An example of “ground breaking” research done by the Soil Conservation Authority: Septic Tank Effluent Management - SCA past achievements

Most of you Golden Oldies, during your careers, would have been entirely focused on soil erosion, dry land salinity and working with farmers and graziers to promote good land management. Quite a few, perhaps, might also have provided general land capability advice regarding to different forms of land use and, especially, to all those people who lived on the land, well away from any sewerage system, about how to manage domestic wastewater. After all, the SCA was also the referral authority for land subdivision and rural residential development in proclaimed catchments. We had a responsibility for protecting water quality in these streams.

I was once, very early in my SCA career, perhaps in the late seventies, called as a technical witness to an AAT meeting about a proposed unsewered subdivision in the infamous Rosslyn Reservoir catchment. It was my first experience of a case run by lawyers where the answers can only be pitch black or brilliantly white and they force you to choose. Needless to say, I failed the test, because as a scientist, I could recognise shades of risk but did not recognise legalese. I stepped straight into a legal trap.

However, as we all know, the SCA had already been developing land capability rating tables for a variety of land uses, of which rural residential subdivision and septic tank effluent disposal was an important component. At the time, there was only one method for effluent disposal: the septic tank absorption trench. This methodology had been the province of the Victorian Health Department, but the EPA had taken it over due to environmental considerations, not human sickness so much. But the SCA claimed a subsection of this terrain in so far as it applied to proclaimed catchments.

My first time to become involved was when Parks & Gardens, or it could have been the MMBW, requested the SCA to check out the soil at the Warrandyte State Park for a toilet system that could not be connected to sewer, as was the case for all of Warrandyte and many surrounding suburbs, including Park Orchards, where Frank Gibbons lived and where, inspired by his love for that area, my family had also bought a house. It was proper public service courtesy that I should take my soil auger and spade to the Park in the company of one Fritz Balkau, a nuclear physicist (I think), who was on the EPA staff. It is all so long ago, but I think this would have been in 1975-76.

Fritz brought an EPA soil percolation test method where one uses a soil auger with a 10-inch diameter and excavates a cylindrical hole some 0.4-0.5 m depth, which is filled with water, using a prior soaking depth of 300 mm of water, to cover the subsoil portion, and then one measures the drop of water level in the hole over, say, 10-minute intervals. The exact procedure I do not remember. The idea was that so long as there was a satisfactory drop of water level, say 25 mm in that time interval, the soil was either okay or not okay for septic systems.

As we can all appreciate, what Fritz and I, a nuclear physicist and soil scientist, were doing was utterly primitive and empirical and had nothing to do with a scientific approach to how fast water moves away in soil. The funny thing is that I was certainly not conscious of that. We were not measuring a soil property at all. We were just pottering around like amateurs. We were measuring some arbitrary process. None of us asked ourselves if the size of the hole, its depth and the initial depth of water in it made any difference to the outcome. This, in reality, was and still is the typical methodology for the so-called "Percolation Test". It is more a mythology than a methodology. We should have been doing some literature research before going out on site[1]. All the same, the EPA had it's percolation test officially registered by NATA.

In those early days, the Dept. of Health and the EPA also tended to be dependent on data from America, see Table 1.

Table 1. Loading rates for the percolation test based on empirical evidence from the USA.

Time for 25 mm drop (minutes)	1	2	5	10	20	40	60	>60
Loading rate (L/m^2.day or mm/day)	150	125	100	75	50	30	25	N.S.

The soil property that controls the rate of loss of water in a hole is its hydraulic conductivity and hydraulic gradient resulting from capillary suction exercised by the surrounding soil and any gravitational effects. I discovered later that the soil's hydraulic conductivity can be calculated from a percolation test method if the precise size and shape of the test hole is known, the initial depth of water and the rate of drop of the water level in the hole, with all the data inserted into a correct mathematical equation. The hydraulic conductivity is a soil property, whereas the percolation rate is a property of both the geometry of the test hole, the choice of starting water level, choice of time intervals between readings and the soil's capillarity. A perc test provides a "dirty" outcome that cannot be used for design because it measures a whole lot of effects, not just a soil property.

The loading rate in Table 1 had nothing to do with the actual hydraulic conductivity of the soil. We don't know if all American soils are equal to all Australian soils, so why use it? It is pure empiricism. The existing "science" provided no mathematical equation to convert the percolation observations to a proper saturated soil hydraulic conductivity, Ksat value whereas such equations have existed in the technical literature[2] well before Fritz and I pottered around in Warrandyte State Park. Engineers and irrigation scientists have developed these equations long ago. For engineering purposes, such as designing a drainage system, the percolation test method is not capable of providing usable outcomes.

Here again, in those early days, the faster one could get rid of the effluent the better, groundwater quality protection did not come into the equation. That consideration ought to be the basis of the land capability table too.

[1] Bouma, J 1971. Evaluation of the field percolation test and an alternative procedure to test soil potential for disposal of septic tank effluent. *Soil Sci. Soc. Amer. Proc*. 35:871-875

[2] Poirée, M and Ollier, Ch 1962. *Irrigation* (Edition Peyrolles).

LAND CAPABILITY RATING FOR ON-SITE EFFLUENT DISPOSAL

Areas capable of being used for on-site soil absorption of all-waste septic tank effluent from a single family dwelling.

LAND FEATURES AFFECTING USE	CAPABIITY CLASS				
	1	2	3	4	5
SLOPE (1)	0 to 5%	5% to 8%	8% to 15%	15% to 30%	More than 30%
SITE DRAINAGE	Excessively well drained, well drained	Moderately well drained	Imperfectly drained	Poorly drained	Very poorly drained
FLOODING (2)	None	-	-	Less than once in 25 years	More than once in 25 years
DEPTH TO SEASONAL WATERTABLE	More than 150 cm	150 cm to 120 cm	120 cm to 90 cm	90 cm to 60 cm	Less than 60 cm
PERMEABILITY (3)	Faster than 1.0 m/day	1.0 m/day to 0.5 m/day	0.5 m/day to 0.2 m/day	0.2 m/day to 0.05 m/day	Slower than 0.5 m/day
DEPTH TO ROCK OR IMPERVIOUS LAYER	More than 200 cm	200 cm to 150 cm	150 cm to 100 cm	100 cm to 75 cm	Less than 75 cm
GRAVEL AND STONES	Less than 5%	5% to 20%	20% to 40%	40% to 75%	More than 75%
BOULDERS AND ROCK OUTCROP	Less than 0.02%	0.02% to 0.2%	0.2% to 2%	2% to 10%	More than 10%
SHRINK-SWELL POTENTIAL	Less than 4%	4% to 12%	12% to 20%	More than 20%	-

Notes: (1) SLOPE: Reduce class limits by half in slope failure hazard areas.
(2) FLOODING: Upgrade one class if floods are low velocity, shallow and easily diverted with banks.
(3) PERMEABILITY: Based on determination of hydraulic conductivity, "K".
Where K exceeds 0.6 m/day, risk of polluting water bodies must be considered.

So, what I would like to stress with this writing, is that the SCA, I am sure, for the first time in Australia, intended to look at wastewater behaviour in the soil in a proper scientific context, where water moves through the soil in response to capillary (matric) pressure potentials based on modern soil physics. The person who did that work was Joost Brouwer. Some of you might remember him from staff conference meetings where some of you Golden Oldies participated in sports and running and perhaps can remember Joost being one of the fast runners. Mostly, however, Joost was housed at La Trobe University, where his research was done under the supervision of Steve Willatt, not at Cotham Road, Kew.

Joost had completed BSc level courses in both soil science and irrigation science at Wageningen University, The Netherlands, and needed a minimum of 6 months of practical training before he could be admitted to the MSc program. He contacted me, having received my name and address from one of his supervisors, and asked if he could do his half year practical training with us. We, i.e. the SCA, had been looking for a person to carry out proper research on septic tanks and their environmental impacts, but hadn't yet been able to get the funding. We had to tell Joost that the research we needed could not possibly be done in 6 months but required probably 2 years. Would he be prepared for a long stay and work under supervision of La Trobe University? Well, he was.

With the help of Frank Gibbons, and probably others in the Authority, the funding finally came through and Joost, taking a calculated risk, flew out and arrived in Melbourne before the funding had been fully completed. In the first few weeks, he stayed at our place in Park Orchards, getting himself oriented and prepared for his studies. The day I picked him up from Tullamarine and drove him to Park Orchards, whilst crossing the Yarra River and surrounding open country, he told me the names of all the birds we saw. Whilst waiting for his visa and other admin arrangements, he had already familiarised himself with the avifauna of Australia!

Looking back at the old times and rereading some of the first published papers on the behaviour of septic tank effluent in the soil, I think "authoritative" and "timeless" is a proper indication of the quality of that work. All the work that has been done on research of septic systems in Australia before that time has been ad hoc, quite limited, superficial, without any real understanding of how water in soil moves.

Because soils are porous mineral materials, with particles having surfaces that attract water, they act like capillary systems. A lump of wet soil held in the hand will drip water until the dripping stops, but at that time the soil still holds water against the force of gravity. When the dripping ceases, the capillary attractive forces of the largest pores in that lump of soil, still containing water, are holding that water at a suction (matric potential) equal to the force of gravity. Therefore, to understand the movement of water in the soil below a septic effluent trench, we need to know what forces act on that water.

Soil further away from the trench will be drier and hence any water in that soil will be subject to a stronger capillary suction (matric potential) and therefore effluent from the trench will be moving not just vertically, under the influence of gravity, but also sideways towards the further, drier soil. It turns out that gravity is just a very minor force pulling water away from an effluent trench. Gravity only becomes significant when the whole soil is saturated, so that capillary potential is zero. Gravity then is the only force still acting on the water in the soil.

The text in the box below is a copy of part of Joost Brouwer's first paper on his research presented at the Water Resources and Hydrology Symposium, September 1979.

Mathematical symbols describing the process are:

h = pressure or matric potential of soil water expressed on a volume basis in: $J.m^{-3} = N.m^{-2}$

z = gravitational potential of soil water relative to an arbitrary horizontal plane, also in: $J.m^{-3} = N.m^{-2}$

H = hydraulic potential of soil water, here equalling h + z in $N.m^{-2}$

v = flux, the volume of water crossing a unit area per unit time in $m^{-3}.m^{-2}.s^{-1} = m.s^{-1}$

dH/dx = hydraulic gradient.

The flow of water through the soil, irrespective of the state of saturation, has been found to be governed by Darcy's Law:

$$v = -k(dH/dx)$$

which expresses that the volume flux is proportional to the gradient of hydraulic potential in the direction of the flux. k is by definition equal to the flux when dH/dx = 1.

Darcy's Law[3] was formulated by a French engineer in 1856 who was working on sand filtration systems for purifying drinking water. In form it is precisely similar to Ohm's Law in electrical networks, which states that the current through a conductor between two points is directly proportional to the voltage across the two points. Introducing the constant of proportionality, the resistance I = V/R, where R is the current strength in Ampères, V is the voltage across the conductor in units of Volts, and R is the resistance of the conductor in units of Ohms. Every civil engineer, geotech engineer, irrigation specialist ought to know and be able to apply Darcy's law and one hopes every soil scientist does too.

I am adding this extra paragraph on electricity because large numbers of us have always fiddled around with electrical items and car engines that won't start because their batteries are dead, and therefore we, the general public, know what these terms mean. It can help us understanding Darcy's law, which is the exact equivalent of Ohm's law. We won't get water to

[3] *Darcy, H. (1856). Les fontaines publiques de la ville de Dijon. Paris: Dalmont.*

move through soil if the hydraulic gradient between two points is zero and we won't get an electric current between two points if the voltage at each point is the same.

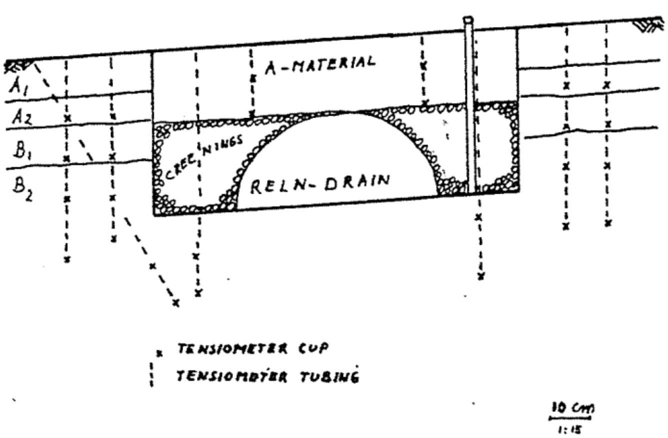
I have found that this utterly basic concept is very poorly understood by many people working in the septic tank effluent management field, all the way to the EPA itself. I have been in a case where a corrupt Environmental Health Officer, working in tandem with a corrupt Shire Councillor was trying to saturate a soil in an abandoned apple orchard so that he could "prove" the soil could not absorb effluent by flooding the test holes with water until finally several of his percolation test gave zero results. I used the electrical analogy to explain my case that his work was tantamount to shorting a battery.

The owner of the land informed me, prior to my own soil testing, that a Shire Council official, who was a land developer in his spare time, had approached him with an offer to buy the land and develop it himself and spare the owner all the hoopla. When the answer was "No!" the threat was made "You will never sell that land".

I took this event up to the Ombudsman, in this case a retired civil engineer, who was flabbergasted by the behaviour of the Council Shire official and the EHO, being told that, because I was not accredited with NATA for the EPA percolation test, my views and my report were not acceptable to Council. The Ombudsman lacked legal powers to do take the case further. I also took the case to the EPA and the Dandenong Valley Authority but got no help from either. The owner was finally able to subdivide the land after Jeff Kennett amalgamated many councils and the corrupt councillor was lost his position. The EHO got a job with another council and then did his own land capability assessments which he then approved officially".

Another very common misunderstanding is the septic effluent in an effluent absorption field can only exit at the base, whereas in fact sideways movement and evapotranspiration of a wide zone surrounding the trench are usually the main output areas.

So, how did Joost find the magnitude of levels of matric potential of the soil water at a range of positions below and beside the absorption trench over time? I now quote from his paper:



He placed 26 tensiometers in the soil in a plane perpendicular to the trench at various depths by which he could measure soil moisture tension (capillary suction) at each of these spots simultaneously. A tensiometer is a small ceramic cup, 28 mm long with 6.5 O.D. diameter, glued to 10 cm of hard Perspex tube, out of which two plastic tubes led to the surface; one into a container of mercury to measure soil water tension around the ceramic cup, and the other a filler tube used when flushing the system of air bubbles.

He also inserted a standpipe in the trench to determine the level of effluent poncing in the trench over time.

The ceramic cups are capable of letting water, but not air, move out and in from the surrounding soil. As the soil around a tensiometer cup dries up and the soil moisture suction increases, water from the cup and the connecting tube moves out into the soil. At the same time as the water from the reservoir is lost, the mercury in the connecting container moves up. Because mercury is 13.56 times denser than water, a small rise in the mercury level represents a 13.56 times larger increase of the rise of water if, instead of mercury, the ceramic cup had been attached to a water container. By using mercury one can easily cover a very large range of values of negative water pressures due to increased matric potential (capillary suction) from drying soil. Conversely, if the soil becomes increasingly wet, water can flow from the soil into the cup and lower the level of mercury in the attached container.

The principle of this method is best explained by a diagram and a picture.

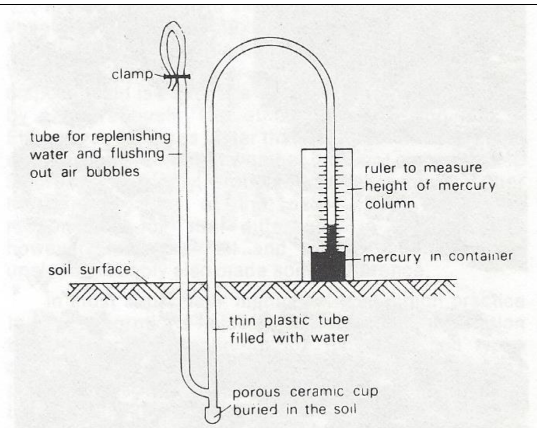


Fig 1. Tensiometer for measuring soil water suction.

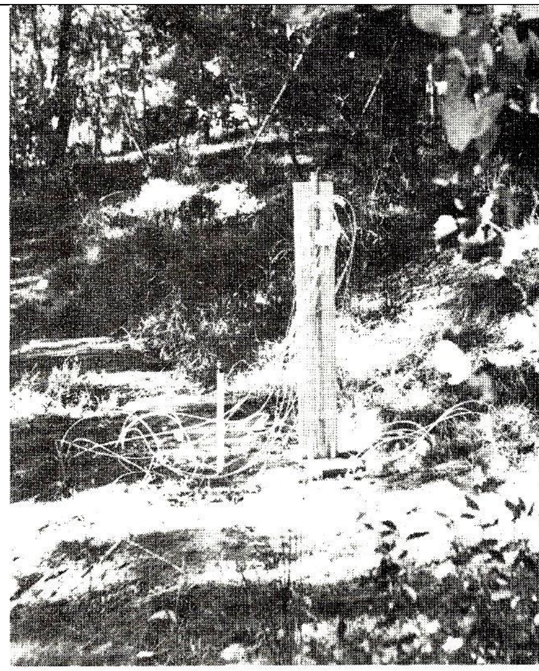


Fig 6. Absorption trench monitoring assembly at Eltham.

Having a network of points in a vertical plane across a septic tank effluent trench allows one to plot the direction of flow from the trench into the surrounding soil because the water must always flow from low capillary (matric) suction to high capillary suction areas. By connecting all points where the matric suction = 0, one can plot the position of the water table. The figures below represent an effluent disposal system at North Whittlesea during a dry and a wet period.

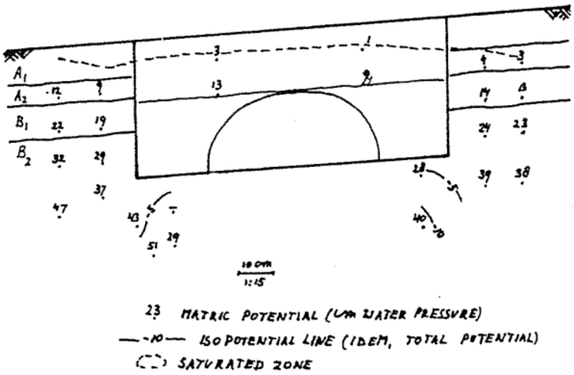


Fig.3 : Isopotential lines North Whittlesea
19 November 1978 (wet)

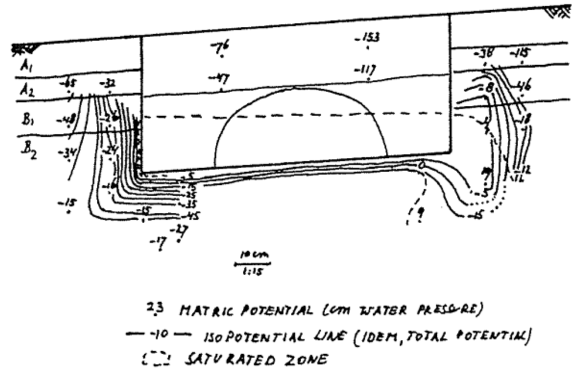


Fig.5 : Isopotential lines North Whittlesea
29 November 1978 (dry)

What the picture on the left illustrates is that even in wet weather, in this particular system, the matric suction increases with depth and towards the sides. Therefore, the effluent is still infiltrating and also going sideways to soil that is drier than the soil in the upper portion of the trench. There is a perched water table just a few centimetres below the soil surface. The picture above on the right shows a closely bunched system of parallel isopotential lines, indicating there is a very strong hydraulic gradient pulling effluent away from the trench, both sideways and downwards.

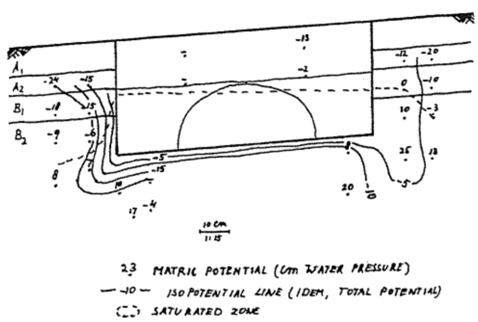


Fig.4 : Isopotential lines North Whittlesea
24 November 1978 (intermediate)

The third picture shows the hydrological situation during an intermediate period, not very wet nor very dry. There is water standing in the trench, but the perched water table does not extend much out of the trench in the surrounds.

The North Whittlesea system was measured on a daily basis, including rainfall on the site and the house had been fitted out with an electronic switch that recorded every time the toilet was flushed. This system took only toilet wastewater. It was a gargantuan job to carry out all that monitoring over lengthy periods in all seasons, but it yielded a much-detailed picture of how an effluent system behaves.

Joost was also interested in what happened with the nutrients, especially phosphorus and nitrogen, that are contributed to the soil from septic tank effluent. In North Whittlesea it was proved that N and P hardly move far away from the edge of the trench. Of course, this can vary depending on the soil type and its permeability, but with soils that have significant fines nutrients just stay around. The “control” refers to a soil sampling site well away from the effluent trenches. Groundwater pollution very often turns out to be a non-issue.

Date of Sampling	Depth of Sampling (cm)	POSITION OF SAMPLER RELATIVE TO TRENCH														
		CONTROL			TRENCH			2m DOWNSLOPE			5m DOWNSLOPE			10m DOWNSLOPE		
		TKN	NO_2	NO_3	TKN	NO_2	NO_3	TKN	NO_2	NO_3	TKN	NO_2	NO_3	TKN	NO_2	NO_3
20 Nov'78	15-20	1.4	0	0.07	30.6	0.011	0.12	0.7	0	.03	1.1	0.002		1.0	0	0.02
	35-40		0.003	0.04				0.5	0	.02	0.6	0	0.02	0.7	0	0.05
21 Nov'78	15-20	1.1	0	0	28.2	0.36	0.30	0.6	0	0.001	1.4	0.008	0.02	0.6	0	0.01
	35-40	0.5						0.4	0	0.003	0.5			0.4	0	0.01
22 Nov'78	15-20	1.1	0.001		36.8	0.14	0.21	0.6	0	0.001	1.4	0.017	0.01	0.9	0	0.002
	35-40	0.4	0.002					0.4	0	.01	0.3			0.5		
24 Nov'78	15-20	1.1	0.005	0.01	66.0	0	0.07	0.7	0.002	0.003				0.8	0	0.01
	35-40	0.3						0.5	0		0.3			0.4		

Date of Sampling	Depth of Sampling (cm)	POSITION OF SAMPLER RELATIVE TO TRENCH									
		CONTROL		TRENCH		2m DOWNSLOPE		5m DOWNSLOPE		10m DOWNSLOPE	
		TOTAL P	ORTHO P	TOTAL P	ORTHO P	TOTAL P	ORTHO P	TOTAL P	ORTHO P	TOTAL P	ORTHO P
20 Nov'78	15-20			6.9	2.3		0.02				0.01
	35-40	0.03	.04				0.02		0.02		0.01
21 Nov'78	15-20	0.16	.03	6.5	1.0	0.04	0.02	0.07	0.01	0.18	0.01
	35-40	0.62	.02			0.14			0.01		
22 Nov'78	15-20	0.34	.02			0.26	0.01	0.25	0.00	0.03	0.03
	35-40								0.01	0.11	0.05
24 Nov'78	15-20						0.01			0.26	0.01
	35-40					0.03	0.01		0.01	0.20	0.03

Joost also checked out two more systems mentioned in his first paper and several more that are described in his doctoral thesis. Going back to his full thesis I note that most of his experimental sites were located in moderate to high rainfall areas, thus had acidic soils that were non-sodic. They were in North Whittlesea, North Eltham, Kinglake West, Doncaster-Templestowe and Mount Macedon. Three sites were on cracking clays, Kangaroo Ground, Wollert and Lara. There was one site at Bacchus Marsh on a yellow duplex soil, which probably was also sodic. More work has to be done on septic systems on sodic soils and how these soils must be treated to function better remains to be investigated.

No one else in Australia had ever done as thorough and fundamental a job on how septic effluent systems behave in Australia. So, as the result of a research project run by the Authority, this work needs to be acknowledged as an important achievement. It earned Joost an invitation to present a paper at an USEPA and the National Small Flows Clearinghouse meeting at the International Symposium on Wastewater Treatment in Unsewered Areas, organised by the USEPA; Annapolis, Md, USA, 17-21 April 1989. It gave the SCA a seat in three successive editions of the Australian and New Zealand Standard (AS/NZS 1547) "On-Site Domestic Wastewater Management" where, because of our involvement with soil permeability testing methods, the Constant Head In-Situ Soil Permeability Test was incorporated into the Standard, and where that method is finally also promoted in the EPA's Code of Practice – On-Site Wastewater Management.

It was CSIRO's Dr Tjeerd Talsma who demonstrated this in-situ constant head test at a conference in Tatura, I think in 2002, and donated one of his permeameters to the SCA that we subsequently copied for our own use. The methodology and theory was already in print in 1980[4]. It just illustrates how slow good science penetrates the world around.

[4] Talsma, T., and Hallam, P.M. 1980. Hydraulic conductivity measurement of forest catchments. *Aust. J. Soil Research,* vol.18, p.139-148.

Following Joost's work, it was Robert Patterson in Armidale who promoted the research on domestic wastewater systems, first with his own doctoral research, and, after that gave that field an all-mighty push with his bi-annual conferences. Patterson's work is worthy of a separate chapter. I thank them both for having profited from them so much. I also acknowledge that much of this work took place out of the daily view of the SCA's Field Division and, so, might not register with the bulk of the Golden Oldies.

Robert van de Graaff - 8-2-21