effluent Trench

Bacteria in the effluent trench varied by a factor of 20 between the sampling runs in December 1997 and March 1998 (Table 4). In the first run, faecal coliforms (FC) were 360,000 cfu/100mL. Of these, *E. coli* accounted for 200,000 cfu/100ml. Faecal streptococci (FS) were 160,000 cfu/100mL, and *C. perfringens* were 11,000 cfu/100mL.

Bacterial Levels in Groundwater

With the exception of the second-run samples from bore 9 and the well, bacteria were undetected (<10 cfu/100mL) in all bores on both sampling runs. This demonstrates the effective filtering capacity of the unsaturated sand beneath the effluent trench.

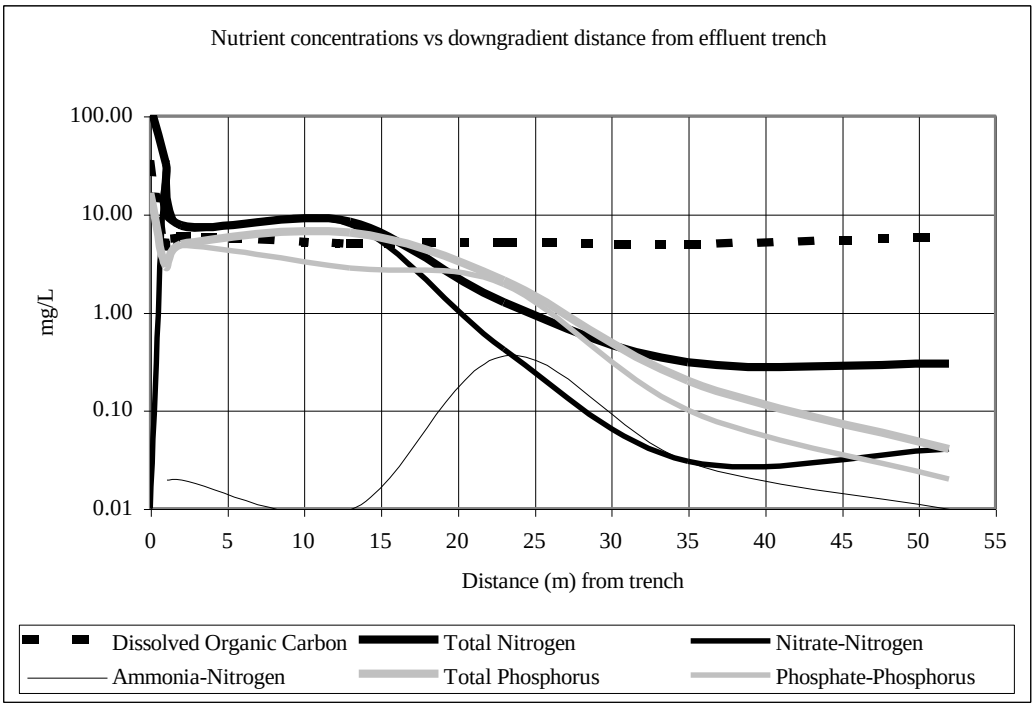

Figure 3. Nutrient Concentrations in Groundwater at Increasing Distances from the Wastewater Trench in the Detailed Survey at Lauderdale

Table 4. Bacteria in the Detailed Survey

		Effluent trench	Groundwater bore	bore	bore	bore	well	bore	bore	bore	Surface Water
Sample		1	2	3	4	5	6	7	8	9	(Roof
Distance (m) from HWM		55	54	53	52	42	36	32	20	3	runoff
Distance (m) from trench		*0*	*1*	*2*	*3*	*13*	*19*	*23*	*35*	*52*	to well)
Bacteria (cfu/100mL)											
Faecal coli (FC)	Dec-97	360,000	<10	<10		<10	<10	<10	<10	<10	<10
	Mar-98	8,600,000	<10	<10	<10	<10	50	<10	<10	30	
Faecal strep (FS)	Dec-97	160,000	<10	<10		<10	<10	<10	<10	<10	<10
	Mar-98	160,000	<10	<10	<10	<10	200	<10	<10	50	
E. coli	Dec-97	200,000	<10	<10		<10	<10	<10	<10	<10	<10
	Mar-98	8,600,000	<10	<10	<10	<10	<10	<10	<10	30	
C. perfringens	Dec-97	11,000	<10	<10		<10	<10	<10	<10	<10	<10
	Mar-98										

5 Conclusions

The main findings about wastewater disposal into the sand aquifer in the Detailed Survey at Lauderdale probably apply to similar coastal situations elsewhere. They are:

- A metre of unsaturated sand between a wastewater trench and the water table provides an effective filtration environment for bacteria.
- Nutrients are reduced tenfold by infiltration through a metre of sand above the water table, and are further reduced by one to two orders of magnitude during lateral transport in the aquifer.

The first finding explains why bacteria were generally undetected in the Town Survey. The second conclusion supports the inference that the slow moving groundwater results in effective denitrification of NO_3-N to nitrogen gas.

Current environmental dogma says groundwater should not be used to treat domestic wastewater. However, at Lauderdale and perhaps elsewhere, the environmental and economic benefits of doing so outweigh the beneficial uses of the groundwater.

Acknowledgment

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Reference

Hem, J. D. (1989). *Study and Interpretation of the Chemical Characteristics of Natural Water*. USGS Water Supply Paper 2254