Extract from talk on

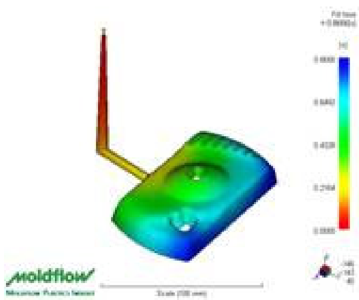
“Solving the water Crisis’

Part 2 Innovative solutions to the water crisis

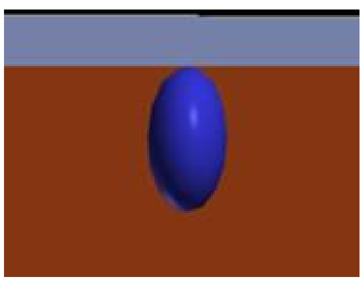
Colin Austin March 2006

Innovative solutions to the water crisis.

This talk is about finding innovative solution to the water crisis. I will explain the thinking behind the development of many ideas and am happy to fill in the technical details if this is of interest.



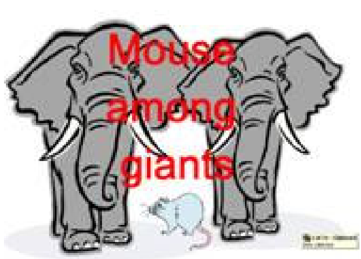
In the early seventies, as a humble lecturer at the RMIT in Melbourne I developed a piece of software which could predict the filling pattens as a hot plastics flowed into a cold mould.



This may seem to have nothing to do with water but is very relevant. The mathematics is the solution of a moving front problem, totally analogous to water moving through the soil during irrigation.

I set up a company, called Moldflow, which by luck had the right product at the right time, and grew to become one of Australia's most successful exporters of technical software. Our customers were the giants of manufacturing in the electronics, car, domestic appliance and aerospace industries.

At first people were totally sceptical that it was possible to solve the complex problem of a hot plastics flowing into a cold mould in a three dimensional geometry. But we showed it could be done. Any one of the many large companies in the plastics industry, with their highly competent research departments and could if they so wished have developed their own version of the technology.



We were a mouse among giants, remote from our markets. How could we possibly hope to survive? We could not possibly hope to compete head on. When I moved into the water field many years later I found the same situation.

Research into water

Both here and overseas there is a vast network of research into water issues, such as our CSIRO. All highly competent organisations, it would be shear madness to go head to head against such well resources organisations.

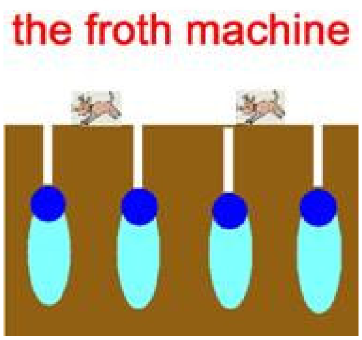
We had to be different and create a process of continuous innovation always staying one step ahead. Impossible you may say, but these highly competent organisations follow a highly disciplined approach to research, what I call competence research, every step following logically from the previous step.

But innovation rarely follows a logical step by step path. We adapted an approach I have labelled pioneering research. New ideas are more often than not generated by some process which appears to be random. We deliberately created that process, starting projects without any clear idea on the end result, (none of the milestones beloved of grant givers), knowing that they would likely fail but that they may lead onto other approaches which in turn my fail but eventually lead to that sort after innovation which would give us the jump start.

A continuous process of zig zagging about cutting project and diverting resources to new approaches.

Innovation means accepting risk and crazies

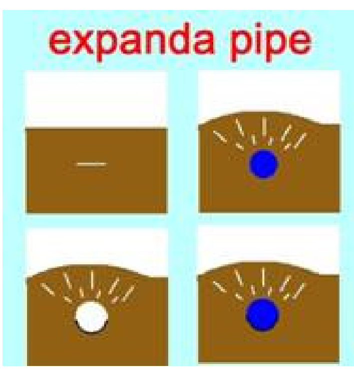
This was the approach I adopted when I moved into the water field. Let me just give a couple of examples of this approach in the water field by telling you about a couple of crazy projects, which probably no sain researchers would want to be associated with.



The first was the 'froth' machine. I knew that plant need air as well as water and that water does not travel readily through the soil. The idea, was to pump an air water froth through the soil so the air would carry small droplets of water to all parts of the soil.

Now to make the froth we had a huge high pressure fan which would blow a highly velocity air stream through pipes and we would inject water into this air stream.

Now this was a total failure, all that happened was that the air would rise to the surface in a jet and the water would run down into the ground. The only compensation was the sight of the farm dogs going totally berserk trying to locate the millions of air jets coming up from the subsurface pipes.



Another idea was the 'expanda' pipe, again with the same objective of getting a mix of air and water into the soil. We ploughed a layflat pipe into the ground, pumped this with high pressure water so the pipe would expand and crack the soil. We then drained the pipe and pumped water into the soil tube left around the pipe directly into the earth.

Both totally 'way out' ideas; - which failed. But eventually they led, through many twists and turns, into very practical methods of achieving that magic air water blend.

Risks and rewards

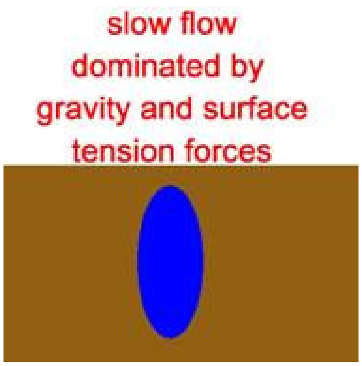
If this approach to research seems a bit wild and could never work in the real world let me just say that Moldflow grew to become the leading exporter of technical software in Australia, still totally dominates its niche area of technology and was eventually floated on the NASDAQ exchange for $140 million.

This was the approach I adopted when I moved into water. I knew I could not compete head on so I needed to do something different; - where failure was an accepted part of the process.

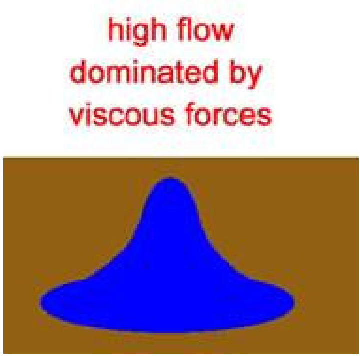
For many years, basically since the famous dust storms in the early eighties I had been experimenting with soil regeneration. I had come to the conclusion that water was the key, develop the right climate for micro biological action and maintain those conditions throughout dry periods to keep the microbes alive.

The start, replacing flood irrigation

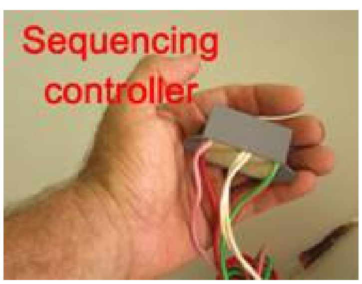
I wanted to find some alternative to flood irrigation and decided to explore subsurface irrigation.



With my background in the moving front fluid flow area it was obvious that the conventional approach to subsurface was far from ideal. Water would simple percolate down into the soil with only a small lateral movement. .



By injecting the water at much higher flow rates, for short periods of time, the water will be forced sideways by hydraulic action, rather than downwards.



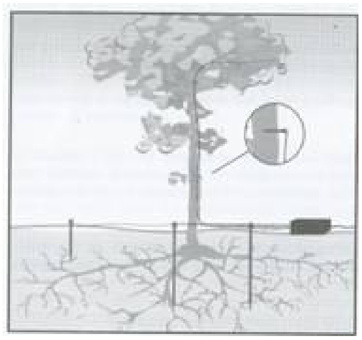
This meant redesigning the delivery system. It is just not practical to have huge pumps and pipes so I split the irrigated area into small sections and developed a very simple sequential switch which would divert the flow to the next section automatically as soon as the water reached a certain depth.

Later we realised that controlling irrigation depth is the key to efficient irrigation, the sequencing controller was a spin off device ahead of its time.

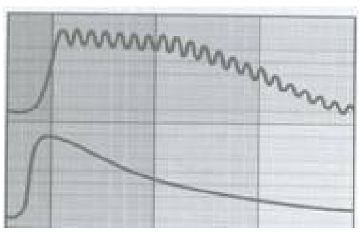
It was becoming obvious that the cost of such a system could never be economically justified. However during the El Nino's in the 90's it was clear that many farmers were coping perfectly well simply by better scheduling.

Changing targets - Scheduling

We clearly needed to switch our direction. Scheduling really has two problems, knowing when to irrigate and how much water to apply.



Knowing when to irrigate is not really so difficult. We developed a simple plant and soil moisture sensing system.



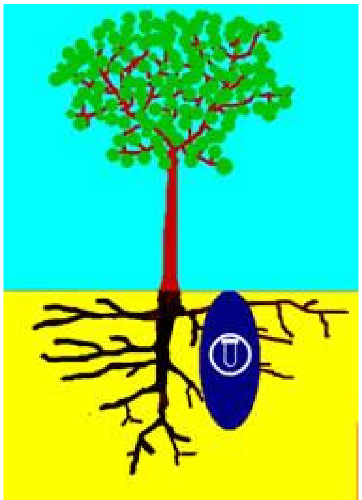
The plant sensor graph would be essentially flat (apart form diurnal variations which can be readily removed mathematically) until it was short of water when the dip indicates when it is time to irrigate.

Such level of instrumentation may not fall readily into place in a traditional farm but we developed a very simple evaporation meter which gave a pretty good indication of when to irrigate. The reality is that most farmers have a pretty good eye for their crops and know when to irrigate.

The real problem is knowing how much water to apply when it is time to irrigate. In fact if you can always apply the right amount of water it does not matter that much when you irrigate (as long as it is ahead of stress).

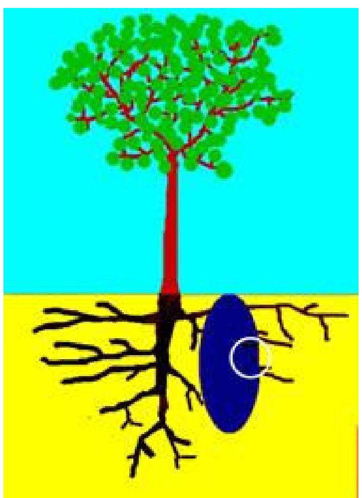
Conventional wisdom – can be wrong

The conventional wisdom is based around the water holding capacity of the soil; - a useful concept but of much less practical value.



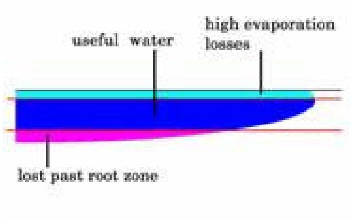
The fact is that water does not by some miracle move through the soil to give a uniform water content. It is almost impossible to apply water uniformly, plants do not take up water uniformly from the soil and any odd rain will totally alter the water distribution anyway. We are looking at complex and continuously moving three dimensional water distributions.

In theory soil moisture sensors could be used to calculate the total water content but this means a three dimensional array of sensors which is totally impractical outside the research field.



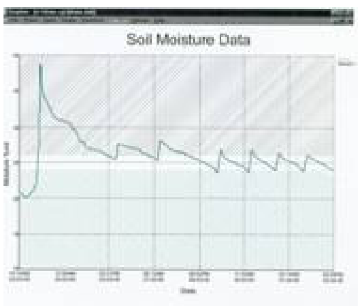
Yet the reality is that soil moisture content is not the key factor, after irrigation we know that where the soil has been wetted, it is at field capacity. We are far more interested in where the water wetted the soil, the position of the flow front.

Irrigation depth the key



More specifically we want to know how deep the water has penetrated. Irrigation depth is the key to irrigation efficiency and also environmental management, too shallow and the water is lost by evaporation too deep and it is lost past the root zone possible causing problems with nutrient run off or salinity.

Irrigation depth is a very simple concept, readily understood by farmers, much easier to measure and control than soil moisture, the problem is to relate water applied to penetration depth, which of course varies with many factors. Some like soil characteristics change slowly with plant growth and others like water content change rapidly.



The solution adopted was a predictor corrector scheme, measure data before and after irrigation, analyse data over a number of irrigations and continuously correct the relations. In practise this means all the farmer has to do is specify a required penetration depth and the software will predict how much water to apply. Adaptive (or self learning) irrigation depth control.

Irrigation depths should not be the same for every irrigation; it is more effective to apply a series of irrigations at a shallower depth followed by a deeper irrigation when needed.

There was, and is little doubt that this was an important and practical technical development, which could have far reaching effects for water management in this and other countries. However at that time there was very little interest in the control of irrigation depth despite its beneficial effects on water use and the environment.

Africa

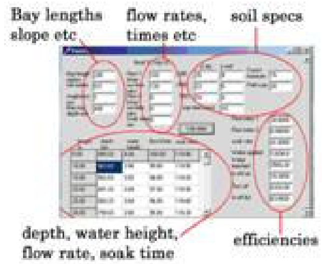
I have to admit I found this was very disappointing but at that time I was approached by World Vision to look at the problems of providing irrigation for sustenance food production in Africa.

The low cost tubing I had developed for subsurface irrigation looked a potential solution however instead of subsurface it was used to feed conventional furrow irrigation.

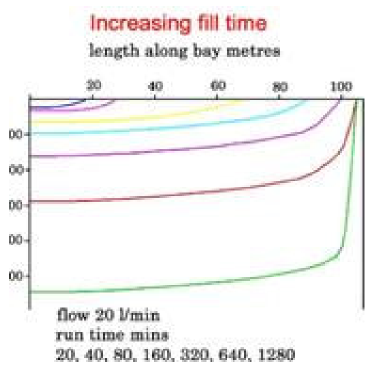
Experiments in Australia showed this could be very effective but case histories in Africa were very varied. This was a rapid learning experience. It does not matter whether the technology works in the research environment but whether the local people, the farmers, can make it work.

In one of those round the houses stories, having started trying to replace flood irrigation I was now back to finding out ways of making flood irrigation more efficient.

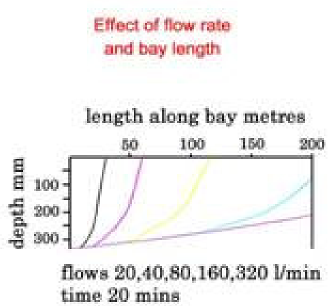
Computer simulation – provide rapid learning



I wrote up a computer simulation of flood irrigation. The big advantage of simulation is that it is possible to carry out literally hundred of experiments in a few hours. This gives a learning experience and level of understanding which just cannot be obtained by physical experiments.



Some six years after trying to make flood irrigation obsolete I was now finding that it is possible to make flood highly efficient, at a fraction of the cost of subsurface, but this is the cost of learning.



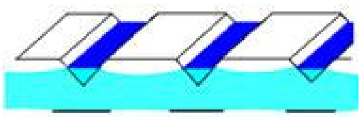
The simulation showed that by using short runs and rapid flows it possible to achieve very high efficiencies and so a system called Micro flood was developed.

This required small areas to be irrigated in sequence and a simple valve called the tilt or sloshing valve was developed.

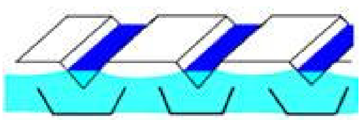
Again technically successful but still not the total solution in Africa with all its' problems of lack of skilled people and extension services to support the farmers.

Innovation must be useable by the users

Some farmers simply did not have their blocks levelled correctly or the flow rates were too low and the furrows ended up flooded at one or the other end, with water being lost deep into the ground.



As an experiment I laid a piece of polythene film under a furrow to reduce downward soak. The results were simply dramatic, with water flowing to the end of the furrows with pooling.

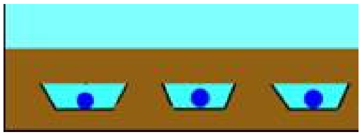


Next step was to lay the polythene to form a trough under the furrow. This was not expected to work as it was thought that the soil would become water logged and the roots would rot.

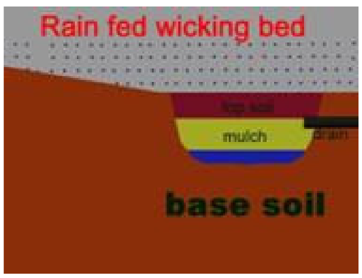
Exactly the opposite happened, the plant productivity and growth were far better than anything we had achieved before. Why was a bit of a puzzle as the soil should have been too saturated for good growth.

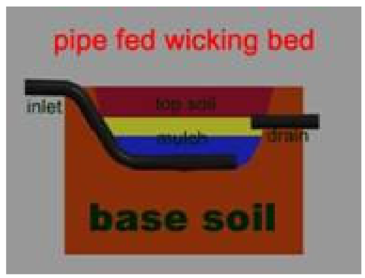
But eventually we conclude that the mechanism was very different to conventional flood irrigation. We only needed to irrigate at much less frequent intervals. We had a pool of water under the ground and the water would wick upwards to provide moist, not wet soil, far better growing conditions than the saturate and dry out cycle of conventional flood irrigation.

Back to subsurface irrigation



It was then only a small step to use a subsurface pipe to replace the furrow and, run the lines horizontally, let the water cascade from one bed to the next and we had a highly effective and productive form of subsurface irrigation, we now call wicking beds.





Wicking beds can be rain fed or from external water sources

Digging and filling a wicking bed

Back to subsurface irrigation. Yet another cycle in the loop! Typical of the process of pioneering research.

Africa was to provide yet another learning experience and give us a totally different view on irrigation.

Water has two dimensions – volume and usefulness

Like most people in the irrigation business I was focused on irrigation efficiency, yet this is not the real problem in Africa. People will be starving even in years when there is reasonable rainfall. All it takes is a couple of weeks of no rain, (in their nominal rainy season) and the seed heads will simply fail to fill and mature, even though the plants look green and healthy.

Engineers have the concept of entropy to manage the two dimensional problem of energy, giving it a quantity and a measure of usefulness. Just as with water we have quantity and a second dimension which could be called useful life. Extending the useful life of water can have a far bigger impact than simply improving the efficiency of use of water.

The wicking bed system is much more than an efficient way of irrigating. It is;- but the real value is extending the useful life of water by harvesting and storing water.

Implications for Australia

There are very significant implications for this in Australia. If for example we take a rainfall map of Australia, work out the area between the isobars to calculate the total amount of rain falling on Australia, divide by the total population we see that the amount of water we receive per person per day approaches1 million litres.

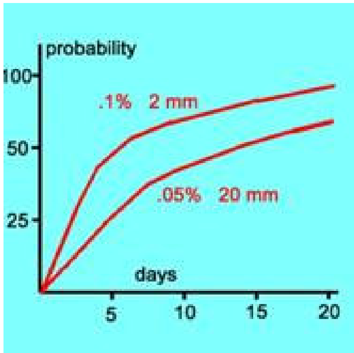
Australia is not short of water, we have more per head than most other countries. We have adopted the technologies of dams and distribution system from other countries without realising that our core problems are our flat plains and rainfall patterns which require different methods of harvesting water.

Now of course some of this rain falls in the tropics and just flows out to sea. Other rain falls on the desert where no one lives, although the rainfall (in mm) may be small the huge areas distort the statistics. May be we should adjust the raw figures, but this would be pedantic because it makes no real difference. There are huge quantities of water falling onto Australia.

Using our conventional technology we only harvest a minute proportion of this, about 1 in 2,000. This has profound implication for the way we manage our water. Engineers use the concept of entropy to balance the quality of heat against its use. We simply do not use high pressure steam (high quality energy) to heat our houses.

But this is exactly what we do with water. Using the energy analogy we are using premium water from our dams (which has a long useful life) when there is an abundant supply of low grade water (with a shorter useful life) readily available for low grade uses like irrigation.

Rainfall – a question of probabilities



This all come down to probabilities of rain. For every region and season there is a probability of rain, say 1 in 10 of a rainfall of 2 mm or 1 in 20 of a 20mm rainfall for rain the next day. If we know this number we can readily calculate the probability of rain falling within say 10 or 20 days ahead. For example if there is a 1 in 20 chance of rain next day there is a 64% chance of rain in the next 20 days.

What this means is that if we can manage our irrigation so we can cope for 20 days without needing to irrigate again that on average we would save 64% of our premium water. Again this is a question of probabilities, there will be time when it does not rain and we have no option but to use precious dam water.

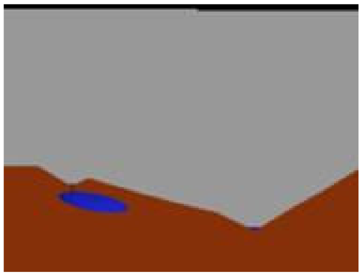
On the other hand there will be times, when we get lucky rainfalls, when we can virtually eliminate using any water for irrigation. The practical implications of this are that the dams can be filled during these wetter periods so when the drought does come the dams are full. A sight I have not seen for many years.

Our dams have plenty of storage capacity, but we never let them fill up. Instead we are using water from the dams when there is plenty of alternative water available.

Net result; - there is no water in the dams when we really need it.

Extending the useful life of water

There are many technologies which can help us extend the useful life of water wicking beds are just one, swales, leaky dams (with percolation holes) and twin dams or all cheap and available technologies.

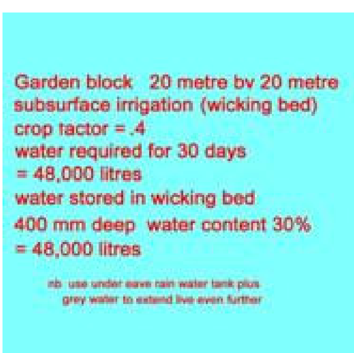


For many years I used the twin dam system to irrigate my orchard. There was a small ephemeral creak through my block, which I damned. When it rained this small dam would fill, trigger a limit switch would fill a top leaky dam and turn on the irrigation (in the middle of a rain storm). The quantity of water held in the dams was relatively small, the bulk was stored in the soil and was slowly released as it infiltrated down the slope.

I could get enough water in the soil to last for a month. As long as I had one decent rain per month I did not need any external irrigation. There were a few seasons when there was not enough rain, but most years I did not need any external water.

Of course there are conventional ways, (such as household tanks) of storing water. But the size to store reasonable amounts of water can be prohibitive. For example 5.4 metre diameter and height to store 120,000 litres for a 30 days supply.

Storing water in tanks for irrigation is at best a marginal proposition.



By contrast as wicking bed can store 30 days of irrigation water without taking up any garden space.

It can also be used to recycle grey water and may be supplemented by a smaller tank.

Using plants to harvest water

We can even use plants to harvest water. This Egyptian spinach has an impressive root system with both deep roots and surface hair roots. It mops up any small rains then virtually hibernates until the next rain. Normally small rains of say 2mm are simply lost by evaporation on the next hot day.

The paradigm shift

Now there is no such thing as a free lunch, the fact is there is some cost, small may be, but it is still there. Probably more importantly, is the mental and physical effort in managing these systems.

The reality is that people are used to having volumes of water available at minimal cost. We could clearly extend out existing system of water catchments but at great environmental cost (and now less acceptable to much of the community).

There needs to be a change in thinking, a paradigm shift, in the communities' expectations of water delivery and the willingness to adopt alternative water practices. I see no alternative but for the Government to lead such a paradigm shift.