Water and Land Management

A foundation for economic planning in Australia

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Introduction

In most parts of the world, supplies of fresh drinking water are diminishing. The reasons are not hard to understand – population increase, pollution of ground and surface waters, over-exploitation of existing resources, deforestation of catchments and increasing demand for agricultural purposes. Finding new sources of water and managing demand are problems exercising water authorities everywhere. At the time of writing, even economically developed regions such as Australia and California are facing severe water shortages.

I started writing this essay in 2007 when the worst drought in 100 years dominated headlines around Australia. My initial motivation to broach the topic was the intense and often perplexing debate about the best water policy for Australia. It quickly became apparent that water policy cannot be discussed in isolation, even though this is how politicians attempt to frame the debate. A holistic approach is required, which at the very least includes land use policy. It then became clear that water and land use policy are implemented within a social and economic framework, and from a Proutist[1] perspective water and land use planning must be the starting point for local or *block-level* planning.

Block-level planning is one of the key features of Prout's economic agenda. The *block*, in Prout parlance, is equivalent to a local government area (LGA).[2] Prout broadly supports economic decentralization and therefore promotes cooperatives (locally owned and managed businesses) and economic planning at the local (LGA) level as well as at the federal or country level.

Those wishing to promote an economic plan for their local area will have to turn their minds to water and land use policy. But developing policy is not easy. The Australian Greens summarize their water policy in just seven points (see Appendix 3) and the Wentworth Group of Concerned Scientists[3] in just five points (see Appendix 4), but behind these summaries lies the deliberation of some of the best informed minds in the country. It may be politically expedient to present water policy in succinct statements, but such statements must be supported by a depth of research – sufficient to handle the controversies that will undoubtedly arise. This essay offers some general

background information to help formulate a water and land use policy informed by a Proutist perspective (that is, a perspective which promotes economic decentralization and cooperative enterprises). While the focus is on Australia, the ideas should be applicable to most parts of the world.

The politics of water is intense. Supposing a community or country could come up with a water policy that represented the best possible compromise between the desires of urban consumers, farmers, environmentalists, miners and business, the reality when it came to implementation would be something different. Water scarcity threatens livelihoods which fuels fear and greed. If you want to get some taste for the intensity and complexity of water politics in Australia, an arid country suddenly confronted with water scarcity, read Ticky Fullerton's highly readable account, *Watershed*[4].

Developing policy is also difficult because one has simultaneously to deal with big picture thinking (ethics, culture, long-term future) and technological detail. Furthermore, water policy must vary from place to place, so it is difficult to make definitive statements that suit every situation. Nevertheless it seems worthwhile to make the effort because water policy is not just about water, but about land management, resource management, agriculture and industry, all of which are located at the heart of block-level planning.

Structure of the Essay

The obvious water policy issues revolve around supply, demand and storage. But a long-term water policy requires a holistic approach and this document is based on the premise that water policy cannot be separated from land management, agricultural practice and of course economic policy.

We begin with a brief historical review which is necessary in order to appreciate contemporary water policy issues, both general and Australian. Next we deal with the supply, demand, storage triangle because these present the obvious policy challenges. Finally we review the all important issues of land management and water administration.

To give you a feeling for what is to come, here are some key features of the approach to water policy advocated in this essay:

1. A decentralized approach to water harvesting and storage, that is, local planning and management.
2. Water harvesting integrated with land management and planned on a catchment by catchment basis.
3. Water harvesting preferentially (but not exclusively) by the capture and storage of rainwater where it falls.
4. Water is a public resource, a minimum requirement of life and necessary for collective security. The proposition that water should be

privately owned and traded, like any other economic commodity, cannot be supported.

5. Maximum utilization of water will require demand management and scientific research directed to water efficiencies.
6. Rational distribution of water to be achieved through water trading by publicly owned utilities and farmers' irrigation cooperatives, with independent statutory bodies having a regulatory role.

Some History

Water policy in the 20th century is best understood in the light of European experience in the preceding century. The story begins early in the 19th century with the introduction of the water closet, first into fashionable homes, followed by more general adoption. Today we might assume this to represent a step forward in public hygiene, but quite the contrary – it inaugurated a disaster that killed hundreds of thousands of people over the coming century. The water closets discharged into sewers which, in turn, discharged into rivers. Private water companies drew water from those same rivers and returned it to the taps and pumps of the general populace. European rivers were sewers and not enjoyed by those of delicate disposition. "I counted two and seventy stenches – all well defined – and several stinks", wrote Samuel Coleridge of a boating trip on the Rhine where it passes through the romantic city of Cologne. A sitting of the Houses of Parliament in London, 1848, had to be adjourned because of the appalling stench bubbling up from the Thames.[5]

As early as 1828, a distinguished physician, William Lambe, warned the public that drinking water known to contain "the decayed and decaying remains of myriads of animals and vegetables, in every stage of decomposition and putrefaction", might be harmful to health. Yet despite repeated epidemics of cholera and typhoid (a cholera epidemic in London, 1848, claimed 3,000 lives in one week alone), it took 100 years of heated controversy before common sense prevailed and drinking water was kept separate from sewage. Why did it take so long?

The first difficulty confronting water and sanitation experts of the period was lack of an appropriate theory of disease. Bacteria had not yet been discovered – cholera and typhoid were believed to be caused by a *miasma*, 'something in the air'. Without an adequate germ theory to stimulate investigation, progress was difficult. An important discovery was made in 1854 when all the cases of cholera in a Soho epidemic could be traced to a particular water pump. This discovery forever linked public health to water quality and was an important turning point in the history of public sanitation. But controversy persisted because there was still no agreement on the causative agent linking the two.

Indeed the controversy increased because of a second difficulty. The first water analysts, whose job it was to determine water quality, were inorganic chemists. (The science of organic chemistry was not yet recognized.) And their primary interest was the degree of enrichment of water by health giving salts believed to cure dyspepsia, rheumatism and other disorders. Money could be made from the right kind of mineral water and hence Bath and Harrogate became fashionable spas frequented by the rich.

As towns competed with one another to promote the therapeutic value of their springs, water quality experts felt the pressure to provide favourable analyses. From which it was but a short step for private water companies in London and other cities to promote the quality of their water over that of their competitors. It was a battle of the experts, with water quality chemists opposed to sanitary engineers. Here is a sample of the 19th century debate:[6]

> *Sanitary engineer*: "…a stream which receives daily the evacuations of a million human beings… with all the filth and refuse of various offensive manufacturers… cannot require to be analyzed, except by a lunatic, to determine whether it ought to be pumped up as a beverage for the inhabitants of the Metropolis of the British Empire."
>
> *Response of water chemist*: To drink tap water containing microscopic animalculae is "no more harmful than eating fish".

It was a case of reformers invoking science to sanction change and conservatives invoking science to prevent it, a situation which is disturbingly reminiscent of contemporary debates about environmental pollution and water quality. This situation deserves additional comment precisely because it is so relevant.

Scientists like to claim that they arrive at theories through observation and experimentation. Experience precedes theory. In practice the process is more cyclical, with experimentation stimulated by pre-existing theory to build new theory. If the cycle is broken for want of a satisfactory theory, investigation stagnates. Furthermore, scientific knowledge is not absolute – it is always subject to review. Scientists are happy with this state of affairs. Indeed they see it as a strength and as a necessary protection against dogma. But when science is required to inform public policy, its open-endedness becomes a weakness which powerful people exploit to serve their own interests. Thus we observe, even today, that scientific uncertainties about, for example, pesticide toxicity levels or climate change, are deliberately exploited to frustrate the political decision making process.[7] [8] While a solution in these cases would be an appeal to common sense or adherence to the pre-cautionary principle, in practice politics today is no better at framing public policy based on science than it was in the 19th century. The policy debacle surrounding climate change is a case in point. And future generations will look back in disbelief!

Something to think about

How long can we live?

Life expectancy in developed countries has risen steadily since 1840, and for women at the rate of about three months every year![9] Despite the recent epidemic of lifestyle diseases in developed countries, such as obesity, diabetes and hypertension, some scientists believe that there is no reason why longevity should not continue to increase. We may well ask why longevity is increasing. Is it due to modern antibiotics and drugs? In fact the greatest increases have come from low-tech public health measures such as the following (in order of importance):[10]

1. Clean drinking water.
2. Sewage treatment and separation of sewage from drinking water.
3. Use of soap for personal hygiene.
4. Mass vaccination.
5. Public housing – ensuring dry, disease free shelter for the great majority of the population.

Contemporary Issues

The realization that drinking water quality was an important determinant of public health had a profound effect on European social consciousness, one that is difficult to appreciate in the 21st century. But with regard to water policy that impact persisted pretty much throughout the 20th century. The provision of *plentiful, safe and palatable water for all* became a primary duty of the state. Water and sewage companies were nationalized because private companies were resistant to implementing changes that served the public interest but did not advantage themselves. For the liberal conscience, clean water became a matter of human rights. For the conservative, it was a matter of state security because epidemics sweeping through squalid city slums incited public unrest. And if further justification was required, archaeologists were uncovering evidence that great civilizations of the past, such as Mesopotamia and Acadia, had fallen for wont of good water management.[11]

Another hallmark of 20th century water policy was *water as an engineered product*. To obtain water in abundance required the building of large dams far from cities. The water then had to be piped to treatment plants where complex quality control ensured that the water delivered to houses was of a satisfactory standard. Indeed the greater the engineering prowess of a nation's water infrastructure, the greater its industrial might. The Hoover Dam (USA) and the

Snowy River Scheme (Australia) were very much products of that mind set. It has been described as the epoch of the *hydraulic society*, the apex of modernism.[12] Of particular note is that the provision of water in the *hydraulic society* had almost nothing to do with land management, ecology and the dynamics of biological systems.

From an economic point of view, 20th century water policy was dominated by the so-called *supply side paradigm*. Water resources planning, at least in developed countries, attempted to ensure that consumers did not suffer a restriction of supply. Attempts to restrain water use played a role only in times of drought and could be accomplished only if the public perceived a crisis.[13]

In retrospect it was inevitable that such a system would break. Population increase and growing per capita consumption increased the demand for water, while pollution of surface and ground waters made it more difficult to maintain supply. The privileging of water supply within the hydraulic society encouraged both excess quantity and excess quality for routine uses such as toilet flushing and garden watering. In short, the supply side paradigm proved unsustainable.

And so we come to the 21st century, where the emphasis has shifted from supply to *demand management*. While governments continue with efforts to increase water supply, they are confronted by the political costs of building large dams and recycling sewage and the energy costs of desalination. Thus the new approach is to reduce demand and to make much more efficient use of what water is available.

The emergence of economic rationalism in the late 20th century has also had an impact on water policy. Why, the rationalists ask, should water be different from any other commodity? The excess demand for water can simply be corrected by increasing its price. Besides, the price of water in the *hydraulic society* does not reflect its true economic cost. If water were privatized as it was in Britain in 1986, the increased price would provide incentives for entrepreneurs to find new methods to produce more water. Water freely traded in an open market would solve the mismatch of supply and demand. Perhaps not surprisingly the Business Council of Australia issued a report in September 2006 titled *Water Under Pressure: Australia's Man-made Water Scarcity and How to Fix It.* Its main argument, well publicized in the media[14] was that water shortages are due to economic mismanagement and could be solved by private investment to build water infrastructure. The then Federal Environment Minister, Malcolm Turnbull, welcomed the report by saying:

> The big urban water utilities are very profitable businesses. If those businesses are allowed to invest and do what they should do, which is to deliver the water the cities need, then we will not have – on a long-term basis at any rate – water restrictions in our major cities.[15]

Democrat Senator Bartlett was more circumspect. While admitting that the primary water issue is not about scarcity but about management, he cautioned against private ownership of water utilities because of the likelihood of profiteering.

> Water pricing and water markets desperately need to be reviewed; however, we should be wary about private ownership of water. Water availability is in the national interest and we should be concerned about profiteering to the detriment of water users or the environment. We need to separate ownership from pricing.[16]

Water is one of the last essential commodities in Australia not yet privatized. It has therefore become a focal point for competing visions about the future. For example:

- Water privately owned and traded in free markets to achieve efficient distribution versus water as a public commodity managed in the interests of the community.
- Water as a highly engineered product for a modern hydraulic society versus water cycled through ecosystems, passed from one community to another, with purity maintained by wetlands and managed aquifers.
- Public health as a product of mass inoculations and antibiotics versus public health as a product of a clean environment from which healthy food and pure water are harvested.
- Farms as agri-business, financed by *managed investment schemes* offering high rates of return to wealthy, city-based corporate investors versus farmers as custodians of the land and water and as producers of high quality food.

It turns out that visions about water management impinge on visions about the future of our society.

Australian Water Issues

Australia is a large continent. It is geologically old, it is mostly flat and it lies in the sub-tropics where temperatures are high but rainfall uncertain. These features conspire to produce a continent with a unique relationship to water. Except for the northern and eastern fringes, much of the continent is arid and afflicted with salt. Perhaps because of this, 80% of the Australian population is urban and almost all of it is coastal. And yet, surprisingly given the obvious aridity of the continent, Australians have a higher per capita water use than any other country in the world.

Commenting on Australia's profligate use of water, Dr. Rick Evans told the ABC science programme Catalyst:

> In a broad sense we have been spoilt. We have been used to using far more water than we need to use. We have been used to seeing it as an infinite resource for which we can just turn on a tap, or pump water out of a bore and it's just there. In reality that is not the way the rest of the world operates. We need to have a culture change.[17]

One is also reminded that Australians are among the highest per capita emitters of greenhouse gases and second only to the USA in per capita production of landfill waste. It is clear that Australia urgently requires policy initiatives to encourage maximum utilization of scarce resources.

The classical European water cycle, which usually informs hydrology text books, does not apply to most of Australia. Instead of mountain fed rivers that flow to the sea, Australia has shallow catchments most of which flow in-land across vast flood plains. Compared to other continents, Australia's big rivers hardly rate. The combined flow of all Australia's major rivers is about one-hundredth that of the Mississippi alone. The annual flow of Australia's greatest river, the Murray, equates to just one day in the life of the Amazon.

In her seminal publications, Mary White (described by Fullerton[18] as Australia's own Rachel Carson) argues that the early Europeans failed to understand the Australian landscape and the movement of water through it. Despite its dried and rugged appearance, the continent is ecologically fragile and it was perhaps inevitable that the imposition of European-style agriculture would wreak havoc.[19] For White, salt pans in agricultural land are a harbinger of impending disaster, just as the decimation of insects by DDT was for Rachel Carson. Of great concern is the long lag time between cause and effect in large-scale ecological systems, and the continent is only just starting to show the effects of 200 years of abuse.

Today about 70% of water consumption in Australia is used for agriculture. Furthermore farmers holding free-hold title are responsible for some 70% of the land. Consequently most of the difficult water policy decisions in Australia are directly concerned with land use and farming practice. The following is a list of just a few of the issues we face. There are no simple answers – these are deep moral and social questions:

- Much of Australia's agricultural land is in fact marginal for farming. Difficult decisions must be made about what farming is sustainable in a given catchment. These decisions require balancing long-term costs against short-term gain.
- Unwise irrigation practices have caused environmental devastation in Australia. Difficult decisions must be made about allocations to irrigation. This will involve trade-offs between economic and environmental costs.
- Water has multiple uses – irrigation, electricity, drinking supply and environmental flows. How to apportion scarce water will involve difficult

decisions. The power company Snowy Hydro was recently attacked for buying electricity from coal-fired power stations.[20] Its own hydro-electricity would of course come without a carbon cost. The company argued that it was preserving dwindling water supplies for town consumption and irrigation.

- Farmers care for 70% of Australia's land. If we are to reverse the destruction of wetlands, recover biodiversity, improve water quality and plant more trees for bio-sequestration, who is going to bear the costs? On-going civil disobedience campaigns by farmers (for example, see reports of deliberate illegal land clearing[21]) highlight this question.
- Australia's iconic tree, the eucalyptus, does not mix well with traditional agriculture. It has deep tap roots which lower the water table. Indeed it might be argued that the eucalyptus contributes to the aridity of the Australian continent. Elsewhere in the world, notably India and the Middle East, the eucalyptus has been ruthlessly removed from cultivated areas. Difficult decisions will need to be made as to how much we alter Australia's natural landscapes to satisfy human food and fibre requirements.
- Indigenous land management involves burning, partly to aid hunting and partly to encourage growth of edible herbaceous and tuberous plants. This practice, which is common to savannah communities around the world, is sustainable but maintains the landscape ecosystem in a state of arrested development. In particular it reduces tree cover almost 100 fold – trees which are needed for building soil, biosequestration, agroforestry, to name just a few. Choices will have to be made between legitimate land management practices.

Something to think about

If only Australia were in the northern hemisphere!

Australia is a major producer of wheat, wool, mutton, beef and cotton. The country has made a lot of money growing food and fibre. But for how much longer? Australia's past agricultural practices, in particular its profligate use of water and reckless land clearing, are simply not sustainable. European farming practices have provided a short-term bounty, but the creeping cancer of dryland salinity and soil erosion are a warning that the bounty will indeed be short term.

Why is so much of the Australian landscape so fragile for agriculture? Cotton has been grown in the USA for two hundred years, in some places for three hundred, without insurmountable problems. Cotton has been

grown in Australia for around 50 years and already some would argue the crop should not be grown in the country. Why the difference?

It is partly about rainfall reliability. The cotton belt in the USA enjoys a sub-tropical climate with abundant rain, well distributed through the year. This is ideal for cotton and the crop can be grown in Georgia and Mississippi without irrigation. Rainfall in Australia is less reliable, making irrigation essential. But irrigation in an arid climate with mobile salt requires more care and self-restraint than has been exercised to date.

However, it is not only about water. More importantly, according to Fullerton[22] US soils "are much deeper and richer, and able to buffer the abuse". Northern hemisphere soils were formed comparatively recently. The repeated advance and retreat of glaciers during the last ice ages pulverized rock, creating deep fertile soils. By contrast Australian soils are ancient and depleted. The last time glaciers performed their rejuvenating function was 300 million years ago. Dry, desiccating winds and water have long since eroded the surface, leaving a flat landscape with shallow soils and flood prone.

Australian ecosystems have adapted well to unpredictable rain. After a downpour, the deserts burst into life, a cacophony of plants and animals, all anxious to complete their life cycles before the return of arid conditions. But agriculture requires certainty, and the attempt to create certainty with dams, weirs and irrigation has destroyed a surprisingly fragile landscape.

Key Concepts

1. Just as 20th century water policy focused on hydraulic engineering, so the 21st century approach will be about ecosystem management and biotechnology. It will be about working with the water cycle and ecological and biological processes rather than usurping them. We cannot live outside ecosystem dynamics.
2. Water policy requires a *holistic* or *integral* approach. That is, it must simultaneously address global warming, drought, deforestation, land management, biodiversity, environmental flows for rivers, agriculture and so on. In Australia, it must also accommodate our unusual geography.
3. Except for the peripheral fringes of the far north, water is the limiting factor for human settlement and agriculture in Australia. Consequently water deserves to occupy a central place in community and economic planning. Water harvesting must be integrated with land management and planned on a catchment by catchment basis.

4. Harvesting and storing rainwater where it falls is the preferred method to obtain water. This approach lends itself to decentralized planning and management.
5. Deforestation contributes to climate change. Apart from producing food, Australian farmers should also have the responsibility for reafforestation and biosequestration. Agro-forestry is an ideal way to combine these two with food production.
6. Water is an essential requirement of life. Consequently, it should be managed as a public resource for the welfare of all. This will require appropriate cooperation of all levels of government and a regulatory role performed by independent statutory bodies.
7. Maximum utilization of water can be achieved through demand management and scientific research.
8. Rational distribution of water can be achieved through a mix of both planned allocation and water markets. Water traders would be licensed public utilities and irrigation cooperatives, with strong regulation to ensure that the community interest is served.
9. Water management has a cultural component. Encouraging respect for the Earth and its resources should be a central feature of an education for a sustainable future.

Supply – Water Production and Harvesting

The Water Cycle

Every schoolchild learns about the water cycle. Ocean water evaporates, falls as rain on the land and then flows back to the ocean either over the surface or underground (Figure 1). The cycle is driven by the heat of the sun, by wind and by gravity. So why reiterate this here? Because what is not necessarily clear from school is that the cycle is a unitary system on a global scale – its various parts all around the globe are interconnected. Rain in Europe is affected by currents far away in the Indian Ocean. Disrupt one part of the cycle and the entire global cycle is disrupted.[23] The importance of this fundamental truth cannot be over-emphasized. Some disruptions are obvious – if we take too much water from the rivers for irrigation ground water dynamics are disrupted. If we take too much ground water, surface waters suffer. Ground water flows and surface water flows are not separate systems.

Some human interventions, however, are not so obvious. Human induced climate change is already having an impact on currents in the Indian Ocean which can affect rainfall in far away Greece.[24] Clear felling large tracts of land

reduces rainfall because rain clouds do not form so readily over cleared land. India and Western Australia offer good examples.[25]

We ought not to discount the consequences of disrupting the global water cycle. A WHO report[26] estimates that "almost two billion people were affected by natural disasters in the last decade of the 20th century, 86% of them by flood and droughts". That's well over a quarter of the world's current population affected by severe water imbalance. Floods are the second most frequent kind of natural disaster, after windstorms. The largest cause of deaths through natural disaster is famine brought on by drought.[27] Many of these catastrophes can be attributed in part to human interference in the landscape and the water cycle. In what follows, we compare the merits and demerits of individual sources of water. But it is to be remembered that whatever the diversity of sources, humans are tapping into one and the same water cycle and that such interventions on a large scale can have unexpected consequences.

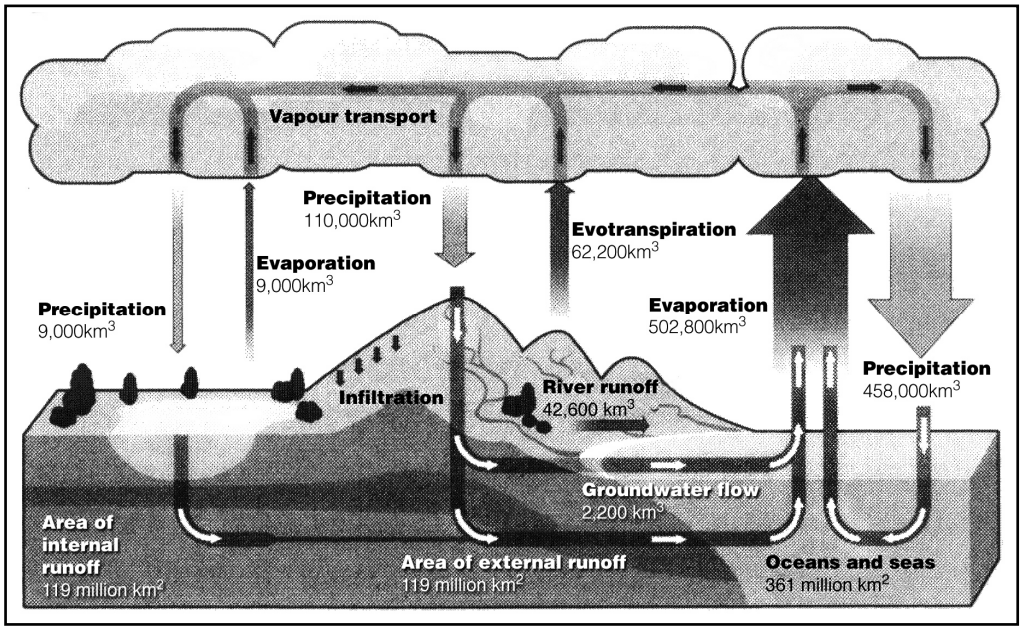


Figure 1: The water cycle on a global scale. Volumes attached to arrows represent annual flows. Numbers at the bottom of the diagram represent areas and static volume. In one year, the sun evaporates the equivalent of 125 cm depth of water off the world's oceans. However two thirds of this falls back onto the ocean and only one third makes it over land. But small fluctuations in this ratio can have major consequences for life on land. Australia has a higher rate of evapo-transpiration than other continents. In fact, because much of its river water is used for irrigation, some 90% of rain falling on the continent is returned to the atmosphere by evapo-transpiration. Note that one km^3 of water equals one million megalitres and a megalitre is the approximate equivalent of an Olympic swimming pool. Diagram from Black[28], reworked by Sahitya Graphics.

Surface Water

The harvesting and management of surface waters to provide potable water has been the primary focus of water policy in Australian cities until recent times. There is a strong logic to this. Rainwater is (assuming the absence of air pollution) fit for immediate drinking. The further water disperses through the environment, the more likely it is to become contaminated with pollutants, salts and other minerals. Furthermore once it reaches the ocean or deep aquifers it becomes more difficult to recover and process. In theory, the earlier we catch rainwater, the cheaper it should be to process and the better the public health outcomes.

The difficulty of course is that captured rainwater needs to be stored. Nature provides lakes and ponds but these are not necessarily located where humans can make best use of them. Hence the necessity to construct tanks, weirs, reservoirs and dams. The issues of storage will be discussed subsequently.

The harvesting of rainwater is most efficiently achieved where the rain falls on hard surfaces. Placing a dam at the bottom of a river catchment is rather like placing it below a sponge. As an example, despite heavy rain on 6th June 2007 on the Brisbane River catchment, very little of it entered the dam because the catchment soils were so dry. By contrast, rain which falls on a hard surface can immediately be diverted to a collection point. Consequently the possibilities for harvesting water in cities are extremely good given the large expanse of roofs and roads. Stormwater run-off from most Australian cities goes directly to the ocean where it is lost. The obvious problem with harvesting water in cities is pollution. Sydney and Adelaide are now addressing this problem by purifying water in aquifers – more on this below. Brisbane already harvests stormwater for its parks.[29]

If a policy of harvesting rainwater where it falls were actually followed, it would result in a highly dispersed system of collection and storage, since one cannot predict where rain will fall. In practice, the 20th century hydraulic society has opted for large dams sited at the end of large catchments. The principle argument in favour of this strategy is economic efficiency. We return to this issue in a subsequent section.

To summarize the advantages and disadvantages of using surface waters:

Advantages

- Easy to access.
- Rainwater should have high purity.
- Trapping water high in a catchment prevents fast moving water concentrating too quickly and causing erosion.

Disadvantages

- Surface waters require surface storage. Rainfall is unreliable – the more unreliable the rain, the bigger the storage required.
- Rain does not necessarily fall where it is most needed. Transporting water can be expensive.
- Many parts of the world cannot use surface waters because they are polluted. In developing countries 90% of domestic sewage and 75% of industrial wastes are released directly into lakes and streams.
- There are significant evaporation losses when water is stored in farm ponds, shallow dams or transported through canals. This is a particularly serious problem in Australia. Irrigators in the Murray Basin, for example, get just 80% of the water pumped to them. The rest evaporates in transit through canals, with concomitant concentration of salts.
- It is difficult to construct deep dams in much of Australia's flat landscape. The average depth of the proposed Traveston Dam north of Brisbane will be five metres. This is sufficiently shallow to allow the waters to heat up, leading to rapid evaporation and eutrophication.[30]

Ground Water

Ground water constitutes some 98% of the available liquid freshwater on the planet but the intemperate use of it is creating many problems. Ground water accumulates from the downward percolation of rain, river and lake waters and is stored in the pore space of soils, sand and rock. Sometimes it is useful to make a distinction between sub-surface water and deeper aquifers. Sub-surface water is closely associated with surface water and is immediately available to plants. By contrast, aquifers contain older water which is not necessarily accessible to plants.

Aquifers consist of thick layers of sand or stone permeated with water and trapped underneath (and sometimes on top) by impermeable rock. Thus, depending on the placement of the impermeable rock layers, an aquifer may or may not be isolated from the water table upon which farmers depend for growing crops. The water in deep aquifers is sometimes called *palaeo-water* or *fossil water* because it will have been underground a very long time, perhaps millions of years.

Many parts of the world rely heavily on ground water for town supply. Denmark, for example, obtains some 98% of its water supply from ground sources, Saudi Arabia 75%, London 70-75% and U.S. cities average 30-40%. By comparison, Australian cities acquire about 10% of their water from underground. There have been demands that this percentage increase.

Management of aquifers is necessarily an important component of water policy in Australia because, although the surface is arid, massive amounts of water lie beneath the surface. How that water should be used is not a simple issue. For some 60% of the continent, there is little or no surface water, so it inhabitants are entirely dependent on ground water. For ground water use to be sustainable, the rate of extraction must be less than the rate of recharge. In arid regions, recharge of local aquifers is likely to be minimal – the water is fossil water accumulated in the distant past when rainfall was much higher than today. For decades, hundreds of bores into the Great Artesian Basin (currently there are 892 of them[31]) have been allowed to spill water senselessly onto a sunburnt landscape 24 hours a day, every day of the year. Obviously such practices are unsustainable. For many aquifers it is difficult to measure the rate of recharge and therefore to determine whether current use is sustainable or not.

The advantages of ground water use

- Aquifers tend to be spread over a large area so it is possible to extract water where it is required, obviating the need for expensive pipelines and transport.
- Water stored underground does not evaporate.
- Ground water is typically filtered and purified as it moves through an aquifer and hence tends to be less polluted than surface water, especially in heavily populated areas. It is precisely for this reason that European cities have come to depend on ground water for town supplies.

The disadvantages of ground water use

- Ground water abstraction, in excess of replenishment, lowers the water table thereby affecting local wells and agriculture. The famous Ogallala aquifer in the USA (containing 20% more water than Lake Huron in the Great Lakes) is being depleted at a rate 14 times faster than nature can replenish it. Likewise irrigation in India is using water so fast that local water tables are dropping year by year. A well of 10 metres a few years ago now needs to be 80 metres deep and in some locations wells must be refilled by tanker. China, with a population of 1.2 billion people, has only half the water it needs, and relatively insufficient areas of arable land. It relies heavily on ground water but its water table is falling at about 1-2 metres per year. The country's development policy requires diverting most of its useable water to industry at the expense of agriculture. According to Mary White,[32] China is an *ecological catastrophe* waiting to happen. What happens when China cannot feed her people?
- While not subject to evaporation, ground waters can become saline due to leaching or seepage from irrigated farmland. Even when not polluted by human activity, water in aquifers can be contaminated with heavy metals

and other minerals, such as arsenates, leached from the rock matrix. In just three districts of Bangladesh alone, arsenicosis kills over a million people a year, with many more suffering side effects. This problem could be entirely prevented by collecting rainwater, which is abundant in Bangladesh.

- Irrigation with ground water containing even low levels of salt can exacerbate salinity due to evaporation.
- Abstraction of ground water is a form of mining which can lower the land. For example, abstraction of water for industry is causing Venice to sink into the sea.
- Professor Lance Endersbee[33] claims that much of the world's ground water is a non-renewable resource, that is, it is not replenished by percolation from the surface. He claims that rapid consumption of ground water has put the world on the edge of a catastrophe, far more serious that global warming. This is a controversial and disputed claim but it has received some media coverage.[34]

Despite the call for Australian cities to use more ground water, this strategy should be approached with extreme caution. Unlike other Australian cities, Perth in Western Australia gets some 80% of its water from ground aquifers. The consequences for local eco-systems have been devastating. Lakes and wetlands are drying up with spread on effects to animal and bird populations. Furthermore, excessive freshwater abstraction has sucked in salty ocean water from the coast.

Desalination

Desalination involves the removal of salts from ocean or brackish water to generate freshwater. The most common methods are distillation and filtration (which includes reverse osmosis). Both of these are energy intensive and therefore expensive. Consequently the oil-rich, rain-poor Middle East has been the only part of the world to rely primarily upon desalination – at least until now. In response to the worst drought in 100 years, Australia is contemplating a desalination plant in all of its major coastal cities. Indeed the Queensland government recently flirted with plans to build a desalination plant on Bribie Island to supply Brisbane city. With a $3 billion price tag, it would have been the world's largest.

Distillation consists of applying heat to salty water to create water vapour, which is then condensed to produce pure water. Distillation is more cost-effective in conjunction with steam-turbine power generation because the steam released from the power plant can be sent directly for distillation. Distillation technologies account for approximately one-half of the world's installed desalination capacity.

Reverse osmosis is a low temperature, high-pressure membrane filtration process that forces water through the molecular structure of several sheets of thin plastic membranes to filter out minerals and other impurities, including salts, viruses, pesticides and organic molecules. The membranes are like microscopic strainers. A difficulty with current technology is that the plastic membranes become clogged with bacterial bio-films and offer unnecessarily high resistance, adding to costs. However, scientific research directed to these problems is bearing fruit.

For more information on desalination see the accompanying endnote.[35] Like all other water sources, desalination has it advantages and disadvantages.

The advantages of desalination

- An obvious advantage is that desalination is climate independent. Rainfall is irrelevant. When placed by the coast, desalination plants have virtually unlimited supplies of ocean water.
- Desalination, particularly using filtration technologies, provides superior quality water, regardless of the quality of the source water.
- Water desalination is commonly described as a *hardware technology*, meaning that it is accomplished by means of pumps, filters and other pieces of equipment that can be scaled to meet the expected demand. Additional capacity can be added with relative ease by increasing the numbers of filtration elements. This flexibility is important when trying to optimize capital investments to match demand projected over time.
- The hardware nature of desalination allows for new cost-saving innovations, such as foul-resistant membranes and improved energy recovery devices, to be incorporated into existing plants with relative ease.
- Desalination plants have more flexibility of siting compared to conventional surface-water alternatives, thus minimizing treated water transmission costs.
- Desalination is gaining cost competitiveness as surface and ground waters become more difficult to manage.

The disadvantages of desalination

- Desalination is energy hungry. Power costs can account for 30-60% of the operational costs. Thus, slight variations in power rates (remember peak oil) directly impact the cost of treated water. Note, however, that Sydney and Perth, unlike the Gold Coast, have opted for desalination plants powered by renewable energy.
- A by-product of the desalination process is a highly concentrated saline stream that requires careful management and disposal. Anticipation of strong objections from the fisheries industry operating around Bribie Island

possibly persuaded the Queensland government to delay plans for a plant on the island. Some of the most common methods for disposal of the concentrate are: solar evaporation ponds, injection into depleted oil and gas fields and open-ocean discharge. Safe disposal of the concentrate is a significant cost factor.

- Desalination requires both pre- and post-treatment of the water. The objective of pre-treatment is to remove suspended matter in the source water and to condition the water by adding anti-scalants and lowering the pH to improve membrane performance and prolong operational life. Desalination by reverse osmosis is so effective that a post-treatment phase is required to re-mineralize the product water and readjust the pH. As in all public water supplies, treatment concludes with chlorination. As a matter of interest, drinking highly demineralized water is extremely bad for health, since, on its passage through the body, water is re-mineralized by drawing on the body's reserves.

We are entitled to view desalination as the apotheosis of the *hydraulic society*, the ultimate in the engineering of water. It is yesterday's thinking fulfilled with the latest in modern technology. It does not require that we carefully manage catchments. It does not require that we use water more efficiently. It does not require that we stop polluting surface and ground waters, or that we stop using the oceans as the ultimate sewer. It is a business as usual solution. It is however a rational solution in a country where surface and ground waters are polluted, where energy is cheap and where greenhouse carbon is not costed. In 2010, Australia is just such a place, but what about 2020?

Other Water Sources

Cloud seeding

Cloud seeding has a controversial history. The first documented case of human-made rain occurred in 1947 near Bathurst. Ongoing research led to the commencement of cloud seeding experiments by Hydro Tasmania and CSIRO[36] in 1964. Typically silver iodide, dry ice or hygroscopic salts are sprayed onto already existing rain clouds. It takes about 30 minutes for the ice crystals formed to grow to sufficient size and fall out of the cloud under their own weight. As the ice falls, it melts to become rain.

While Hydro Tasmania claims three successful experiments, CSIRO remains sceptical. Trying to prove that a particular rainfall event is caused by seeding is a difficult statistical exercise because of the great variability of normal rainfall. The CSIRO says its trials conducted in Victoria in the 1970s and 1990s were unable to prove that cloud seeding worked. Scientists at the National Academy of Sciences (USA) in 2003 came to the same conclusion. The official position of the American Meteorological Society (AMS) is that there has been some

statistical evidence showing a 10% increase in precipitation after cloud-seeding, but no conclusive cause and effect. Another observation to emerge from cloud seeding experiments concerns the effect of air pollution. The AMS claims that clouds in the USA are full of aerosols, dust and industrial pollutants, which impair a cloud's capability to produce rain.

Despite the uncertainties, some forty countries, including South Africa, the United States and China spend big money to practise weather modification and the emerging consensus appears to be that cloud seeding works but one has to get the conditions exactly right – and there are many variables. Snowy Hydro has announced it will undertake a six-year $5 million trial in the Snowy Mountains, spraying clouds with silver iodide. The company predicts that snowfall could increase by 10% and deliver improved environmental flows to the Murray River. The Queensland government also plans to trial cloud seeding in the drought stricken southeast of the State.[37]

The budget for cloud seeding experiments runs into millions. Would the money be better spent achieving water efficiencies in other ways? A desalination plant costs in the hundreds of millions, an order of magnitude greater, but of course the yield is certain. If a cloud seeding experiment works, the increased crop yields for farmers in one season alone can be worth hundreds of millions. These are the kinds of calculation that exercise water engineers.

Figure 2: A 'hole' remains in a deck of stratus clouds after seeding with dry ice.

Caption in the lower right reads: "Effects of seeding Altostratus Clouds over Green Bay, Labrador: 45 minutes after seeding with dry ice." USAF photo from Sewell 1973.[38]

Perhaps cloud seeding becomes a more viable proposition if we do not think in terms of increasing rainfall but rather targeting rainfall. Much rain has fallen in parts of Southeast Queensland over the past few years, but not in the catchments which supply Brisbane city. The cloud seeding experiments

proposed for the region are intended to target rain towards dam catchments rather than have it fall over the ocean or in places where it cannot be stored.

Something to think about

It's not just about drinking water!

Clouds are not only seeded for rain. Other motivations for weather modification include attempting to reduce the severity of hurricanes and dispersing fogs that threaten to drift over airports. Here are some more unusual experiments in cloud seeding:

- From 1967 to 1972, the US military seeded clouds with silver iodide to extend the monsoon season over North Vietnam, specifically the Ho Chi Minh Trail. The targeted areas experienced monsoon seasons extended by an average of 30 to 45 days. The motto of operation Popeye was *make mud, not war*.
- Russian military pilots seeded clouds over Belarus after the Chernobyl disaster to remove radioactive particles from clouds heading toward Moscow.
- During the July 2006 G8 Summit, Russian President Putin deployed air force jets to seed incoming clouds, intending that the rain should drop over Finland rather than the summit location. The attempt failed and rain drenched the summit anyway!
- In Southeast Asia, large-scale forest burning produces a haze that pollutes the regional environment. Cloud seeding has been used to improve the air quality by encouraging rainfall.
- For other interesting information, see the Wikipedia entry on cloud seeding.[39]

Air dehumidification

One of the side effects of the drought in Australia has been a downward pressure on metropolitan property values as gardens die for lack of water. An enterprising Brisbane company is selling modified refrigeration units which cool air and extract the moisture. One unit generates 500 litres a day. Compared with other sources of water, the process is extremely expensive (the units sell for $20,000 AUD) but apparently justified in some city blocks by the retention of property values.[40]

An Australian inventor claims to have invented a wind turbine which can extract an average of 7,500 litres of water per day from the air.[41] This is enough for a small village but the device is yet to be independently tested.

Afforestation

It is well known that deforestation or land clearing has a major impact on local hydrology. In Australia, the effect is to raise the water table and bring salts to the surface where they are concentrated through evaporation. However it is now becoming clear that deforestation has another effect – it directly impacts on rainfall. Studies in the Western Australian wheat belt suggest that drought is as much a product of land clearing as it is of global warming. How this works has only recently been understood.

The wheat belt in Western Australia is the largest artificial feature on the Australian continent visible from space. One sees it as an orange strip of cleared land, surrounded east and west by darker native vegetation. The natural vegetation to the east is separated from the wheat belt by a rabbit proof fence that extends north from Esperance to Geraldton. It was originally designed to keep rabbits from invading the wheat belt, but today it provides an ideal opportunity to study the effect of land clearing. The soil type and geological features are identical on both sides of the fence. The only difference is that to the west of the fence, the land has been totally cleared for cropping.

Since the clearing of the land, rainfall on the wheat belt has declined by 20% with devastating effect on yields and soil fertility – a consequence of global warming, one might presume. But the problem with this explanation is that over the same period of time rainfall to the east of the fence has increased by 10%. According to Professor Tom Lyons[42] at Murdoch University, who has studied the weather on both sides of the fence, even the clouds over the native vegetation are quite different from those over the wheat belt. Wheat requires a lot of water to grow and transpires a lot of moisture into the atmosphere. By contrast the native vegetation is frugal with water and yet rain clouds form overhead. So what is going on?

It seems that the dark native vegetation absorbs much more heat than the cereal crops and the warm humid bush air therefore ascends high into the atmosphere to the level where clouds are formed. Furthermore, the warm rising air passes through cooler air and generates turbulence which is also helpful for cloud formation. By contrast, the cold humid air above a wheat crop is stable and does not rise into the atmosphere. It can be blown away by winds.

The conclusion from the Western Australian study is that it is possible to increase rainfall over land by maintaining tree cover and that failure to do so allows clouds to pass overhead and drop their water elsewhere. In India, it appears that de-forestation makes the difference between clouds dropping their rain over land versus over the ocean. According to Professor Lyons, tree cover has its effect on a scale of about 20 km. The take-home message – trees bring rain.

Inter-catchment Transfer

Water grids

The strategy behind water grids, and even their terminology, is derived from the electricity grid. The idea is to link multiple suppliers and consumers into a large network. This allows for more flexibility in providing power where it is needed and it increases security in the event that one generator should break down. The Queensland Water Commission is preparing plans for a Southeast Queensland Water Grid that will link dams hundreds of kilometres apart.[43] Their website claims the following advantages for a water grid:

- It provides a network of two-way pipelines to connect major bulk water sources in the region.
- It allows water to be moved from areas of surplus to areas of shortfall.
- It allows risk to be managed at a regional level rather than on a storage basis.

The proposed water grid will link three existing dams, two proposed dams, a desalination plant on the Gold Coast (currently under construction) and a recycled water plant.

The Queensland government has even more ambitious plans. It has authorized a $2 million feasibility study into the construction of a $7.5 billion, 1200 km water pipeline from North Queensland to Brisbane over the next 50 to 100 years. The justification is that the north of the State has plentiful water[44] but it is needed in the southeast to cope with population increase and climate change. The pipeline would draw water from the Burdekin and feed into the southeast water grid. Apart from the huge capital cost, the running costs are likely to be more than $250 million a year.

The northern parts of Australia have always tempted the south with the allure of limitless water, and schemes to take that water south are at least 100 years old. More recently (in 1998) Western Australian MP Ernie Bridge claimed that Australia could be drought proof within 10 years using only a minute percentage of the major northern rivers to achieve the result. And in the 2006 State election, the Western Australian Liberals ran (and lost) on a pledge to build a canal from the Kimberleys to Perth. That would have been a canal of some 3,700km and costing $2 billion.

Grandiose hydraulic engineering projects are usually rejected by environmentalists. Multi-billion dollar desalination plants, canals and pipelines have one element in common – "faith in large-scale engineering solutions to solve environmental problems".[45] But all too often such grand ideas turn out to be grand follies. The Snowy River Hydro-electric scheme, it is beginning to appear, may be no exception.

The Snowy River Hydro-Electric Scheme

Australia's greatest of all public works is the iconic Snowy Mountains Hydro-Electric scheme, an unquestioned marvel of hydraulic engineering. But at 30 years old it is beginning to look a bit sick. Grand idea or grand folly? As might be expected, the answer is hotly contested.

The Snowy Scheme brought new sources of electric power on line to feed industrial growth and it opened up vast tracts of land for irrigated agriculture. Economic statistics tell a story of unparalleled success. The gross value of Australian agriculture in 1997 was about $28 billion. Much of it came from the Murray-Darling Basin – Australia's bountiful food bowl, as big as France, and producing food and fibre worth $10 billion a year, about a third of it attributable to irrigation waters diverted from the Snowy.

In fact, 99% of the headwaters of the legendary Snowy River were diverted through mountain tunnels into the Murray-Darling Basin. Put another way, one catchment was killed in order to give life to another. But the profligate use of water in the Murray-Darling Basin has created a litany of serious environmental problems – salinity caused by a rising water table, destruction of wetlands that purify ground water, loss of wildlife habitats and loss of native fish due to polluting algae. It is also becoming apparent that not even the economic advantages are unambiguous. Lost agricultural production in the Murray-Darling Basin due to land degradation, salinity and soil erosion was estimated in 1998 to be around $220 million per year. In a 1998 ABC Lateline program Dr Judy Messer of the Nature Conservation Council, NSW, stated:

> Clearly the Snowy Mountains Scheme is ecologically flawed. Whether it is economically flawed or not is yet to be proven. But it may turn out that way in the future, if the lands go out of production because of salt.[46]

Transporting water by ship

A business called "Solar Sailor Holdings Ltd." is planning to ship 50 super-tankers per year of water (500,000 tonnes per ship) from the west coast of Tasmania to Sydney. The ships will be powered by wind and solar-power. According to CEO Robert Dane, the business expects to make a profit of $300 million AUD per year per city supplied. The economic feasibility of the plan has however been questioned.[47]

Towing icebergs and towing freshwater in large plastic bags

Towing icebergs to nearby ports was once considered a serious option for cities at high latitudes. However the melting of ice sheets due to global warming makes this a doubtful long-term option. Freshwater floats on salt water and it is therefore theoretically possible to tow water over the oceans in large plastic bags. But once again the economic viability of this approach is doubtful.[48]

Advantages of inter-catchment transfer

- Allows water to be moved from areas of surplus to areas of deficit.
- Allows risk to be managed at a regional level rather on an individual storage basis.

Disadvantages of inter-catchment transfer

- Water is expensive to move up-hill and even horizontally through pipes.
- There is a real and demonstrated danger of a *disconnect* between the ability to supply and willingness to consume. This is because the environmental and social costs of wasteful consumption are not entirely met by those who are profligate.

Figure 3: A cheaper way to transport freshwater over the ocean. The world's first commercial merchant ship pulled by a giant high-tech kite aiding its engines to slash fuel consumption and cut greenhouse gas emissions was launched in Hamburg, 14th December 2007. The SkySails system purports to be able to lower a ship's annual average fuel costs by between 10% and 35%.[49]

Indirect Potable Reuse

Indirect Potable Reuse is the technical term for water recycling. The traditional urban water cycle works something like this. Water is taken from an elevated river or dam, gravity fed to town, treated and then made available to the consumer. Typically the water is used once, for anything from drinking, toilet

flushing to dust suppression at a building site. The waste water is then pumped to a sewage plant (but not necessarily), from which the effluent is pumped to a downstream location or to the ocean. This *one-use urban water cycle* is wasteful.

Recycling water, especially sewage water, is a contentious issue and it has taken a severe drought for it to become electorally possible in Australia. The genuine concern of consumers is that, given the great diversity of drugs, hormones and chemical pollutants ingested by people today, can we be sure that those also will not be recycled.[50] The chairman of National Water Commission (as reported in *The Age*, 1st May 2007) argues that this problem can be solved by technological innovation. He claims that recycling will make "unlimited supplies of urban water" available.

The truth is that people in most parts of the world are already, albeit unknowingly, drinking recycled water, because downstream towns are drawing on waters that have previously been used by upstream towns. The fraction of wastewater effluent in a European river can be as much as 50%.[51]

In planned indirect potable reuse, treated wastewater is intentionally returned upstream to be mixed with native water and then treated again for potable use. Critical to the acceptability of water recycling is the intervention of multiple *barriers* to remove contaminants. These barriers may include all or some of: settling ponds, filtering, reverse osmosis, dilution, sterilizing and use of wetlands and aquifers for natural cleansing.[52] However the entire process is extremely expensive – better surely, to minimize water consumption in the first place.

Water Storage

Homeostasis

The primary objective of water management is to supply water of appropriate quality, when and where there is a demand for it. The policy challenges are quantity, quality, location and timing. Behind this simple statement lies a deeper and more fundamental concept, *homeostasis*. Homeostasis is the ability of a living system to maintain a stable internal environment despite a fluctuating external environment. It is the *sine qua non* of life – indeed one might say that the struggle to achieve or maintain homeostasis *is* life. Simple cells maintain a constant internal concentration of critical nutrients, such as sodium and potassium, and they expend considerable energy to do this. Animals and plants maintain a metabolic equilibrium between all parts of the organism. The development of warm-blooded animals capable of maintaining metabolic activity even in sub-zero temperatures was a momentous milestone

in the evolution of life on planet Earth. From an evolutionary point of view, it seems as if the more a species can guarantee the constancy of its internal environment, the greater are the opportunities for it to develop sophisticated behaviours and to push the boundaries of life.

A common means of maintaining homeostasis is the *reservoir*. For example, a reservoir of fat or starch enables plants and animals to have instantly accessible energy to meet unexpected demands in an unpredictable world. The reservoir is drawn down in times of hardship and replenished in times of plenty. This mechanism is fundamental to life and is referred to in Sarkarian philosophy as *prama trikona*,[53] that is, equilibrium established through the triangulation of forces. The intuition is that a triangulation of vectors (three forces interacting with one another) forms a stable structure, whereas larger polygonal sums of vectors are not stable.

Interestingly enough, despite the critical importance of water for life, very few animals have developed the ability to store water internally. Even the camel only stores water in virtual form as fat. Animals typically adopt the *just in time* strategy, drinking from a water hole when thirsty. This inadequacy at the individual level is dealt with in human communities by collective approaches to water storage and management. Indeed, we may trace the story of human civilization by its ability to manipulate and store water. The core idea is that the more a society is able to maintain stable supplies of water, the greater the possibility to develop the social, political, military and cultural institutions that define human civilization. Nomadic life was constrained by the need for proximity to clean flowing water. Subsequent to the development of agriculture, the ability to construct canals and irrigate fields was of momentous importance, because it ensured a stable supply of water despite the fickleness of rain. This is as true in the modern capitalist era as it was 3,000 years ago.

In Sarkarian philosophy, a modern economy is a living system. Just as cells, animals and plants maintain homeostasis, so also an economy. A healthy economy is one which can maintain a stable supply of the necessities of life at stable prices despite the exigencies of weather, etc. Hence communities maintain stores of rice, businesses maintain inventories and capitalists maintain hedge funds. Homeostasis of the total economy is the result of all its individuals and businesses maintaining their own equilibria. Even the home refrigerator is a manifestation of homeostasis – it obviates a trip to the shops after every meal.

Yield

Water management strives to maintain an equilibrium between the supply, demand and storage of water and to influence the biological and psychological impulses that impinge on achieving that equilibrium. From a purely engineering perspective, it is convenient to think of water resources in terms of

reservoirs, inputs and outputs. Reservoirs may be lakes, dams, weirs, aquifers or even, as we shall see, soil and tree roots. Input to surface reservoirs depends on springs, precipitation and snow melt in the upstream catchment. Input to aquifers depends on the amount of water entering recharge zones. The output from a reservoir is the natural outflow plus that which is abstracted for human use, the *yield*. Determining a sustainable yield for any particular catchment or reservoir is surely the most contentious issue in water policy.

Consider the Snowy River whose water has three uses: 1) diversion to the Murray Basin to grow some 30% of the nation's food, 2) to meet the needs of the 6,000 or so inhabitants of the Snowy Basin and 3) to provide environmental flows, that is, to allow the Snowy River to be a river. From an engineering perspective the third use was at one time not considered important, so the *yield* of the Snowy was the 99% of flow diverted to the Murray. But once in the Murray, the water was over-allocated for irrigation. Indeed approved abstractions from the Murray-Darling system amount to some 80% of its average annual flow. No wonder the river is in trouble! In both river basins, yield is at the expense of environmental flows.

Speaking on the ABC Lateline program,[54] Dr. Judy Messer of the Nature Conservation Council of NSW argued:

> The water belongs to the public. It's a public resource which the irrigators are allowed to purchase under license conditions. If you are going to have healthy rivers, you have to allow the environment, the receiving environment, to get enough water to keep the rivers healthy. That is absolutely critical.

Responds Laurie Arthur, a rice farmer in the Murray Basin:

> It sounds very easy – take water off the irrigators, let it run down the river and everything will be fixed. Well that's not the case! White man is on this continent now and we have made radical changes to the landscape and we have to address those changes and the only way we can do it is with profitable farmers.
>
> Our profitability comes from our water use. We need that profitability to put back into our farms for all the environmental projects – we are putting in recycling dams, we are lasering our country. We are using less water. We need profitability to continue with that work.

Responds Dr. Judy Messer:

> Well, the irrigators are the ones that are making the profits so there's no reason why they shouldn't bear the cost. If there is a cost to the environment then everybody has to wear it – it's as simple as that.[55]

Ideally, the yield of a river or reservoir should be determined by its ability to supply over the long term while also maintaining a healthy environment. In practice, yield is determined by a balance of political pressures, and once a

population and its economy become dependent on a water supply it is almost impossible to turn off the tap. But the painful truth is that water for irrigation in the Murray Basin is greatly over allocated. Past yields are not sustainable because nature is turning off the tap.

Surface Reservoirs

Conserve water on multiple scales

We have noted earlier the advantages of collecting rain where it falls – the water is of high purity, it is easy to access and trapping water high in a catchment minimizes soil erosion. However, storing water where it falls requires dispersed, decentralized storage facilities on multiple scales, that is, small house tanks, ponds, weirs, reservoirs and dams of various sizes. As appropriate they can be interlinked by pipelines, canals, culverts and tunnels so that water can be moved from regions of surplus to regions of deficit.

Debates about water storage in Australia are highly polarized. For a concrete example consider the Queensland government's intention, announced in 2006, to build a large dam on the Mary River at Traveston Crossing some 200 km north of Brisbane. This dam will have a surface area larger than Sydney Harbour, it will inundate 600 to 900 farms (numbers have varied between announcements), wipe out a small community and threaten a species of lung fish having great scientific importance. The government is making its case with dramatic photos of dry dams and the threat of no water. The residents of the Mary Basin are adamantly opposed.[56]

What has been the environment movement's response to the dam? The only alternatives mentioned in a recent edition of ECO (a newspaper published by the Sunshine Coast Environment Council[57]) were house tanks and recycling. Of course house tanks and recycling must be essential ingredients in Australian water policy but it seems that, in the Queensland debate, there is nothing between a house tank and a huge dam. Such polarization is limiting our options.

The power scaling law

An important principle of systems that operate on multiple scales is the *power scaling law*. A cryptic version of this law might be: *the smaller it is, the more of them there are.* In the case of water harvesting, this translates into the installation of very many house tanks but the building of very few large dams. But it also means the construction of intermediate size storages, town weirs, ponds and public water tanks of many sizes.[58]

Why is this idea so important? Because the power scaling distribution is observed everywhere.[59] In fact, it is observed so widely in the natural world that it is thought to have survival value, that it offers resilience in the face of

external stresses and change. In the case of water, *reservoirs on multiple scales* (many small reservoirs, few large ones) enables local communities to have control over local catchments but to enjoy the advantages of global connectivity. It offers local security within global security.

Opposition to large dams

The power scaling principle begs the question – what is the maximum sensible size for a water reservoir? Political opposition to large dams has grown rapidly in recent years due to the social and environmental damage that they cause. Large dams are usually defined as those having walls over 15m in height and holding 3 million cubic meters of water.[60] Mega-dams can be over 100 metres tall and hold billions of cubic metres of water – for example, the Aswan Dam contains 168,000 million m^3, or 168 cubic kilometres.

China, the USA and India are the top three dam builders in the world. Most are built for irrigation and proponents point to increased agricultural productivity and the ensuing economic benefits. But the benefits are not evenly distributed. Those downstream benefit but those upstream tend to be losers, especially displaced families. Since 1947, the 4,300 large dams built in India have displaced over 42 million people, predominantly indigenous minorities. When the Mekong River in Thailand was dammed, the numbers of fish, staple food of the locals, dropped by two thirds. But because dam management is centralized, local populations did not derive equivalent compensating benefits. Proponents of large dams simply ignore the negative social and environmental consequences. Opponents argue that a larger number of small reservoirs would have the same benefits for agriculture without the severe environmental and social consequences.[61 62 63]

Opposition to big dams is growing everywhere in the world and their construction proceeds only where highly centralized power can squash local opposition.[64] People who promote centralized economic power are invariably not interested in distributing its benefits. Hence in the harvesting of water, as with the other essential requirements of life, it is better for communities to pursue a decentralized approach.

Managed Aquifer Recharge

Water enters aquifers in recharge areas and emerges from aquifers in discharge areas. We may analyze sub-surface water resources in the same way as surface resources. They are stores of water having both inputs and outputs, and we wish to determine their sustainable yield. However there is a critical difference: the input to storage ratio is much reduced and monitoring aquifer flows and therefore calculating a sustainable yield is difficult. Consequently it is easy to draw on sub-surface waters for a long time before the consequences of excessive abstraction are realized. As noted earlier, Perth derives some 80% of

its town water from ground aquifers but the devastating effect on local eco-systems is only belatedly apparent.

Some cities around the world have introduced *managed aquifer recharge* to help replenish aquifers. For example, Perth has plans to return 20% of its treated sewage to aquifers.[65] Adelaide already has such a system and Sydney has an experimental system where stormwater runoff from roads is captured and returned to an aquifer which runs under the city from Centennial Park to Botany Bay. Just ten metres of aquifer are sufficient to remove phosphate pollutants and twenty meters to remove coliform bacteria. But water moves slowly through the aquifer, taking ten years to traverse its eight kilometre length.

Something to think about

Fossilized water

Water moves through the Great Artesian Basin at about one metre per year. The time taken to travel from recharge areas on the western slopes of the Great Dividing Range in Queensland to discharge mound springs in arid South Australia is around two million years.

Soils and Wetlands

Soils

A handful of average soil consists of about 45% by volume of minerals, silt and sand, 25% air, 25% water and the remaining 1-5% is organic matter. Of course these proportions vary greatly from soil to soil but the point to note is that soils can store an extraordinary quantity of water over an entire catchment. The figure of 25% is typical for a loam soil that has been saturated with water and then allowed to drain. Of that 25%, about half is water available to plants and the remainder is tightly bound to soil particles. The water holding capacity of a soil is, however, greatly influenced by its organic matter content, enabling a healthy soil to soak up water like a sponge.

We have already noted that harvesting water in a soil covered catchment is rather like catching water on the surface of a sponge. However sub-surface water is not necessarily lost to the water engineer. Rather the soil, microbial life and plant roots constitute a *biological reservoir* of water. The *bio-reservoir* is yet another manifestation of ecosystem homeostasis – water is stored in times of plenty and slowly released in dry periods, thereby helping to maintain an even flow of water in rivers despite seasonal fluctuations of precipitation.

Trees are an excellent form of flood control, and planted in appropriate places within a catchment they mitigate the need for costly engineering of embankments, drains, etc. And of course water is purified as it passes through a tree plantation. The planting of native water-frugal species along river banks is an important water conservation measure. The most appropriate choice of tree species will depend on the individual catchment and its function in the larger water management plan. The bigger objective is to restore the biological diversity and ecological integrity of waterways.

Wetlands

The term *wetland* is the more general and more modern name for swamps, billabongs, ponds, salt-marshes, mudflats and mangroves. Wetlands are simply areas of land that have acquired special characteristics from being wet on a regular or semi-regular basis. The term also applies to depressions in the landscape of our more arid regions that only occasionally hold water, but which, when they do, teem with life and become environmental focal points.[66]

Wetlands are a crucial component of the normal water cycle because they link surface and sub-surface waters. Indeed in a country as flat as Australia, surface and sub-surface waters cannot be considered separate systems. During the wet season, water flows as a sheet over the landscape. During the dry season, the water shrinks to a chain of ponds. Water still flows but more slowly, sometimes on the surface, sometimes below ground. Wetlands are not wastelands. Destroying a wetland breaks a link in a chain and the entire water cycle breaks down. Some additional benefits of wetlands include:

- Wetlands improve water quality by removing, using or retaining nutrients, organic waste and sediment which is carried to the wetland with runoff from the watershed.
- Wetlands reduce severity of floods downstream by retaining water and releasing it during dryer periods.
- Wetlands protect stream banks and shore lines from erosion.
- Wetlands recharge groundwater, potentially reducing water shortages during dry spells.
- Wetlands provide food and other products, such as commercial fish and shellfish, for human consumption.
- Wetlands provide fish and wildlife, including numerous rare and endangered species, food habitat, breeding grounds and resting areas.
- Wetlands offer opportunities for recreation, bird watching, photography and outdoor education.

The Commonwealth Government of Australia is signatory to an international convention on wetlands known as the Ramsar Convention. This commits

countries to maintain an audit of wetlands and to preserve and improve their quality. Approximately 4,700 regionally important wetlands have been identified in Australia. Those in the north tend to be in better condition than those in the south, where grazing pressure, exotic weeds, feral animals and urban development continue to threaten wetland integrity.

Demand – Water Consumption

Demand Management

Water consumption is frequently divided into four categories:

- Domestic consumption serviced by water companies.
- Power generation – steam is used to drive generators.
- Industrial – everything from beverage manufacturing to pulp mills.
- Irrigation waters for agriculture.

More recently environmental uses of water have leapt into prominence – water to maintain biodiversity and flows in streams. And of course there are lesser uses of water for recreation (fishing, parks, sports) and art (e.g., fountains).

Worldwide, it is estimated that irrigation accounts for about 70% of water use. 15% is used by industry and 15% for household purposes. The figures for individual countries vary greatly depending upon economic development. As might be expected, undeveloped countries use more in agriculture, developed countries more in industry.

Water use in Australia is also dominated by agriculture. The breakdown is: agriculture 70%, households 8%, water service 8%, electricity and gas production 6%, manufacturing 3%, mining 3%, other 2%.[67] The 8% household consumption is divided between: gardening 106 kL (average annual volume per household), bathroom 50 kL, laundry 39 kL, toilet 32 kL, drinking and cooking 23 kL and miscellaneous 10 kL.[68] Statistics such as these are useful because they inform efficient water saving programs. No wonder that garden watering is the first activity to be banned in a drought.

As noted earlier, the modern trend in water policy is to place more emphasis on limiting demand and to make more efficient use of limited supplies. Supply-driven policies are not sustainable in a world where water is becoming relatively scarce. Factors that have forced communities to adopt demand management are:

- Climate change: Catchments which once received rainfall to fill dams no longer do. Rain appears to fall more frequently over the ocean or in places where it is not easily captured. People in hot climates use more water than those in cooler climates. The average daily per capita water consumption in

Darwin is 522 L, in Brisbane 300 L, in Sydney 230 L, in Melbourne 220 L and in the UK 150 L. Thus within Australia the current mass migration of people from the colder southern States to warmer Queensland is placing increased demand on the nation's water.

- Population increase and changing demographics: Even if population remains stable, changing demographics have a remarkable influence on per capita consumption. For example, a single person household consumes about 220 litres per person per day (Lpd) compared to about 100 Lpd in a five person household. The trend to single person households in Australia will increase water consumption even if population declines slightly.
- Higher expectations: Affluence has increased per capita consumption in recent decades. Up market houses, often with a swimming pool, use 225 Lpd versus 96 Lpd for poorer suburban houses.[69]
- Pollution of surface waters by chemical and organic pollutants originating from both our agricultural and industrial practice.
- Increasing rates of ground water abstraction which have depleted aquifers.
- Increasing public opposition to large dams.
- The need for environmental flows.

Two obvious targets for reduced consumption are the *one use urban water cycle* and agricultural practices. We consider these separately.

Reducing Urban Water Consumption

Demand management to reduce the consumption of potable water is the most easily achieved water policy initiative required in Australia. It makes both economic and environmental sense. Indeed a report[70] commissioned by the Mary Valley local governments (those affected by the aforementioned Traveston Dam), calculates that realistic demand management plus water recycling would obviate the need for a new dam over the next 50 years. The report calculates that demand management options are cheaper than attempting to increase water supply – $1.15 per kL of water saved versus $3.00 per kL to supply water from the proposed Traveston Dam. The main savings come from reduced pumping of water which is energy expensive. If one also factors in greenhouse costs, then demand management is even more cost effective. Demand management buys time for governments, delays the need for expensive infrastructure and reduces operational costs. Demand management options typically include:

- Retrofitting more efficient infrastructure – by far the most costly option.
- Rebates for water efficient equipment and water tanks.
- Restrictions on use of water for non-essential purposes, such as car washing.

- Advertising campaigns to change consumer behaviour.
- Repairing leakages from the public reticulation system – reported to account for up to 20% (even 50%) of public consumption.
- Incentives to change industry practice.

An essential component of demand management is to fund research into small-scale water technologies so as to promote *economies of decentralization*. Three quite simple measures are:

- Quality management: Water of drinking quality is required for very few uses – for drinking, cooking, bathing and washing dishes. Lesser quality water is required for gardening, washing the car and flushing toilets. An efficient water system would supply water of a quality appropriate for its intended use. This could be achieved, for example, by supplying each urban house with dual reticulation, one for drinking quality water, the other for lesser quality water. Clearly the costs of dual reticulation would have to be justified by savings elsewhere.
- Dual water supply: One step in this direction is the increasingly popular dual water supply, where houses install rainwater tanks. By appropriate plumbing, rainwater becomes the preferred source for selected uses. In order to guarantee drinking quality water from urban house tanks, kitchen bench water treatment plants are now available that remove impurities by reverse osmosis – an impressive example of scientific research promoting *economies of decentralization*.
- Household recycling: Wastewater from showers and hand basins could be given basic treatment and then used for gardening purposes.

Reducing Agricultural Water Consumption

There are three major policy initiatives: 1) the introduction of water efficient, drought tolerant crops and animals, 2) the introduction of efficient irrigation technology, and 3) efficient farming practice.

Water efficient plants and animals

Farm products vary greatly in the water consumed. The figures in Table 1 suggest that Australia should not use irrigation water for livestock. Not only is meat production profligate in its consumption of water, but the economic return per litre of water consumed is the lowest of all farm commodities (see Table 2). However it is dairy, cotton and rice that are the biggest actual users of irrigation water in Australia. 25% of the Murray-Darling irrigation water is used to grow just one crop – cotton. In times of drought questions are rightly asked about the justification of growing such crops in an arid continent. Other crops, especially fruit and vegetables, offer higher returns for less water.

Table 1: Water use by crops

Among the cereals, rice uses twice the water of wheat and maize. Millet is the least thirsty. For the same amount of water as rice, sorghum produces 4 to 5 times more protein and yields three times more food than rice.[71] Figures in table are from Leaman.[72]

Product 1kg or 1 litre of produce	Litres of water required per kilo of product
Fine wool for suit	685,000
Wool	171,000
Steak	50,000
Butter	18,070
Cotton	5,300
Rice (white)	2,385
Rice (paddy)	1,550
Wheat	1,010
Citrus juice	780
Milk	600
Maize	576
Wine	360

Table 2: Economic returns of water used

The figures in this table are derived from a table in Leaman.[73]

Commodity	Return $/Megalitre	ML/hectare	% of all irrigated lands
Vegetables	1,295	3	2.6
Fruit	1,276	7	4.4
Grapes	600	8	5.2
Cotton	452	7	15.5
Coarse grains	116	3	3.5
Dairy	94	7	39.5
Rice	31	11	11.3
Sugar cane	21	7	8.0
Beef	14	4	7.2

Rice growers are understandably defensive about their huge infrastructure investments. They point to scientific research which promises to grow rice with 30% less water using a combination of no-till technology and drought tolerant rice varieties.[74] Inefficient water practices persist because water is not properly costed. A combination of triple bottom line accounting and government regulation to prevent old world approaches (rice/flood irrigation) would accelerate the introduction of efficient farming practices.

Irrigation technology

In many parts of the world irrigation is essential for agriculture but unwise irrigation has incurred great costs. Somewhat belatedly the Australian government has initiated a $10 billion National Plan for Water Security, much of which will fund the following programs to increase irrigation efficiency.

Losses: In the Goulburn-Murray irrigation system alone, evaporation, leaky irrigation pipes and seepage from channels are estimated to lose 900 GL each year.[75] That is enough water to supply the entire city of Melbourne for four years. A major component of the Commonwealth government's water spending is to repair leaks, move water through pipes rather than open channels and to build enclosed reservoirs.

Trickle irrigation: Irrigation water sprayed into the air results in about 70% loss due to evaporation. By contrast flood irrigation (for rice) raises water tables and mobilizes salt. The expensive alternative is to deliver water directly where it is needed, by trickle underground.

Dry root irrigation technology: Developed by Australian scientists, dry root irrigation is used in grape crops around the world as a precise tool for root watering. It reduces evapo-transpiration and water needs by up to 50%.[76] The technology also appears to work for citrus and pear. The trick is to supply trickle irrigation underground on two sides of a plant. The water is delivered alternately through one side and then the other. The roots not receiving water send a signal to the leaves to use water more frugally, while water supplied on the other side maintains yield. The downside is that the technique requires highly skilled management and is not easily transported to Third World agriculture.

Precise long-range weather forecasts: The Australian Government is funding satellite receiving stations, a radar rainfall network and upgrades to computer infrastructure. The goal is to improve long-range forecasting which will enable farmers to plant crops appropriate for the season's expected rainfall, so reducing demand for irrigation water.

Something to think about

Should we use water like this?

• Cubbie Station is an 80,000 hectare property in Southeast Queensland on the headwaters of the Darling River. It produces cotton. To irrigate a very thirsty crop, the property has the largest private dam in Australia. It is only five metres deep but more than 30 kilometres on a side, so that it stores more water than Sydney Harbour.[77] Located in a hot climate, the dam loses an equivalent of two metres of water each year to evaporation.

> As drought hits harder, there are demands for the government to buy the station and shut it down.[78]
>
> • BHP Billiton extracts 34 Mega litres per day of water from the Great Artesian Basin to feed its copper and uranium mine at Olympic Dam in South Australia. The State government allows the company to take the water for nothing. In fact, the government has approved tripling the size of the mine and the company is seeking approval to increase its take of water to 150 Mega litres per day every day for the next 70 years. That's 60 Olympic swimming pools of water a day, for the lifetime of the mine, for free. It amounts to about one third of the artesian water flowing into South Australia.[79]

Efficient farming practice

There are three major issues concerning water use in modern agriculture: 1) reduced water retention on farms caused by land clearing and the mismanagement of wetlands, 2) pollution of waterways due to excessive use of fertilizers, and 3) soil erosion. Here we focus on fertilizers and pollution.

Worldwide, agriculture is the biggest polluter of water, more so than domestic sewage and industry. Nitrogen fertilizers are the chief culprit because they are readily soluble in water and rapidly find their way into the relatively still waters of lakes and ponds where they cause eutrophication.

Much of the nitrogen applied using conventional farming methods is not absorbed by the plants it is intended to feed – hence the water pollution problems. Less could be used if it were judiciously applied. Organic farming practice makes much more efficient use of applied nutrients. For example, experimental work by the little known Brazilian agronomist Ana Primavesi[80] (brought to the attention of the English speaking world by Bunch[81]) indicates that common agricultural crops can be grown with much lower applications of nutrient with little reduction of yield. The science behind this is interesting.

Orthodox plant nutrition adopts the Nutrient Quantity Concept (NQC) – that is, apply all nutrients in sufficient quantity so that no one nutrient is limiting yield. As an alternative to NQC, Bunch uses the results of Ana Primavesi to advocate the Nutrient Access Concept. NAC is a more appropriate soil fertility model for ecologically managed soils.

> That is, crop growth above a certain extremely low concentration, does not depend on the concentration of nutrients. It depends, rather, on the constant access of plant roots to the nutrients, even when these nutrients exist in very low concentrations. The Nutrient Quantity Concept's remedy of increasing the concentration of nutrients by applying large amounts of chemical fertilizer misses the point almost entirely. What is needed is a constant supply of even a very small but well-balanced

> amount of nutrients over time, and the unobstructed access of plant roots to these nutrients.[82]

Plants compensate for the low nutrient levels by a flourish of root growth. As long as water and low level nutrients stay available, plant yield does not suffer. Fertilizer, applied in high doses at one or two points during a plant's life cycle, has the effect of suppressing root growth. Furthermore, rain washes away idle nutrients leaving the plant late in life with both a deficient root system and diminished availability. Interestingly, the examples that Bunch provides in support of NAC include practices that are familiar to sustainable farmers; that is, maximize organic matter production, keep the soil covered with green manures and cover crop mulches, reduce tillage, maximize soil biodiversity, and feed crops largely through mulches.[83]

The NAC approach to farming recognizes that the soil is a complex ecosystem, not just an inert matrix to anchor plants in the ground. A well-managed soil displays tightly coupled cycling of nutrients between soil organisms and plants. Nutrient levels in the soil may not be overtly high but the rhizosphere metabolism ensures that plants have access to a constant supply. Furthermore, organic matter in the soil retains the moisture necessary to support ecosystem cycling of nutrients.

Something to think about

How the Israelis do it

Australian irrigators visiting Israel are in awe. Israel has an arid climate like Australia but the average annual per capita water consumption of Israelis is about one-quarter that of Australians. (See Appendix 1.) Two thirds of Israel's water originates in the River Jordan in the Golan Heights – hence the strategic importance of the area. The Sea of Galilee is the main storage. According to Fullerton, "Dams on the farm are the norm, using artificial liners to prevent seepage. And whereas almost all water in Australia is used just once, in Israel… the average bucket of water is used between five and seven times! For example, water which may have been pumped from 800 metres underground is used first for tourist spas… then to warm hothouses, and then on to different species of fish (eels, then catfish). This now enriched water is then taken for hydroponic tomatoes and herbs, with the rest going to drip irrigate field crops of olives, melons and alfalfa. Since 1984, the use of freshwater on farms has halved while the value of production is still rising."[84]

Land Use

Sustainability

Defining sustainability

Acknowledging the requirement for *sustainability* sets fundamental constraints on human activity, whether in the economic, social or ecological arenas. The context, of course, is the addiction of modern capitalism to growth in a world where the limitations to growth are increasingly apparent. Little surprise then, that there are over 100 definitions of *sustainability*! The definitions may be scientific but the battleground is ideological. In the realm of intellectual and political discourse, sustainability ranks as one of the 'big ideas'. It has a global reach that transcends national and cultural boundaries. It is, for example, one of four Core Concepts discussed at the 2007 Universal Forum of Cultures sponsored by UNESCO, the others being *cultural diversity*, *knowledge* and *peace*. These four themes were chosen because they encompass the vast majority of issues and problems confronting humanity today.

One of the most cited definitions of sustainability is that proposed by the Brundtland Commission[85] – sustainable development is that which "meets the needs of the present without compromising the ability of future generations to meet their own needs". A process is sustainable when it can be carried out over and over without negative environmental effects or unacceptable costs to any of the stakeholders involved.

While sustainability sets constraints on human activity, we can also approach it as a liberating concept – as about design.

> It is a concept that recognizes that human civilization is an integral part of the natural world and that nature must be preserved and perpetuated if the human community is to sustain itself indefinitely. Sustainable design is the philosophy that human development should exemplify the principles of conservation and encourage the application of those principles in our daily lives.
>
> "In order to integrate ecology and design, we must mirror nature's deep interconnections with our own way of thinking about design. The concept of sustainable design holds that future technologies must function with the way nature works.[86]

Dimensions of sustainability

Sustainability has economic, social and ecological dimensions. Probably all human activities have consequences in each of these three dimensions, so we are confronted with competing assessments of sustainability. We have already come across this in the debate about environmental flows for the Murray-Darling Basin. While environmentalists argue for the importance of *river*

health, farmers argue for the necessity of *farm profitability*. This debate exposes a fundamental divide between views of the world which place ecological sustainability as the absolute long-term constraint versus those which place economic sustainability as the absolute constraint. According to the economist's worldview, healthy businesses are necessary to motivate entrepreneurial adoption of resource efficient technologies. Consider this excerpt from an editorial of *The Australian* newspaper (9th February 2007), commenting on Dr. Tim Flannery's award as 2007 Australian of the Year:

> Professor Flannery is a well-documented global warming extremist… [He] predicts sea-level changes of many metres. Such hyperbole is in line with his deep-green anti-development, anti-immigration credentials… [He] should be asked to justify the immediate social costs of stopping coal exports, both here and in the countries that rely on Australian coal for their electricity and jobs… *The Australian* supports the position … to seek a technological solution that can be exported to assist the world in meeting the climate change challenge.[87]

But the reality is that environmental degradation is proceeding at a pace much faster than the adoption of ameliorating technology. As the president of the Australian Conservation Foundation warns:

> The economy is, of course, crucially important, as is the social well-being of our citizens. Both now depend on urgent action to deal with our environmental problems. Unless these problems are recognized, the well-intentioned attempts to improve economic and social indicators are doomed to fail.[88]

A matter of scale

Definitions of sustainability vary according to the scale of one's immediate concern – and this is a serious problem when it comes to adopting sustainable practice. Farming offers a good example. Typically at the paddock level, the dominant constraints to sustainability are agronomic and the goal is to maximize yield over several seasons. At the farm level, the dominant constraints to sustainability are economic – to keep the farm going as a viable business over the farmer's lifetime.

At the landscape or catchment level, the dominant constraints to sustainability are ecological – for example, it is necessary to maintain adequate water and nutrient cycling to sustain life in the catchment. At the regional or national level, the main sustainability constraints are macroeconomic – that is, to export sufficient produce in order to maintain employment, to import machinery, to sustain rural community life. At the global level, the constraints are once again environmental, with the current focus on climate change (Figure 3).

This, at least, is how the economically developed world currently constructs sustainability. But in reality, ecosystem dynamics recognize neither political boundaries nor abstract human constructs. Rather they operate on all scales,

from the paddock to the planet. Which brings us to a fundamental principle: *In order to achieve ecological sustainability on multiple scales, it is essential to adopt land use planning*. Land use planning begins initially at the landscape or catchment level but the results of it filter down to the farm and paddock level and they filter up to the regional and global levels. The Western world has evolved social and economic systems where no one person or group takes direct responsibility for what happens in a catchment. Individual farmers answer to their farm and politicians answer to macroeconomic indices. Landscape or catchment management falls through the cracks, as it were, inadequately cared for.

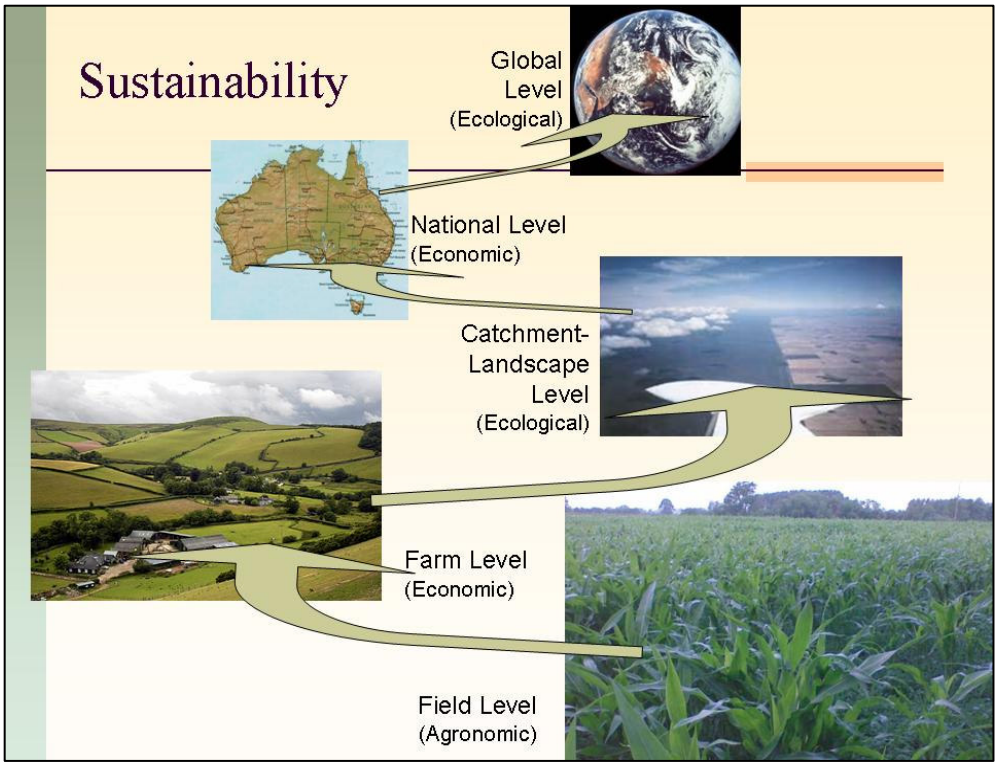


Figure 3: The sustainability of agriculture is defined differently at different temporal and spatial scales.

Measuring sustainability

How do we know in practice whether a particular human activity is sustainable? Can we measure it? Economic sustainability, as narrowly defined in modern economics, is easy to measure – it depends on continued

profitability under competition. Social sustainability revolves around the concept of social capital and sociologists have even developed measures of it. But how do we determine ecological sustainability? It is now generally accepted that ecological sustainability has four components reflecting the status of four fundamental ecosystem processes:

- The cycling of water.
- The cycling of nutrients.
- Flow of energy.
- Biodiversity and the relationships between species.

These processes operate only within certain limits and they are intimately interconnected with one another. Since human society can exist only within nature, all human economic, social and political activities must ultimately operate within the limitations of these four fundamental processes. In *modernity* (that view of the world, espoused in the *The Australian* editorial above, which expects technological ingenuity to overcome all obstacles), progress is about conquering the limitations posed by nature. In the ecological worldview, progress is about working with them, leveraging them.

Something to think about

Sustainability is finely tuned

Ecosystem dynamics depend on four fundamental processes: the cycling of water, cycling of nutrients, flow of energy and species interactions. These four processes are intimately intertwined. As an example, consider the following relationship between ocean bacteria and climate change.

Algae living in the oceans produce large amounts of the substance *dimethyl-sulpfonio-propionate* (DMSP). DMSP is broken down by marine bacteria to a volatile compound known as *dimethyl-sulphide* (DMS). DMS enters the atmosphere and contributes to the condensation of water and the seeding of clouds. On a global scale, cloud cover regulates surface temperatures. Note the conjunction of nutrient cycling (marine bacteria contributing to global cycling of sulphur), water cycling (sulphur compounds affect cloud formation), energy (cloud cover affects the proportion of the sun's energy retained in the atmosphere) and species diversity (the cooperation of diverse species to process sulphur-containing compounds and cycle it around the planet).

It is well within today's technology to genetically modify bacteria to produce DMS at a faster rate. One can imagine seeding the oceans with the modified bacteria in an attempt to modify the balance of cloud formation – the use of DNA technology to manage climate change.

Agro-forestry

This section proposes that *agro-forestry* must become the dominant form of agriculture in Australia and indeed in all parts of the word where trees can grow. According to Colin Tudge, author of the widely appreciated *The Secret Life of Trees*,[89] agro-forestry "offers one of the principle hopes for a sustainable world" – it is "one of the great hopes for the future". The logic is simple – we have to maintain a large portion of our continent covered in trees but we must also farm the land. The two activities in Australia have for the past 200 years been considered antagonistic concerns – land-clearing still tends to be viewed as a necessary pre-condition for profitable farming. In Queensland, land clearing is a potent political issue with farmers resolutely opposed to attempts by the Queensland government to restrict clearing. A land management revolution would integrate forestry and farming into a single enterprise. The psychology which places farming in opposition to forestry appears strongly associated with the Anglo-Saxon tradition. Britain long ago felled its forests while Germany and other central European countries retained them as an integral part of their culture and economies. Even today, the German landscape is a patchwork quilt of crops, forest and villages.

There are many advantages to maintaining land under trees:

- Tree cover encourages rain to fall as already described.
- Trees and plant cover in general allow organic matter and micro-organisms to build up the soil encouraging the bio-storage of water.
- Trees plus healthy soil purify passing water.
- Trees bind the soil and prevent erosion.
- Trees are a carbon sink and now considered an essential part of the strategy to combat global warming – biosequestration. Indeed, after burning of fossil fuels, tree clearing is the second largest contributor to greenhouse gases. It is not just the burning of trees, or the loss of a carbon sink. Sub-soil processes particularly in peat forests release huge amounts of carbon when the trees are cut.
- Forest trees provide food for honey bees in the off-season when human annual crops are dormant. In Australia, honey bees are responsible for pollinating one third of the food we eat and they pollinate $2 billion worth of agricultural product. The pollinating service provided by bees is far more important than their honey. The rapidly growing almond industry is just one example of a crop totally dependent on pollination by bees.
- Forests provide homes for birds – birds that eat insect pests that might otherwise be sprayed with insecticide – birds that eat seeds which get transferred around the landscape.

In short, trees are at the heart of terrestrial ecology and play a vital role in both the local and global circulation of water. How can trees also become a vital component of feeding the world?

Colin Tudge considers the overwhelming predominance of cereals in the world's food basket to be partly an accident of pre-history. It might have been different. Tree crops, such as olive, coconut, macadamia, avocado, pistachio, walnut, cashew and almond to mention just a few, offer highly concentrated calories and nutrients. If cereals had not existed, says Tudge, human civilization would have flourished nonetheless on tree crops. And imagine the possibilities if as much effort had been applied to maximizing tree yields as has been devoted to cereal yields. In addition to the above advantages, tree prunings have multiple uses. And once trees stop producing, their wood can be used for construction and furniture. The trunks of old rubber trees provide an excellent cabinet timber and earn Malaysia and Thailand billions of dollars in export earnings.

Something to think about

Can planting trees halt the spread of dry land salinity?

Dry land salinity threatens to become Australia's worst environmental disaster. Clearing trees over large swathes of land has upset the finely tuned balance between water, trees, soil and salt. In May 2000, Peter Garrett (then president of the Australian Conservation Foundation and now Minister for the Environment) announced that it would take the planting of 40 billion trees over the coming decade at a cost of $65 billion to remedy the problem. Seven years later, nothing like that target has been reached. One of the problems is the traditional antagonism of broad acre farmers to trees. And not all scientists agree that replanting trees can solve the problems caused by clearing them. Fullerton[90] quotes a top CSIRO scientist as saying, "Trees [as a remedy for dry land salinity] are a waste of time for most of Australia."

So what are the problems? First, some 50% of a salt affected catchment would have to be treed, which, Australia wide, would be a huge cost. Second, trees transpire a lot of water, thus reducing available water for irrigation. Planting trees may be good for the environment but it is bad for irrigators – at least that is the claim.

The response of environmentalists is that much of the water lost by transpiration is returned to the land as rain. Furthermore, the shade provided by trees reduces pond evaporation and their roots hold a lot of water which is released in times of drought.

Clearly more research has to be done. But one difficult truth remains. There may be large areas of Australia that should never have been put under agriculture. This dilemma brings us to a contention of Sarkar in

Ideal Farming[91] that it is better to attempt to increase the productivity of existing fertile land rather than to bring marginal land into production. On the other hand, Sarkar clearly supports irrigation farming and he points to the Israelis as a model.

The challenge is to find ways to integrate trees with farming. Trees provide many services to farm animals. Well spaced, they act as wind breaks. They ameliorate diurnal fluctuations in temperature and of course provide shade and shelter. Leaves, twigs and other prunings in many parts of the world are used for animal feed. Pigs and poultry scavenge the forest floor removing weeds, seeds and insect pests.

Tropical forests offer many opportunities for agro-forestry because of the diversity of animals and plants that they support. Coffee and tea do best under the shade of taller trees. But the buttresses and shallow roots of tropical trees are easily damaged by hard hoofs and indeed it is now well established that trampling cattle and sheep have done irreparable damage to Australian wetlands. In this regard, the soft padded alpaca from South America holds great promise. The number of alpacas in Australia is now well over 20,000 and although the industry is small in comparison to the sheep industry, the fine fibre produced by Alpacas earns a premium. In an agro-forestry combination, the Alpaca could do well in Australia.[92]

Australia is home to many plants having nitrogen-fixing nodules – most famously the Acacia (Wattle). Nitrogen-fixing nodules not only enable trees to grow in the most infertile of soils, they also leak nitrogen, thereby enriching the soil and benefiting companion crops. Consequently leguminous trees are of special importance in agro-forestry.

Tree crops often take 20 to 30 years before they deliver maximum yield. Therefore mixed farming, using the spaces between trees for other crops and animals, ensures that farms become productive earlier.

Australian governments are promoting tree plantations for both good and bad reasons. A South Australian government scheme is in the good category. It aims to plant 2.5 million trees on private and public land along the Murray River corridor to promote bio-diversity and carbon sequestration.[93] In the bad category are plantation forests financed by Commonwealth government sponsored Managed Investment Schemes (MIS). These attract cashed-up city investors because they offer tax breaks but it is not at all clear whether these *get-rich-quick* plantations can survive in the absence of generous tax concessions.[94] The disastrous effects of MIS plantations are felt in Tasmania where water hungry eucalypt forests are drying up neighbouring farms.[95] As Tudge warns:

> Eucalypts are famously desiccating, with long tap roots reaching down to the ground water, transpiring long after other trees have given up. They may create drought around them and kill surrounding trees if planted in the wrong places.[96]

Planting the wrong tree in the wrong place for the wrong reasons cannot be justified on environmental grounds and ultimately it will also fail economically.

There are a multitude of possibilities for agro-forestry in Australia because the country has a diversity of climates. The challenge is to get it right in each location. Here are two possibilities, but there are many others:

Guayule rubber

Over 2,000 rubber producing species are known worldwide, but only two, *Hevea brasiliensis* and guayule (*Parthenium argentatum*), have been commercially exploited for natural rubber. Today, *Hevea* is essentially the sole source of natural rubber grown in tropical parts of the world. Guayule on the other hand tolerates arid and semi-arid conditions and would do well in Australia and many other parts of the world. Rubber plantation work is tedious but could be made more interesting if trees were grown in a mixed agro-forestry plantation with other crops and animals. Guayule rubber has the potential for commercialization as a non-allergenic natural rubber. The marked increase in use of protective coverings following the HIV epidemic has resulted in an explosion in the number of people sensitive to rubber. Once sensitized, a person is unable to undergo surgery unless non-allergenic surgical equipment is available. Guayule is the only plant which can produce this product.[97]

Diesel trees

This incredible tree from Brazil (botanical name *Copaifera langsdorfii*) produces a biofuel that can be tapped directly to power tractors and other machinery. A one hectare plantation could feasibly produce 12,000 litres of fuel a year, enough to make a small farm completely self-sufficient. A Mackay nursery (in Queensland) is growing trial seedlings which thrive in tropical conditions. Many other species of tree can produce oil but the advantage of the diesel tree is that its sap can be placed directly in a diesel tank without expensive processing. When the trees reach a 30cm diameter, a hole is drilled into the centre and a tight-fitting pipe installed and plugged. The first fuel can be tapped after seven to nine years, but it takes 15 to 20 years for trees to reach maturity.[98]

To Burn or Not to Burn

Knowledge of fire – how to make it, preserve it and use it – was part of the toolkit that the first Aborigines brought to Australia. As they moved inland into

increasingly unfamiliar landscape, they learned how to put fire to it and make a good living from both plants and animals. In considering the purpose of Aboriginal burning, most have assumed that it was to drive animals into traps where they could be slaughtered, but Gott[99] argues that it was more likely to have been an agricultural practice. Periodic firing every three years or so prevented tree cover from becoming dense and encouraged the growth of herbaceous and tuberous species, which were a major staple food. Clearly, the use of fire in this way was a skilful practice perfected over centuries and entirely sustainable.

There has been much debate among ecologists over the status of the savannah ecosystem. Is it a natural climax vegetation or is it an artefact of human occupation and, in particular, of the use of fire? The question is difficult because the landscape type has been so stable for many thousands of years. According to Flood,[100] the current consensus is that both in Africa and in Australia savannah is a human creation. Indeed Tim Flannery[101] has described the Australian landscape as an *Aboriginal artefact*. Left to its own devices savannah eventually returns to a dense cover of trees. For example, in southern Victoria land which in the 1800s had a cover of 20 trees per hectare today has 3,000 trees per hectare. Fire has been used for so long by Aborigines as a resource management tool that Australian ecosystems, its plants and even animals have adapted to it.

In a review of Aboriginal land management, Bowman[102] concludes that "fire was a powerful tool that Aborigines used systematically and purposefully over the landscape".[103] The use of fire was skilful and central to the maintenance of the landscapes subsequently colonized by Europeans in the 19th century.[104] Bowman also recognizes that the impact of Aboriginal burning is "one of the most complex and contentious issues in Australian ecology", adding:

> This issue is not only important for the development of a comprehensive understanding of the dynamics and evolution of the Australian biota, but is central to the formulation of appropriate strategies for the conservation of the nation's biota.

Catastrophic bushfires in Victoria in March 2009, in which more than 200 people were burned to death, have greatly added to the political intensity of the debate about using fire to manage the Australian landscape. Ecologists had been winning the argument that regular burning is destroying Australia's biodiversity and local councils had placed limits on the amount of burning and land clearing. But after the bushfires of March 2009 which were all the more intense due to a build up of combustible biomass, political sentiment has inevitably swung the other way.

Landscape Design for Farming

Natural sequence farming

If much of Australia's arable land is to be covered with trees, how do we grow our broad acre wheat, barley, oats and other annual crops? According to Peter Andrews,[105] we have to make more efficient use of the land under annual crops. Andrews has developed a land management system called *natural sequence farming* based on more than 30 years investigation of the Australian landscape. *Natural sequence farming* is based on a theory of how nutrients and water move through the Australian landscape. Andrews believes that by careful management of water and nutrients it is possible to recreate the *swampy meadows* and *chains of ponds* that were a feature of a healthy Australian landscape before it was destroyed by European farming methods. *Natural sequence farming* reconnects streams and rivers to subsurface waters. This is important because Australian ecosystems function by allowing water to stay underground for longer rather than remain on the surface where it evaporates or runs to the sea. *Natural sequence farming* attempts to slow the passage of water through the landscape and to retain nutrients within a catchment.

According to *natural sequence farming*, the ideal farm layout divides the land into thirds (Figure 4):

- One third forest on the high ground and ridges accumulating fertility under trees.
- One-third cropping on the mid-slopes exploiting fertility carried down by water from the high ground.
- One-third recovery area where trees, grasses, etc., capture passing nutrients before they wash into water ways and are lost from the local landscape.

Tree prunings and hay harvested from the valley can be returned to the high ground for mulching so completing the cycle. These figures are not hard and fast, rather they attempt to exploit the way that nutrients are cycled in the Australian landscape. According to Andrews, *natural sequence farming* methods allow farmers to achieve five times more productivity on the cropped third of their land, so compensating for the two-thirds under trees.[106] Essentially, trees create the fertility used by crops, and that fertility is transported naturally through the landscape by water.

Andrews claims that *natural sequence farming* methods can rectify a range of environmental problems, such as salinity, erosion, eutrophication and rising water tables. Proponents of *natural sequence farming* point to Andrews' own property in NSW, which retained a covering of green feed during a recent drought that browned off neighbouring properties.

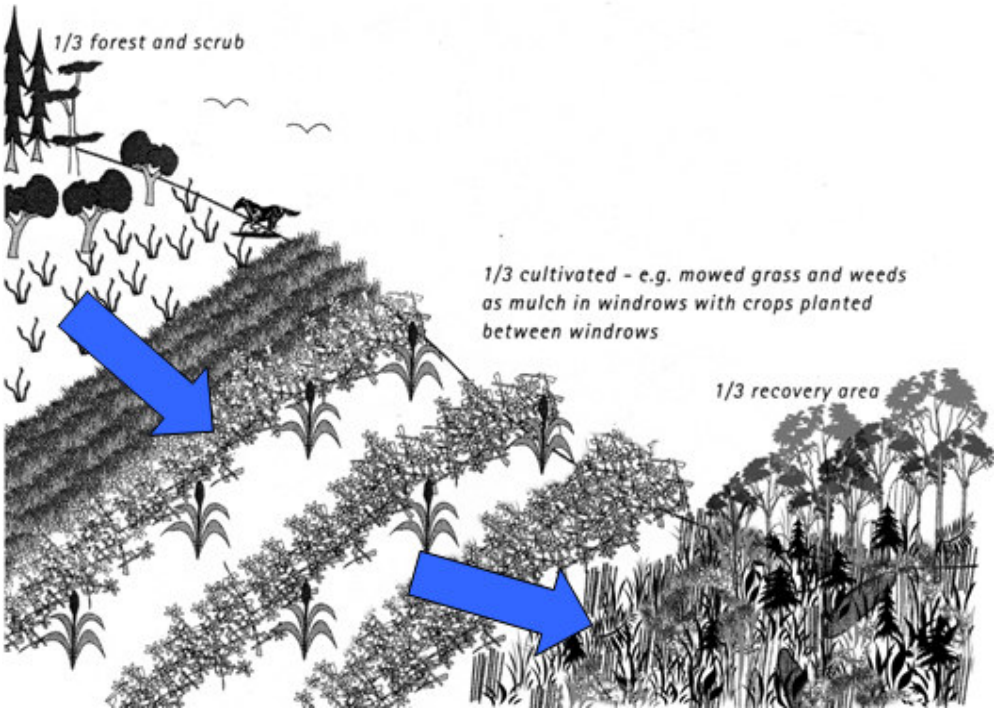


Figure 4: In natural sequence farming, individual paddocks, slopes or landscapes, as appropriate, are divided into thirds. Fertility is generated on the high ground. Water carries nutrients downhill which feed mid-ground crops and are then recaptured in the low ground. Hay and shrubs etc are harvested from the low ground and transported back up hill. This figure has been adapted from Diagram 4 in (Andrews 2006) and reworked by Sahitya Graphics.

Natural sequence farming links to the work of Ana Primavesi described above,[107] because the system retains moisture and nutrients in the soil, and ecological soil management ensures that plants yield well. Note that Andrews and other proponents of organic agriculture are not necessarily opposed to the use of slow release fertilizers to offset real losses from the land. However, they argue that nutrient losses should be minimized and soil fertility can be generated locally.

Permaculture

Permaculture was developed in the mid 1970s by two Australians, Dr. Bill Mollison[108] and David Holmgren,[109] as a set of design principles that could be used to create stable agricultural systems. The term is a synthesis of *permanent agriculture* and the design principles are a response to modern methods of industrial agriculture which pollute land and water, reduce biodiversity and

encourage soil erosion. At the heart of permaculture is the attempt to design landscapes which produce food by mimicking the structure and processes of natural ecosystems.

Although principally an agro-ecological design theory, permaculture has developed a large international following of individuals who have subsequently incorporated a range of alternative cultural ideas. One of the core values is *self-sufficiency* or *self-reliance* – to reduce reliance on industrial systems of production and distribution, which permaculture advocates believe are destroying the Earth's ecosystems. To quote Mollison himself, "I teach self-reliance, the world's most subversive practice! I teach people how to grow their own food, which is shockingly subversive. So, yes, it [permaculture] is seditious. But it's peaceful sedition."[110]

Permaculture design principles draw heavily on the practical application of ecological theory. Each component of a farm design is analyzed in terms of its needs, outputs and properties. For example, a chicken needs water, moderated microclimate, food and other chickens, and produces meat, eggs, feathers and manure while doing a lot of scratching. Design elements are then assembled in relation to one another so that the products of one element feed the needs of adjacent elements. Chickens will eat waste from other parts of the farm and remove weeds. A successful design minimizes waste, fossil fuel consumption and human labour.

Permaculture focuses on maximizing the use of trees (agro-forestry) and perennial food crops because these make more efficient use of energy than traditional annual crops. Permaculture borrows freely from organic agriculture, sustainable forestry, horticulture, agro-forestry and indigenous systems of land management, but its fundamental contribution to the field of ecological design is the development of a concise set of organizing principles that can be transferred through a brief course of intensive training. This helped to spread the ideas more rapidly than would have occurred through a system of university based education.

Perhaps because permaculture became associated with the alternative lifestyle movement, it has not received the attention it deserves from mainstream agricultural scientists. Agri-business will not promote research into farming methods that avoid their products. There have been criticisms, on theoretical grounds, that permanent and therefore mature wooded landscapes cannot be as productive as traditional farmland because, according to the theory of ecological succession, net productivity declines as ecosystems mature. Critics also claim that existing permaculture projects are insufficiently documented to determine how successful they really are. One country where permaculture is claimed to have had much success is Cuba.

Something to think about

Can organic agriculture feed the world?

Much of the debate about the sustainability of orthodox farming practices and the ability of organic methods to replace them hinges on nitrogen (N). The main limiting nutrient for plant production in most parts of the world is nitrogen. So for some the key question is said to be – can organic methods supply N in the same amounts as supplied by artificial fertilizers? It is not just an academic question. At stake is the ability to feed our planet's six billion people. Also at stake are the profits agri-business derives from the production of artificial fertilizers.

The numbers read something like this. Agriculture consumes some 175 to 200 million tonnes of nitrogen fertilizer globally per year. 40% of it is manufactured artificially by the Haber process, while the remainder comes from nitrogen fixation of cover crops and recycled organic matter. Consequently about one third of the world's population, two billion people, depend upon food produced with artificial nitrogen.

Modern agriculture has a "nitrogen addiction", says Mary White. She argues[111] that organic methods (green manures and cover crops typical of the European Middle Ages) could not sustain six billion people. At best, she says, organic methods can produce about 200 kg of nitrogen per hectare which will make 200-250 kg of plant protein, sufficient to support about 15 people. In reality, farming in the Middles Ages, whether in Europe or China, supported only about 5 persons per hectare. On the other hand, White recognizes the environmental damage caused by artificial nitrogen fertilizers and admits that ultimately our current farming methods are not sustainable. All of which leads to a rather pessimistic conclusion (which is not actually stated in her piece on the subject).

Proponents of organic agriculture draw a more optimistic conclusion. First, organic agriculture has come a long way since the Middle Ages. We have already referred to the work of Primavesi and Bunch which demonstrates how plants can be grown with smaller applications of organic N. Second, organic N currently provides about 60% of the world's agricultural N, more than provided by artificial means. This could and would certainly increase if the artificial N addiction were not officially condoned by governments and departments of agriculture.

However the best evidence for the ability of organic methods to feed the world comes from actual comparisons of production by the two systems. A recent meta-study done by scientists at the University of Michigan, Ann Arbor, USA, analyzed the data of 293 independent comparisons of organic and non-organic plant and animal production around the world

and showed that organic methods perform as well as, and sometimes better than, non-organic.[112]

The report makes two significant assertions. The first is that organic methods can provide enough calories to support the whole human population eating as it does today. The second assertion is that nitrogen-fixing legumes used as green manures can provide enough biologically fixed nitrogen to replace the entire amount of synthetic nitrogen fertilizer currently in use. The authors also note that theirs is not the first report to draw such conclusions, and that the scientific case for organics agriculture is now proven.

Integrated farming

Sarkar's contribution to farming and landscape design is known as *integrated farming*. It is, in many ways, similar to permaculture, but the motivation is subtly different. His primary concern is to address poverty and malnutrition, a reality of life for most people in most parts of the world. However the principles of *integrated farming* are also applicable to agriculture in the developed world.

Integrated farming is better understood within the context of Sarkar's socio-economic program known as Prout (the *Progressive Utilization Theory*). An important sector of a Proutist economy is what Sarkar calls *people's economy*, the purpose of which is to ensure the production and distribution of the minimum requirements of life, that is, basic foods, health care, housing, clothing and education. The Proutist approach is to produce these minimum requirements at the local level, that is, to decentralize economic activity so that local people are empowered to produce their own basic needs and not to depend on outside companies. In the case of food, Sarkar's strategy is to create an *edible landscape* using the principles of integrated farming.

The main objective of integrated farming is self-sufficiency and in this respect it is similar to permaculture. Communities should not be dependent on outside resources for their basic requirements. "An integrated approach to farming should include cottage industries, energy production, research centres, water conservation, etc. This approach will help make the farming projects self-sufficient."[113]

Sarkar's farming system promotes massive reafforestation programs which he says are required both to manage the water cycle and to deal with climate change. It should be noted that he was concerned with these issues long before they rose to prominence in public consciousness. In Sarkar's vision, tree plantations are very much part of the village and city landscapes where people live. He prescribes a systematic approach to the planting of trees and associated herbaceous plants (that is, 'filler' plants or intercrops) in the boundary areas of

all schools, farms, orchards, homes and roadsides. He details combinations of trees that can be planted for food, for timber, for shade, for fuel and so on.[114] Like agro-forestry and permaculture, integrated farming is based on a mixture of perennial and annual crops arranged spatially and sequentially to gain multiple ecological and economic benefits.[115]

One notable aspect of Sarkar's farming system is the importance given to companion planting. Indeed, most of his writing on agriculture is devoted to different systems of crop blending and the complementary interactions between plants. In addition to increased productivity, there are ecological benefits that arise from maintaining biodiversity and vegetation cover.[116] Sarkar distinguishes three cropping regimes: mixed cropping, supplementary cropping and crop rotation. Under each category, he lists crop combinations and the months in which they should be sown and transplanted. The detail applies to India, but the principles can be adopted anywhere. "Our system of integrated farming is designed to utilize every inch of land. Not only should the surface land be fully utilized, but the space under the surface and even the space above the surface should be used to the maximum.[117] Here Sarkar is alluding to the layered production systems that are also a part of permaculture design.

On the issue of chemical versus organic fertilizers, Sarkar is pragmatic. He observes that the current system of intensive chemical agriculture kills the soil: "…it is noticeable that whenever chemical fertilizers are used intensively, the land becomes infertile and useless after some time. This is because chemical fertilizers destroy the vital energy of the land so that it becomes lifeless, just like cement."[118] However he also accepts that to achieve maximum productivity, soils may require supplements of chemical fertilizers and research will be necessary to do this without destroying the living components of a fertile soil.

Finally, returning to the economic domain, Sarkar recognizes that modern farming requires economies of scale that cannot be achieved by individual farmers alone. He argues that many agricultural problems, such as conserving water and maintaining soil fertility, require a cooperative approach.[119]

> In the cooperative system there is great scope for agricultural research and development to discover new ways to better utilize and prolong the vitality of land. The benefit of cooperatives is that they combine the wealth and resources of many individuals and harness them in a united way.[120]
>
> Only cooperatives can support the expanding economic requirements of agriculture, like creating ponds, purchasing machinery, uniting local people to pressurize the government for irrigation facilities, etc.[121]

Something to think about

The declining importance of agriculture in Australia

In 1836 Charles Darwin concluded that Australia would never be a great agricultural nation like the USA because of poor soils and unpredictable climate. Whether he was right or wrong depends on whether the bounty of wheat, wool and meat over the past 170 years proves to be sustainable or not.

In Australia, as in most other developed countries, the manufacturing and service sectors are growing so fast that agriculture contributes a diminishing share to wealth. Furthermore, only about 5% of the population is directly engaged in agriculture. Historically, the agricultural lobby in Australia has been powerful and exerted an influence in excess of its economic contribution. The demise of rural communities in Australia today is a reflection of their diminishing economic and political power.

But there are tremendous dangers for Australia in allowing agriculture and, just as importantly, agricultural communities, to decline. First is the loss of food security, that is, our independence and self-sufficiency in producing staple foods. Second is the real danger of losing agricultural skills and even the willingness of people to engage in agriculture. Very few Australians have a realistic understanding of the landscapes on which their food depends and consequently governments are unable to muster the political will to repair the existing damage and to introduce sustainable practices.

Sarkar argues that a healthy developed economy must have a healthy agricultural sector and this requires about 25% of the workforce to be connected in some way with food production.[122] He considers undeveloped countries to have too many people engaged in agriculture and developed countries to have too few. Both are unhealthy, both economically and socially.

A second agrarian revolution

The first agrarian revolution took place in the Neolithic (New Stone Age), about 10,000 years ago, when the world was warming with the passing of the last ice age. The development of agriculture brought about entirely new ways of living because it enabled large groups of people to remain together in one place and to accumulate more tools and implements than could be carried in a nomadic lifestyle. This paved the way for new technologies, new forms of social interaction and trading. While the Neolithic agrarian revolution triggered the flowering of human civilization, some argue that it also brought us inexorably to our modern predicament – ecological and social breakdown. For

example, Richard Leakey[123] argues that the transition from hunter-gathering to farming "involved a dramatic alteration in the relationship people had both with the world around them and among themselves. The hunter-gatherer is part of the natural order – a farmer necessarily distorts that order."

The claim here is that a second agrarian revolution is upon us. The challenge it presents is to re-integrate productive farming within "the natural order". The existing system is breaking down. Farmer suicides and farm debt are running high in Australia. The latest indication of breakdown is a civil disobedience campaign by hundreds of Australian farmers felling protected trees on their properties to protest against strict land-clearing laws.[124] Some way must be found to make farming both an economically viable occupation and an ecologically sustainable one. Colin Tudge argues that *agro-forestry* is that way:

> …societies can build their entire economies around trees: economies that are much better for people at large, and infinitely more sustainable, than anything we have at present. Trees could indeed stand at the heart of all the world's economics and politics, just as they are at the centre of all terrestrial ecology.
>
> The future endeavours of humanity must be geared to biological realities. The world's economies (and the endeavours of scientists and technologists) must serve those realities. Most obviously – once we start to think seriously about the fate of cities, and environmental stress in general, and human employment and dignity – we see that for the foreseeable future, and probably for ever, the economies and physical structure of the world must be primarily agrarian. In the current, crude, unexamined dogma, 'development' and 'progress' mean urbanization. The prime requirement, in absolute contrast, is to make agrarian living agreeable. It can be. It's just that at present, all the world's most powerful forces are against it. Trees are right at the heart of all the necessary debates: ecological, social, economic, political, moral, religious.

The Administration of Water and Land

The Administration of Land

Land use planning has little prominence in Western societies because private property rights make it difficult to place limits on what land owners can or cannot do with their land. One of the positive outcomes of global warming, drought and environmental degradation is the attention they have focused on land use and environmental management. In this section we explore the administrative systems required to ensure that humans can survive without destroying the integrity of the ecosystems on which they depend. There are two dimensions to the management system we require, described somewhat abstractly as the *horizontal* and *vertical* dimensions. The horizontal dimension

refers to the way we divide the landscape into administrative units and the vertical dimension refers to the multiple layers of governance required to manage the complexity of human systems interacting with ecosystems.

Dividing the land into administrative units

Ecosystem dynamics operate on multiple scales from local to global. Therefore in order to administer human activities *and* to ensure their sustainability on all scales, it is necessary to implement a hierarchical subdivision of land. With such a framework in place, it becomes possible to plan resource use and to integrate human activity with the four fundamental ecosystem processes.

There are many ways to approach a hierarchical subdivision of land: using physical criteria, such as topography; biological criteria, such as vegetation type; or human criteria such as political and cultural boundaries. The approach advocated in this essay is to give primary importance to a system based on surface water drainage and furthermore, to make political boundaries consistent with catchment boundaries. Why? Because surface water is the primary determinant of economic and social development.[125] Australia provides ample proof. Too much water (as in the far north), too little water (as in the arid centre) and too unreliable water (as west of the Great Dividing Range) have constrained the spread of human settlement across the continent. Only in the southeast, where the prevailing water cycle was familiar to European settlers, did population and commerce grow rapidly.

Here we state a fundamental principle of economic development: *economic planning begins with land use planning and land use planning begins with water planning*. To give expression to this principle, we propose, for the purposes of political and economic administration, the hierarchical division of land into local catchments, regional catchments, river basins and drainage divisions.

Bioregions

The administration of land based on surface water drainage does not satisfy all the requirements of environmental management. Some ecosystems, for example, alpine regions, span the headwaters of several catchments, and therefore cannot be well managed from a catchment perspective. Recall the four key components of ecosystem dynamics: water cycling, nutrient cycling, energy flows and species interactions. These four cannot be managed in the same way, even though their management must obviously be coordinated. It is now the accepted practice in Australia that conservation of biodiversity be managed on the scale of whole *bioregions*.

Bioregions are relatively large areas of land having a characteristic set of climatic, geological and biological features. To the trained eye of an ecologist, bioregions are characterized by a particular assemblage of fauna and flora whose patterns of interconnectivity depend on local climate, soil, landform,

vegetation and land use. Consequently bioregions provide a useful level of generality for managing some aspects of landscapes, especially biodiversity.[126]

There are currently 85 bioregions recognized across Australia and their boundaries do not follow the constraints of land drainage. So the question arises – why should we adopt a water catchment approach to political and economic administration rather than the bioregional approach? Of course both catchments and bioregions must be managed in parallel, but for the purposes of administering human settlement and economic activity, water is the critical factor. Furthermore, nutrient cycling tends to be associated with water cycling, so catchment by catchment management is appropriate for two of the four eco-system processes. Separate administrative bodies will be required to manage bioregions. Incidentally, energy flows in ecosystems interact with the dynamics of climate change, requiring yet another kind of administrative apparatus.

Levels of governance

The vertical dimension of managing social and environmental systems refers to the several layers of governance required to manage their complexity. Different forms of management are required depending on the process to be managed, its scale and its strategic importance. Here we consider five levels of management that are distinguished by both scale (local to regional) and function:

- Farmers and land care groups (consisting of actual farmers and primary producers).
- Water, sewage and irrigation companies, etc. (constituted as public utilities or cooperatives as appropriate).
- Regulatory authorities (established by both local and federal levels of government).
- Local and regional governments (to coordinate the management of regional catchments).
- Higher levels of government (to manage large aquifers, river basins and water trading).

The next section introduces a system of land division based on water drainage and formalizes the concept of a local government area. Subsequent sections discuss the various levels of governance.

Local Government Areas

The smallest unit of formal governance and economic planning in Australia, as in most countries, is the *shire*, *town* or *city council*, collectively known as *local government*. In Australia, the boundaries of local government areas (LGAs) are, for the most part, accidents of history. They are typically focused on rivers,

because these were the main means of communication during the era of early settlement.

Principle: As far as possible, *LGA boundaries should be aligned to the ridgelines of major river catchments*.

In those cases where a river basin is too large to accommodate a single LGA, the determination of boundaries would start at the catchment source and work its way to the river mouth. For management purposes, it is useful to distinguish between the upper, mid and lower river basin, the upper basin typically being high, hilly country, the mid-basin being flat plains and the lower basin being coastal delta. So for a river basin that embraces several LGAs, it is preferable that the LGA boundaries delineate the upper, mid and coastal regions. LGAs sharing a common basin can be regionally associated. Actual LGA boundaries will be additionally determined by a combination of other factors, most obviously population distribution (discussed below).

The advantages of this local government structuring scheme are:

- It facilitates the monitoring and management of water resources at the local level.
- Local councils can assume full responsibility for a catchment because it lies completely within their jurisdiction.
- It facilitates the management of whole river basins and the work of national water authorities.

As Alexandra[127] cleverly puts it, local government will no longer be about the 3R's (roads, rates and rubbish) but about the 7R's: "roads, rates, recycling, revegetation, riparian restoration, regional reinvestment and resilient regional communities".

What is the optimum population for an LGA?

At the time of writing this paragraph, the Queensland State government intends to amalgamate many LGAs into larger regional entities. The motivation is purely economic – small councils are said to be inefficient. In contrast to the focus on economics, electoral boundaries for State and Federal governments are established with an eye to population distribution and the requirement to have similar numbers of voters in each electorate. Catchment boundaries have nothing to do with it. State and Federal electoral boundaries change frequently, so that voters find themselves in different communities with different demographics from election to election. As a consequence of such fluidity, the sense of community at local level is not carried to the State and Federal levels and there is little correspondence between local communities and the larger political jurisdictions.

There is clearly a tension between the need to build local community and the need for economic and administrative efficiency. When city councils become too big there is loss of community identity but conversely small councils lose economies of scale. This begs the question: what is the optimum population for an LGA? We propose an average of 100,000 people as an appropriate compromise. We note that, at the time of writing this paragraph, prior to council amalgamations, each of the three councils on the Sunshine Coast north of Brisbane has a population of about 100,000. Each includes a mix of both rural and urban development and each could be considered a 'good average shire'. However some flexibility is required. It is clear that the largely empty parts of rural Australia, with huge areas of land to administer, should be allowed smaller population, while metropolitan councils will have a larger population. Subject to catchment constraints, boundaries would need to be revised periodically to accommodate movements in population.

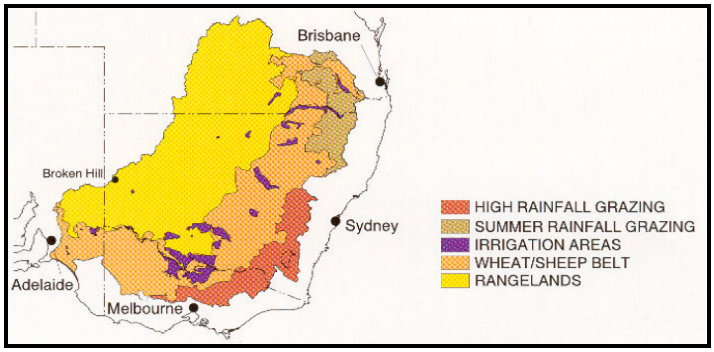
Something to think about

Have the States of Australia passed their use by date?

Although environmental management in Australia is supposedly under the jurisdiction of the State governments, local governments are in a better position to oversee enactment of natural resource policies. They are also in a position to respond more rapidly to environmental problems as they arise, assuming of course that they are adequately resourced.

The State level of government in Australia should be abolished because it no longer serves any important strategic function. The States could be substituted by regional groupings of local governments. These regional groupings would, of course, correspond to regional catchments or river basins. Here are two reasons why the States have passed their use-by date:

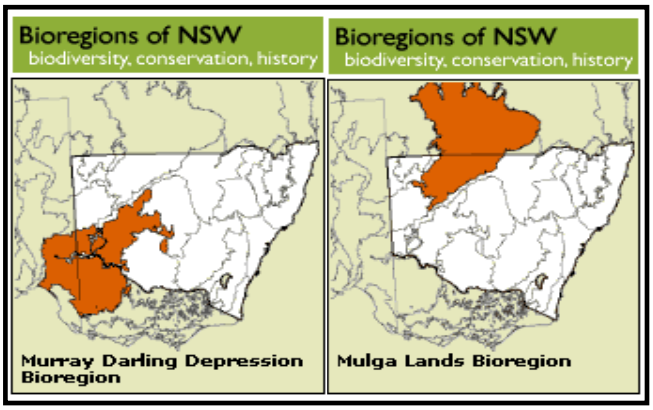
1) Failure to manage the Murray-Darling Basin



In July 2007, the Commonwealth government introduced legislation to bring the Murray-Darling Basin under its control. (Note in the figure how

the basin straddles four States.) Despite objections from Victoria and concerns about concentration of power, whole basin management is the only solution to the inability of the four concerned States, Queensland, NSW, Victoria and South Australia, to do the job.

2) Failure to manage bioregions that cross several State boundaries.



Managing biodiversity requires a whole bioregion approach. It became apparent in the early 1990s that conservation goals could not be achieved if administrative regions were constrained by State borders. Consequently, the States asked the Federal government to coordinate the determination of bioregion boundaries. Today there are 85 recognized bioregions. 17 are found in NSW, but of these only two lie wholly within the borders of the State. In the system proposed in this essay, where LGAs and regional boundaries would be determined by catchments, many bioregions would also cross administrative boundaries. Hence there is a need for a separate administrative apparatus for bioregions.

Land-care and Farmers Organizations

The best persons to care for an area of land are those who actually live or work on it. Their everyday presence ensures that they will recognize small deviations from the natural order of the previous decades. In the case of rural land, the growers, cultivators and graziers themselves are the best caretakers. Unfortunately there are two all too common obstacles to the realization of this truth. First, in most parts of the world, both developed and undeveloped, farming is a marginal or uneconomic enterprise. In such circumstances, land care is low down the list of priorities. Second, much land, both rural and urban, is owned by absentee landlords. The people actual working or living on the land have no incentive to care for it because they could be gone tomorrow.

Rural communities in Australia are in decline. The average age of an Australian farmer is now 61 – young people are turning away from the land.[128]

Farmer suicides and farm debt are running high. We have already noted the farmer civil disobedience campaign to fell protected trees on their properties. The government introduced land-clearing restrictions in order that the tree growth can be used to offset carbon pollution from the country's vast coal mining industry. Farmers argue that they are the scapegoats for climate change and that the ban on tree clearing is yet another impost making it difficult for farmers to earn a living.

Farmers have a legitimate grievance. Two decades of rural policy dominated by economic rationalism and free trade have ripped the heart out of Australia's rural communities. Some way must be found to make farming an economically viable occupation, if it is also to become ecologically sustainable.

Part of the solution is the gradual development of a cooperative rural economy.[129] But another ingredient will be agreements between representative organizations, which in developed countries means both farmer and environmental organizations. An historic agreement has just been signed in Queensland and may be a positive sign of things to come. After many years of fighting between farmers and environmentalists over the rapid rate of tree clearing, the Queensland Premier has brokered an agreement between the Queensland government, Agforce (Queensland's powerful farmers organization) and the Australian Rainforest Conservation Society. Under the agreement, farmers who adopt green land care practices will be rewarded with longer leases. (In Queensland, much rural land is government owned and leased to pastoralists. In fact, the Queensland State government is the largest landholder in the world after China and Russia.) AgForce cites the main issues facing growers in Australia as resource management, land tenure, environmental issues, international competitiveness and withdrawal of rural community services. The above agreement attempts to address the first three of these. Unfortunately, unless the economic viability of farming is addressed, such agreements are unlikely to be effective.

Something to think about

A letter to The Mercury newspaper, Hobart.

"While the State government's recent announcement of $420,000 to help 45 vegetable farmers develop business skills and $4 million for marketing initiatives for Tasmanian produce is laudable (see *The Mercury*, 21st September) it is not addressing the crux of the problem.

"Unfortunately for a number of reasons we are not competitive with the rest of the world because our costs of production are too

high. Forget about all the level playing field talk. It will never happen.

"Many of these costs are outside the farmer's control, such as government charges at all levels and excessive red tape.

"However, many are within our control. Most of our Tasmanian vegetable farms are over-capitalized and too small to be viable in the long term.

"What the government should be doing through the Department of Primary Industries, Water and Environment is examine new business models by which groups of willing farmers could farm cooperatively together as districts, ensuring greater economies of scale.

"The natural resources of the regions, such as water, drainage and topography, could be used more effectively.

"Build infrastructure, such as roads, fences and buildings, that would eventually be located more strategically.

"The savings on machinery costs and the ability to purchase in bulk would also be considerable. The opportunities to build a viable future are exciting, challenging and numerous.

"I know lots of sacred cows will have to be buried but let's have the debate before it's too late.

"This is not about destroying rural communities. It is about saving them while we still have a say in our future."

Rick Rockliff,
Sassafras
24th September 2005

Regulatory Bodies

Principles

Leaman[130] promotes the following principles of water management and water legislation:

- The water cycle is essential for a healthy ecosystem. Water is essential for economic development. Clean water is essential for human health. All three are interconnected. It is not possible to have one without the others.
- Water in all parts of the world in whatever form is linked via the water cycle. It is not possible to divide water into isolated categories, for example,

surface water and ground water, and to have different legislation for each. The water cycle must be managed in its totality.

- There should be no waste – water must be maximally utilized.
- Water should not be unnecessarily degraded because water is recycled to others through the water cycle.
- Water is part of the commons, not given to any one person to squander. Water should be shared equitably and there must be a transparent allocation system subject to appeal.
- Codes of water practice should adopt the *precautionary principle* – when in doubt protect the resource. Water is too valuable to risk.

Water management requires an understanding of all parts of the water cycle within all catchments from local level to drainage division. It requires measurements of precipitation, water flow, ground water levels, evapo-transpiration, water quality and human abstractions and discharges. Water resources are managed for many uses other than abstraction. Consider the following list of competing management demands:

- Flood defence and land drainage.
- Development of water resources, especially storage facilities.
- Control of abstractions by individuals, irrigators, private companies and public utilities.
- Control of water pollution and salinity.
- Control of effluent discharge.
- Control of catchment erosion.
- Maintenance of freshwater fisheries.
- Conservation of the water environment, biodiversity and environmental flows.
- Provision of water based recreation, including fishing.
- Navigation.
- Environmental flows (last in the list because that is where it has traditionally been placed).

Some history – water administration in the UK

The formation of multi-purpose river basin authorities was debated in the UK for more than 100 years before it actually happened. As far back as 1870, Lord Robert Montague, a commissioner in the Royal Sanitary Commission, argued

that "the various interests of land and river, navigation and mills, drainage and water supply, fishing and manufacturers, can be adjusted and developed only by the one management over the whole river".[131] His advice was rejected.

Disastrous flooding events over subsequent decades, primarily due to extensive deforestation of the English landscape, led to the formation of numerous land drainage boards and ultimately to the Land Drainage Act of 1930 which established the notion of *catchment management*. The next advance was the formation of River Boards under the River Boards Act of 1948. But this Act failed to provide the Boards with the power to conserve water. They were purely a data collecting service.

The introduction of spray irrigation after World War Two, with consequent tension between town and country over rights to water, set the scene for the next milestone in Britain's water legislation – licensing. For hundreds of years, water allocation had been determined by a system of water rights based on common law. This system was changed overnight by the Water Act of 1963 which introduced a system of government licensing. No one had individual ownership of the water, rather access was obtained by government license.

Further functions were integrated into the River Boards over the next decade until finally the 1973 Water Act established 29 truly multi-function Regional Water Authorities. However it can be argued that the 1973 Act went too far, because it also merged the regulatory role with the service utility role. Conflicts of interest arose as increasing economic pressures compromised water quality and conservation goals. The defects of this arrangement were used to push through the privatization of water utilities in the Water Act of 1989. A UK National Rivers Authority was established to coordinate the activities of 10 regional units, but of particular importance, the Act separated the regulatory function of the Authority from the private companies providing water services. Today there are 22 water companies whose jurisdiction is mostly catchment based. They are regulated by the Office of Water Services (the economic regulator), the Environment Agency (the environmental regulator) and the Drinking Water Inspectorate (the regulator for drinking water quality). A committee of Secretaries of State has a wider role in developing policy and the legislative framework.

Australian regulatory bodies

Effective water management depends on sound institutional arrangements supported by Acts of Parliament. Australia has three levels of government, local, State and Federal, and at present it is the States that have primary responsibility for water management. In Queensland, for example, the Water Act 2000 vests all rights to the use, flow and control of Queensland's water with the State government. The legislation is implemented by the Department of Natural Resources, Mines and Water (NRWM) and requires that the NRWM

prepare a Water Resources Plan (WRP) for every river basin followed by a Resource Operations Plan which determines how the objectives of the WRP are to be achieved.[132] The plan must have a number of features which would satisfy some of Leaman's principles and which, according to the NRMW, are Australian best practice:

- The plan must specify the long-term consequences of the proposed water allocations so that all users have certainty and security.
- Water resources must be managed to maintain river basin health and to provide for the long-term sustainability of its ecosystems.
- The plan must specify a range of environmental flow objectives to achieve river health and these must be supported by good science.
- Future increases in water allocations must be compatible with the security and environmental flow objectives.
- The planning process should include community consultation.
- Planning must adopt the precautionary principle.
- More controversially, the Water Act 2000 also introduced a system whereby water entitlements can be traded independently of the land to which they were previously attached. Trading is seen as a means of increasing productivity and efficiency because water moves to the highest value uses. However the Water Operations Plan must contain trading rules to ensure that the movement of water does not compromise security and environmental flow objectives.
- The plan must also include demand management, ground water management, etc.

The end result should be a plan that allocates water for domestic, agricultural, irrigation, industrial and recreational users subject to the constraints of environmental health and allocation security.

The whole process looks good on paper and is probably the best that can be achieved in today's social and economic climate, but given the fact that so many of Australia's rivers are in crisis, the regulatory regime is clearly inadequate. Here we address just a few of the problems. They are not unique to Australia and they provide valuable lessons for the future.

Divided responsibility: Many of the important river basins in Australia, most notably the Murray-Darling, do not correspond to State boundaries. The effect is that each State attempts to maximize its take of water and blame the others for mismanagement. A second problem is that there are multiple regulatory bodies even at the same level of government, with overlapping areas of responsibility but with different goals and time-lines. For example, there are

currently five overlapping Australian Commonwealth bodies responsible for water.[133] The net result is that even though everyone accepts the principle of whole river basin management in theory, the reality is nothing like it.

Nepotism: In 2008, the Queensland Labor government announced that it intends to issue a tradable water allocation to Cubbie Station, a huge cotton grower high in the headwaters of the Murray-Darling Basin.[134] Due to water shortages in the basin, the licence is effectively a gift worth about $100 million AUD. Cubbie Station is already the biggest irrigator in Australia and much controversy surrounds its profligate use of water. Of particular concern is that the head of the company was a previous treasurer in the same Queensland Labor Party. It is also of interest that at the time of the announcement, Cubbie Station was deeply in debt due to the Global Financial Crisis. It is easy to agree with a downstream grazier that the issuing of this license is "morally outrageous".

Transparency: Catchment water accounting should be transparent, that is, the accounts should be public documents. However this is not always the case. In places like Tasmania, where water is highly politicized due to large amounts of water consumed by the woodchip forestry, catchment water accounts are kept secret.

Politicization: The author has spoken to person's who participated in the community consultation process that was an integral part of the preparation of the Mary River Basin Water Resource Plan in Queensland. It was quite clear that those pushing for more environmental flows were up against powerful established lobby groups. In the Condamine-Balonne Basin, established users mounted a legal challenge against the science used to determine environmental flows.

Enough of the problems – what are the solutions? There has been much discussion in the Australian media over the past few years concerning an effective regulatory apparatus for water. A key issue is how to deal with the extreme politicization of water which makes it impossible to take timely and effective action. The politicization of water is perhaps inevitable, but some steps could be taken to minimize the problem. One suggestion has been to constitute water boards in a manner not dissimilar to the board of the Reserve Bank. The Reserve Bank has an economic regulatory function, established by statute, with which politicians can not directly interfere. Catchment and River Basin boards would be appointed as appropriate by local and national governments consisting of properly qualified people. To prevent nepotism, selection to such boards should be limited to members of an Australian College of Water Scientists and Engineers. In Sarkar's view, water boards must be given all the power they need to manage catchments according to the best science.

The goal of such a mechanism is to allow politicians to have some control over the general direction of water policy but to prevent them from having any influence over its administration. Decisions concerning water should be made on the basis of the best science available, not the strongest lobby group. Just as the statutory duty of the Reserve Bank is to maintain stable prices within certain limits, so too the statutory duty of a River Basin board might be to allocate water subject to keeping the total catchment's water balance within certain limits.

Catchment accounts and budgeting

Australia's National Water Initiative (a Federal program) is designed to implement total accounting for Australia's water use. One of its objectives is to return over-allocated catchments to balance by 2020. But the presumption is that we know what that balance might be. Much research is needed.

Every catchment and river basin requires a set of water accounts and an annual budget. In theory this is little different from a set of financial accounts – one set of books to keep track of income and expenditure (inflows and outflows) and another set of books to keep track of assets and liabilities (changes in the volume of reservoirs). For any catchment the difference between inflow and outflow should equal net change in the volume of stored water.

Quite apart from the fact that much research is needed in order to establish a set of water accounts, even knowing the figures it is debatable whether it is politically possible to return catchments to balance by 2020. State governments have over-allocated water rights and because these are tradable much of Australia's water is now owned by foreign companies.

Water accounting constitutes just one component of environmental accounting. Environmental accounting is in its infancy and many issues are yet to be resolved. The Wentworth Group of Concerned Scientists has recently put forward a proposal for a set of National Environmental accounts.[135] Data for the accounts would be collected on a regional basis and would monitor the health of five classes of environmental assets: land, water, atmosphere, marine and urban. The accounts would be published each year and would become the basis for determining the effectivness of all environmental restoration programs. The hoped for benefit from a set of water accounts would be, for example, a sustainable allocation of irrigation water in the Murray-Darling Basin.

The Habitat Hectares program[136] in the State of Victoria offers another example of environmental accounting, in this case accounting for land quality and its biodiversity. However the Habitat Hectares program goes a step further and sets up a market that allows land developers to trade in biodiversity. The idea is that the environment provides ecosystem services, that is, it performs

important functions that improve human life. Trees, for example, purify water, prevent erosion and so on. If a dollar value can be put on those services then market mechanisms can be put in place to retain or even increase that value.[137] As an example of this approach, New York's water supply comes from a large natural watershed and it is estimated that it would cost $9 billion to purify the city's water supply to the same extent if nature were not doing it for free.[138] If water is priced with this cost in mind, the revenue can be used to further improve environmental quality.

Politicians like putting a dollar value on ecosystem services because it makes it easier to weigh up conservation costs against competing budget items. But the approach is fraught with difficulty. Most obviously it assumes that all the services provided by a particular ecosystem can be known. But most ecosystems are incredibly complex and all their services cannot possibly be known. Furthermore, how does one put a price tag on the aesthetic, cultural or spiritual value of a particular lake or forest? There is, however, a more fundamental objection – the notion of ecosystem services is entirely focused on benefit to humans. But an ecosystem is really a living entity in itself, not an abstract concept, and therefore has its own moral right to be healthy, quite independent of its value to humans.[139]

Water Companies and Water Trading

Private versus public?

We now turn from the higher levels of water administration to the lower levels, the individuals and companies that get the licences and the rights those licences endow. It is here that the ideological struggles concerning water are the most intense, for it is here that water exposes an ideological faultline between two opposing views of the world. The one view says that resources are most efficiently managed when all of nature, including water, is owned by individuals who chase profit by trading in free markets. In the case of water, this means establishing a water market in which government allocations become a private asset that may be traded like any other asset. The other view says that natural resources, including water, are a gift of nature, part of the common wealth and not, in the first instance, the property of any individual. The common good is best achieved, not by chasing profit, but by public management in the public interest. It is fair to say that progressive thinkers around the world support water remaining in the public arena and certainly this is the Proutist perspective. Only where powerful corporations have captured the political process has water been privatized.

Nevertheless privatization of water remains a keenly fought battle and it is worthwhile to summarize the arguments for and against. There are primarily three modes of management for large water companies in various parts of the world: the private corporation, the traditional public utility and a hybrid, the

government corporation. The hybrid is essentially a business corporation trading for profit with the (majority) shareholding in government hands. It is a half way house, often used by governments as an intermediary step from public utility to full privatization.[140]

Although this essay supports the role of public utilities in a modern economy, their potential disadvantages must be recognized.

> Public ownership has traditionally suffered from a 'cost-plus' mentality, where frequently decisions are not properly costed. Bureaucracies can often be sleepy and over-staffed, with little incentives for innovation among employees. Public ownership can be expensive and inefficient *in economic terms*. Public authorities are also treasury-dominated, and suffer from the myopic nature of this department, which is always reticent to commit long-term investment capital (an attitude otherwise known as NIMTOO – not in my term of office).[141]

The main arguments in favour of public utilities are precisely those where private enterprise is weak.

> [Public utilities] tend to be safety conscious, consumer conscious and environmentally conscious. They do, after all, represent the public interest, and the public generally likes the idea and feels safe. Corners are less likely to be cut and the public authority is accountable to the Minister and Parliament and to the Treasury… Private ownership is supposed to offer efficiency and a cost consciousness, but with more focus on profit comes less focus on safety and the environment.[142]

The inefficiency of public enterprises is part of the dogma of modern capitalism. But the dogma should be challenged. It assumes that chasing profit for shareholders must necessarily generate efficiency. But we have seen in the past two decades that water and power utilities, once privatized, engage in mergers and speculative activities that have nothing to do with their intended community service. The Enron debacle is just one of many examples.[143] More recently we note the exorbitant salaries that the executives of large companies are awarding themselves. None of this is efficient in any sense of the term. By contrast, protocols are emerging whereby publically owned utilities can pursue real efficiency – benchmarking, comparisons with other utilities and comparison with world best practice, etc.[144]

In truth, the major motivation to privatize is ideological rather than to implement good policy. In an era of economic rationalism, governments are reluctant to engage in large infrastructure projects that make a significant impact on their budgets. Private companies, on the other hand, have access to large investment funds and claim to be better at managing the risk involved in large infrastructure projects. Such arguments are self-fulfilling prophesies. Reluctance to spend means that governments have run down existing infrastructure to the point where major investment is now required. Second,

governments have lost the skills which they once had to undertake large infrastructure projects. This is evidenced by the ability of private corporations to outmanoeuvre government bureaucracy (to the disadvantage of the consumer) in negotiations for privatizing the Sydney water system.[145] Australian governments once had the ability to undertake huge infrastructure projects, such as the Snowy Hydro Scheme, and there is no inherent reason why they cannot do so again, given the ideological will.

Not all water projects need be large scale. Indeed, another argument in favour of the decentralization of water harvesting is the consequent downscaling of the investment risk associated with smaller projects. Small- and medium-scale irrigation companies, organized either cooperatively or as trusts, are becoming more frequent in Australia. The motivation for farmers is to secure their water supply and remain independent of large corporations.

Water trading

According to free marketeers, water is just another commodity and its distribution is best achieved through trading in a water market. The implicit assumption is that water must therefore be in private hands. However water *ownership* and water *trading* are two separate issues. Likewise there is no inherent reason why water managed in the public sphere requires that all allocation decisions must be made by government authorities.

The wisest approach appears to be water markets where the dominant traders are public utilities and farmers cooperatives operating within of regime of strict regulatory oversight. Utilities and cooperatives have social and environmental objectives as well as economic, so they are not purely driven by profit. Such an approach allows water to move to higher value uses while ensuring that essential community and environmental needs are met. In other words, when the issue of ownership is separated from the issue of trading, the price of water can be allowed to reflect not just its true economic cost but also its true environmental and social cost.

Leaman argues that water trading can only take place against a background of a well-managed catchment for which all water inputs and outputs are accounted. His scheme has two principle features: 1) water trading should not be denominated in dollars but rather in litres, and 2) allocations to individuals should have transparent equity. He argues against a system that declares or implies that all the water falling in a catchment is owned by the State which then allocates that water as it sees fit. Such a system is against natural justice and will lead to theft and disputes between neighbours.

Once the total allocation in a catchment has been calculated, Leaman argues that every property owner in a catchment has a right to some of the water according to some formula that depends on the area of one's property and the rainfall.

> If you need more, or can make do with less, then a part of your share can be traded by agreement. This is a way of ensuring that everyone values the water they have and wastes none of it. It does not need a price. Any infrastructure installed to supply water can be subject to fees and management charges. The water must not be for sale, but managed.[146]

Note that in Leaman's scheme growers and irrigators might be doing their calculations in dollars but the regulator keeping track of trades would calculate only in litres. The regulator's statutory task is to ensure a balanced water budget for the catchment. Another feature of Leaman's scheme is the abolition of the government sale of water licenses, which has been abused for raising revenue, even when the available water is already over-allocated. In 2006, the average Australian water allocation was just 21% of the entitlement and in some cases the allocations have dropped to zero.[147]

Leaman leaves undiscussed the geographical limits to trading. Should water be traded outside the catchment and what are the limits to a catchment? The difficulty is that selling water from one property has consequences for neighbouring properties. As an example, water licenses in Sunraysia (an irrigation dependent fruit growing district in South Australia) can be sold for $2,500 per ML. Some 18% of Sunraysia's allocations have been sold outside the region, usually by growers attempting to stave off bankruptcy. The subsequent deterioration of the land affects even those who have retained their allocations.[148]

Barber[149] goes beyond the more obvious water trading scenario and proposes that we should also consider the water embodied in traded foods, woodchip, etc. He advocates a 0.02% tax collected on the freshwater embodied in all international trades. The motivation is to encourage countries with high levels of freshwater to retain forests and glaciers. Barber also advocates the adoption of an international protocol for water similar to the Forest Stewardship protocol. Signatories to the protocol would, for example, ban trade with groups that do not practise high water management standards. Of course, levying a tax on embodied water requires one to calculate such quantities in the first place. One approach is water *footprinting*. The *water footprint* of an individual or community is defined as the total volume of freshwater consumed by that individual or community per unit of time or, in the case of a business, it is the water consumed to produce a unit of output.[150]

Community and Culture

Rhetoric versus Reality

The first Earth Summit of June 1992 came to an agreement on best practice water management. The catch phrase was *Integrated Water Resources*

Management and, in theory, the resolutions to emerge out of the summit were all laudable: a commitment to equity and sustainability as the basis for service delivery; water administration on a whole river basin or catchment basis; commitment to consultation with stakeholders; decision making at the lowest possible appropriate level; need for community and women's participation; social mobilization, accountability and transparency. All were explicitly emphasized. So where is the problem?

As spelled out by Black,[151] integrated water resources management and sound water governance do not exist in the ether – they exist only on the ground within specific economic, cultural and political circumstances.

> The context in which policy principles have to be applied – in every case a unique mix of economic, social, cultural, hydro-geological, political, administrative and other environmental factors – determines which policies are suitable and whether they can be made to work. 'Good governance' cannot be invented as if it were a module or imported from outside; it needs its own roots and organic growth to flourish. Very little governance in poor societies is good or effective; it is usually under-resourced, inefficient, undemocratic and corrupt. There is no mystery about this, although the degree to which it is ignored implies that there is. It is simply a corollary of a country or areas within it being seriously 'underdeveloped'.
>
> The water policy principles so painstakingly thrashed out in Agendas and Guidelines may be excellent on paper. But practice on the ground falls desperately short.[152]

Black is particularly critical of big water and irrigation projects funded by international agencies, such as the World Bank, that inevitably centralize the control of water. Such projects establish the very opposite of what is apparently supported on paper. Governments, corporations and banks are reluctant to fund low-tech projects that harvest rainwater locally, that install non-energized irrigation or 'dry' sanitation. Instead they fund large projects that encourage centralized control, national growth against sustainable livelihoods and privatization over public ownership. The ideological commitment to large centralized projects is all the more damaging in societies which are already decentralized and have fragile national administrative systems.

According to Black, the international consensus of the world's leading water warriors (she cites people such as Vandana Shiva and Riccardo Petrella) is clear:

- Water is a vital natural resource and should remain in common ownership.
- Both the water and the pipes which carry it about must be controlled by local democratic power.

- Water must not be controlled by distant corporations having government bureaucracies in their pockets.
- The democratization of water begins by capturing rain locally.

The lesson: *One cannot import first world technology into a Third World culture*. But even in economically developed Western countries, Sarkar would promote a decentralized approach to the harvesting and management of water (See Appendix 3).

Community Supported Agriculture

Community-supported agriculture (CSA) is an approach to food growing and distribution, where a community of individuals pledges support to one or more farms and the growers and consumers share the risks and benefits of food production. A CSA usually arranges for weekly collections of fruit and vegetables from growers, packages them into boxes sufficient for one family over a week and distributes to member families.

CSA began in the early 1960s in Germany and Switzerland and independently in Japan. Responding to concerns about food safety and the urbanization of agricultural land, groups of consumers and farmers formed cooperative partnerships to fund farming and pay the full costs of ecologically sound and socially equitable agriculture. In Europe many of the CSA style farms were inspired by the economic ideas of Rudolf Steiner. The idea spread to the USA in the 1980s and today North America has at least 13,000 CSA farms.[153]

There are many variants of CSA but the basic design is to form a committed group of consumers who are willing to fund a whole season's budget in order to get quality foods. A family does not pay per kilogram of produce, but rather supports the budget of the whole farm and receives weekly what is seasonally ripe. A significant advantage of this approach is that it spreads the financial risk while allowing the grower to focus on what he/she does best – care of soils, crops, animals and co-workers.

Some CSAs have evolved into social enterprises employing local staff, improving the lot of local farmers and educating the local community about organic/ecologically responsible farming. The Food Connect Foundation is a highly successful model of this approach in Southeast Queensland.[154]

Recombinant Ecology

Human beings have settled virtually everywhere on planet Earth and, for better or worse, made their mark on its landscape. It is no longer useful to think of nature as some pristine state, independent of human activity. Rather individual *landscapes have co-evolved with local human culture* and they continue to do so. Just as *fusion music* is an innovative mix of international styles, so in most

parts of the world agriculture is a hybrid of indigenous and introduced species and practices. Landscapes everywhere are in rapid state of flux, demanding new theoretical concepts, such as *recombinant ecology*.[155]

This is particularly true in Australia, where migrants or the descendants of migrants make up an overwhelming majority of the population and own or manage most of the country. Each wave of newcomers has brought not only diverse cultural resources to enrich civil and economic life but also diverse genetic resources to create hybrid agricultural systems.

> In northern Australia, for example, tamarind trees were introduced by Macassans who arrived each year in large fleets of fishing boats. The trees seeded prolifically and now the seasonal fishing camps can be identified from their tamarind trees. In central Australia, a 'hybrid agriculture' has evolved from the introduction of date palms and camels from Southwest Asia; rabbits and beef cattle from Europe; citrus from China; grapes, mulberries and figs from the Mediterranean; store food that is trucked in from the coastal cities; and bush tucker which has co-evolved on this continent for millions of years. Given this diverse agricultural heritage, Australian 'farming' systems of the future will be mixes of indigenous, exotic and colonial components, just as current systems are 'hybrids' of indigenous and exotic species brought together by the 'historical accident' of British colonization.[156]

Learning to Care

"*Getting people to give a damn is the issue*."[157] Caring for a landscape requires *land literacy*. There are two parts to it, a subjective cultural component and an objective or scientific component. Fortunately, both of these can be learned, but the cultural component has been left to chance. It has taken a long time for we Australians to be deeply moved by the landscape which we inhabit, mostly because the majority of us are recent arrivals. The landscape looks and works differently from other parts of the world. It takes time to understand it – time to love it.

Education can help, but not just an education of knowledge. Something more is required – to encourage an ethic that goes beyond purely human concerns, an ethic of respect and love for the natural world. Neohumanist education does just this.

> To walk the earth lightly, internalizing the principle of non-harm, to live gratitude and to work always in the knowledge of our relationship to the physical, organic and human worlds is the heart of Neohumanist ethics and underpins all futures work. Such an ethic is based on the recognition that the human condition is no longer simply the province of human beings. It is, in the strict sense, a Neohumanist condition that incorporates the past, present and future, and also the planetary context. It opens up educational contexts in which speciesism can be addressed along with

> other cultural habits arising from the tendency to view the world as a resource. In sum, the human condition is a spiritual Gaian phenomenon.[158]

Ultimately, caring for water, for landscape, for the world around us, is about love.

> Neohumanism includes within its scope not only human beings and animate creatures, such as plants and animals, but also all inanimate entities as well, for the scope of Neohumanism extends down to the smallest particles of sub-atomic matter… Why should the love and affection of developed human minds be restricted to human beings only?[159]

In *Wisdom of the Elders*, Knudtson and Suzuki argue that both culturally and scientifically there is much to learn from indigenous societies. The defining feature of indigenous societies is a distinctive culture "in which, at least traditionally, they have *a profound and deeply rooted sense of place and relationship with the entirety of the natural world*".[160]

Here is the question – what might the landscape management practices of a modern technologically developed society look like if it displayed *a profound and deeply rooted sense of place*? Clearly we would value our landscape, not just for its agricultural and mineral wealth, but for something more subtle, in the same way that Europeans value their great cathedrals, museums and art-galleries.

The tremendous success of the Landcare programme in Australia is a demonstration that collective consciousness is changing. The revitalization of degraded landscapes is becoming a major collective endeavour, a community art-form equivalent to the building of a sublime gothic cathedral. "Just as thought, observations and skill are used to create culturally significant symbols, environmental repair brings landscape back to life, in a symbolic and material healing of degraded ecosystems."[161]

Environmental journalist Robyn Smith is optimistic. She believes that Australia is finally starting to grow up:

> …we have left our frontier stage behind us and are moving into the next one, one of consolidation and responsibility. It seems that white Australians are now ready to take on the role of stewardship of the land, a role previously taken by Aboriginal Australians.
>
> Survival in this country has always meant cooperation and co-adaptation.
>
> Maybe we have learned the lesson that this is what we need to do in order to prosper as a country and as a people.[162]

Policy Recommendations

The policy recommendations that follow are offered with caution. So much depends on the political and cultural context, quite apart from the ecological context. However, since drought in Australia was what motivated me to begin this writing project in 2007, it seems fitting to conclude with the broad outlines of a policy on water and land management. Notwithstanding my insistence in this essay that water policy cannot be separated from issues of land management, land management policy has not been included below for two reasons. First, the policy list would be extended by many pages. Second, land management is even more dependent on local conditions than water management.

- The purest water is obtained by catching rain where it falls or trapping surface water as close to the rain source as possible. This policy requires many distributed storage facilities. It is consistent with the preferred policy of decentralizing the production and distribution of the essential requirements of life.
- In many parts of Australia, ground water is the only available source of potable water. The iconic Australian outback could not have been settled without it. However, ground water must also be conserved – not abstracted in excess of recharge. Centres of urban population should not rely on ground water, except in emergency.
- Desalination is a poor option, given its cost and the brine disposal problem. However for urban populations, desalination powered by renewable energy sources may be appropriate.
- Capture of rainwater from clean surfaces in the urban environment should be a priority. Treatment of stormwater to potable standard is expensive, as is recycling. Therefore water should be used multiple times before recycling.
- Water storage and treatment in aquifers should be implemented wherever appropriate. The inertness of the geological matrix is an important consideration.
- It may sometimes be useful to link distributed water storage facilities into a water grid, especially in regions with unreliable rainfall. However water grids are expensive to maintain and the policy of transferring water to develop one catchment at the expense of another cannot be supported.
- All artesian wells, that are spilling water freely, must be capped.
- Irrigation channels should be sealed to minimize evaporation and ground leakage. Storage and irrigation practices, which result in the evaporation of 50% or more of the harvested water, should be abolished. This figure can be progressively diminished.

- Promote reafforestation programs of high ground and water ways. Promote agro-forestry.
- The maintenance of a small-scale cloud seeding project appears justified in Australia on the available evidence.
- Water is a common heritage and a necessity of life. Unlike oil, which is also a necessity of modern life, freshwater has no viable substitute. Its depletion in quantity and quality has profound social, economic and ecological consequences. Therefore water should remain in public ownership. It also follows that the distribution of water should not be privatized and nor should water be reduced to an economic asset traded for profit.
- The harvesting, storage and management of water should be decentralized to maximize local water security. LGAs should be organized along catchment boundaries. LGs should be responsible for water accounting, catchment by catchment.
- National water authorities are required to coordinate management of river basins and to supervise inter-basin transfers and aquifers that underlie several river basins.
- Regulatory authorities should be administratively isolated from companies providing the actual water services.
- A system of regulated water trading could ensure efficient distribution.
- Acceptance of the *precautionary principle* which was agreed to at the Rio Earth Summit (1992): "Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

Something to think about

A vision of the future

Policy is not enough. Vision is required. Australian academics are turning their minds not just to modern technology but to the Australian landscape as a vibrant living entity. They see a marriage of bio-technology and managed healthy eco-systems. Here is just one example of a growing literature of futures thinking applied to the Australian landscape. In this example, Alexandra and Riddington imagine a flight over the Murray-Darling Basin (MDB) in 2105.

"In 2105, an international delegation of sustainability experts interested in catchment restoration toured the MDB. Flying low over the catchment this is what they saw. Blue haze hovers over ancient mountain forests in the south. From the foothills, north to the plains, large areas of plantations

and woodland regrowth dominate. Streams snake over the riverine plains, buffered by riparian forests, among mosaics of plantations, short rotation bio-energy forests, and a diversity of crops…

"The rivers sustain significant irrigated crops, despite the reallocation of water to environmental flows, native title claims and climate change. The fertile, arable plains support sophisticated *industrial ecosystems* producing a variety of industrial feedstock, biofuels, bio-pesticides, novel pharmaceuticals and intensive horticulture and viticulture. Precision farming systems use sophisticated monitoring technology to control inputs and focus cropping on areas that maximize profit and minimize risk, including environmental risks. Pest management is bio-intensive and relies on beneficial insects, natural pathogens and plant-based extracts. Bio-digesters produce energy and fertilizers from 'waste products'.

"Traditional crops are still grown, but many new crops feed the 21st century revolution in biological and chemical engineering producing nutritional supplements, fuels, oils, medicinal herbs, resins, tannins, natural rubber, gums, waxes, dyes, flavours and fragrances.

"Former grazing properties support plantations and regenerated forests, earning income from carbon credits, biodiversity bonds, biomass energy and utility timber production. Small residential villages – clusters of eco-housing – are surrounded by productive gardens, small farms, orchards and vineyards. Detailed catchment plans, revegetation and threatened species management plans are being successfully implemented, with few remaining signs of land degradation.

"Agriculture, manufacturing and food processing remain important to local economies with sizeable dairy, cropping, horticulture and timber industries. Agricultural production is concentrated where it is profitable and sustainable, due to ongoing international pressure to minimize agricultural subsidies. Damaging environmental practices are unviable as markets dictate strict environmental performance and proof of eco-efficiency using comprehensively audited, internationally recognized environmental management systems."[163]

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About the Author

Michael Towsey studied biology at Auckland University (New Zealand) in the late 1960s and later obtained his PhD in computer science from Queensland University. For most of his career Michael has been a research scientist. He started in the field of plant physiology, moved to crop physiology and after obtaining his PhD turned to biological applications of machine learning. Michael is a founding member and associate of Prout College. In relaxed mode, he plays in two recorder ensembles and potters around in a community garden.

Appendices

1 Water Statistics

Measures of water volume

Volume (litres)	*Weight (metric)*	*Length cubed*	*Appropriate scale*
1 litre (L)	1 kg	$(0.1m)^3$	Bucket
1 kilolitre (kL)	1 tonne	$(1m)^3$	House tank
1 Megalitre (ML)	1000 tonnes	$(10m)^3$	Weir/farm pond
1 Gigalitre (GL)	1 Megatonne	$(100m)^3$	Large dam
1 Terralitre (TL)	1 Gigatonne	$(1km)^3$	Large lake

Distribution of water on Earth (from Figure 1.1 of Goodman[164])

Oceans (97%),
Freshwater as both ice and liquid (3%) which is divided as:
- Polar ice caps + glaciers (75%)
- Rivers, lakes, groundwater (25%) which is divided as:
  - Surface water – rivers and lakes (1.2%)
  - Ground water (98.8%)

Average annual water balance of world (Table1.1 from Goodman 1984)

	Volume (thousands of cubic kilometres)		
Region	*Precipitation*	*Evaporation*	*Runoff*
Australia	7.1	4.7	2.4
Europe	6.6	3.8	2.8
North America	15.6	9.7	5.9
Total Land Areas	111.0	71.0	40.0
Oceans	385.0	425.0	-40.0

Volumes and flows

Volume of typical Olympic swimming pool (50m x 25m x 2m) = 2.5 ML.
Volume of water in Sydney Harbour = 500 GL.

Total water consumed by 20 million Australians per year: >24,000 GL (1200 kL per person).
Total water consumed by 6 million Israelis in one year: >2,000 GL (333 kL per person).
Total water consumed by Melbourne in 2006: 273 GL.
Amount of water transpired from corn field: 25 – 35 kL per hectare per day.
A single large tree can transpire 500 L of water per day.
Reported flow through Murray River, May 2007 after autumn rains – 103 GL.
Burdekin Falls Dam (North Queensland) in full flood – 13 GL per day. (Williams, 2007)
Variability of annual flow of the Balonne River through the Queensland town of St George:
In a wet year, 8500 GL, with 250 GL a day during a rain event.
In a dry year, 85 GL.
Rice crops require 12-13 ML per hectare.

The Great Artesian Basin

The basin is the largest and deepest artesian basin in the world, covering a total of 1.7 million square kilometres and underlying about one-fifth of the continent, including most of Queensland. The basin is 3,000 metres deep in places and is estimated to contain 8,700 million ML (cubic kilometres) of groundwater.[165] The present rate of extraction from the basin is about 500 GL per year. That is an annual discharge equal to the volume of Sydney Harbour.

The GAB discharges through mound springs, many in arid South Australia. The discovery of the Great Artesian Basin opened up thousands of square miles of country in inland New South Wales, Queensland and South Australia, previously unavailable for pastoral activities. European discovery of the basin dates from 1878 when a shallow bore near Bourke, New South Wales, produced flowing water. There were similar discoveries in 1886 at Back Creek east of Barcaldine, Queensland, and in 1887 near Cunnamulla, Queensland.[166]

Dams and storage

Volume of Cubbie Station Reservoir, Queensland = 500 GL. (1 Sydney harbour)
Variability of Lake Argyle, created by the Ord River Dam, Western Australia:
Average: area = 980 square kilometres, volume = 10,700 GL.
In flood: area = 2,072 square kilometres, volume = 34,000 GL.
Traveston Dam: stage 1 yield = 70 GL/year. Average depth = 5m.
Australia has 450 large dams with a combined capacity of 81,000 GL.
In the Murray-Darling Basin there are 200 major storages (above 1 GL) and 79% of the annual flow is extracted for irrigation.
Victoria has about 300,000 farm dams.

Daily per capita consumption of water for different cities

(see www.acfonline.org.au)
Brisbane 2004 – 339L (Australian Bureau Statistics)
Brisbane 2006 – 312L (GHD)
Official Queensland Government target – 300 L
Sydney – 230 L
Melbourne – 221 L
Melbourne – 206 L (2005-2006). Figure quoted from *The Age*, 1st May 2007
UK – 150 L

2. Interesting (or Disturbing) Factoids

- 34,000 tonnes of dog poo is washed into Melbourne's Port Phillip Bay by stormwater each year.[167] This is relevant if we intend to recycle stormwater.
- Australia has 180,000 kilometres of pipes to supply and dispose of water.
- Australia's largest private irrigation company is the Murray Irrigation Area. It takes 1500 GL from the Murray each year, more than three-quarters of NSW's share of the Murray water.
- The list of pesticides recommended by the National Registration Authority for growing cotton include endosulphan, pyrethroids, ovasyn, kelthane, larvin, methomyl, profenofos, comite.[168]
- "Sandra Postel, one of the top experts on the impact of irrigation practices around the world, says it is a sad fact that no irrigation era in history has survived beyond a century or so." (As quoted in Fullerton.[169])
- To keep the Murray Basin suitable for agriculture, 600,000 tonnes of salt are pumped out of the ground each year and transported out of the basin, a hugely expensive operation. Dry land salinity is Australia's biggest national disaster.
- Until recently, Brisbane was losing 10-20% of its drinking water because of leaky pipes and infrastructure.

3 The Australian Greens Water Policy

The following is quoted from *Policy Snapshots*, distributed by The Australian Greens[170] just prior to the 2007 Federal elections.

Preamble

Australia is the driest inhabited continent, yet Australians are among the world's heaviest water users. We need to use our water wisely and plan for a sustainable future in a drying and increasingly uncertain climate.

Climate change means that we cannot rely on runoff-dependent energy-hungry solutions such as new dams, mega-pipelines and desalination plants to secure our future water supplies. We should embrace water sensitive design principles, meet water efficiency targets, and capture and reuse stormwater.

The Greens will:

- Ensure that all future land-use planning addresses climate change.
- Keep all major water resources and infrastructure in public ownership.
- Set water efficiency standards for new developments and appliances.
- Provide incentives to retrofit existing buildings with rainwater tanks and grey water systems.
- Support the recovery of 3500 GL of water to restore the Murray Darling ecosystems and commit $3 billion to buy back permanent water allocations in the Murray-Darling.
- Ensure that development in northern Australia protects our wild rivers and does not repeat the mistakes of the south.
- Support water recycling and demand reduction initiatives.

4 Proposals of the Wentworth Group

The Wentworth Group has five proposals that State and Federal governments of Australia could implement immediately:

- Clarify water property rights and the obligations associated with those rights to give farmers some certainty and to enable water to be recovered for the environment.
- Restore environmental flows to stressed rivers, such as the River Murray and its tributaries.
- Immediately end broad scale landclearing of remnant native vegetation and assist rural communities with adjustment.
- Pay farmers for environmental services (clean water, fresh air, healthy soils). Where we expect farmers to maintain land in a certain way that is above their duty of care, we should pay them to provide those services on behalf of the rest of Australia.
- Incorporate into the cost of food, fibre and water the hidden subsidies currently borne by the environment.

5 Sarkar's Proposals

Sarkar's proposals for water management are scattered through a number of talks. The key features of his approach are:

- Most emphasis to be placed on the harvesting of rainwater and its storage.
- Maximum reafforestation to encourage rainfall over land.
- Minimal use of ground water by irrigators and industry.
- The decentralization of water storage and promotion of catchment self-sufficiency.

The following are some passages quoted in full, each starting with the name of the discourse and the date it was given. The discourses can be found in *Ideal Farming Part 2*,[171] *Prout in a Nutshell, Part 17*,[172] and *Proutist Economics*.[173]

"Water Conservation" (25th March 1989, Kolkata)

"The inner spirit of our water conservation programme is that the amount of existing surface water should be immediately doubled. But it is preferable if it is increased tenfold. This can best be done by a decentralized approach to water management which increases the depth, the area, or both, of water storage systems. The first step is to increase the depth of those ponds, tanks, dams, lakes, rivers and reservoirs which are already being used for storing water. The second step is to increase the area of these storage facilities, while the third step is to increase the plantations around them… In addition to this, many new small-scale ponds, tanks, dams, lakes and reservoirs should also be constructed. As a general rule, surface water should always be utilized in preference to subterranean water."

"Water Conservation" (25th March 1989, Kolkata)

"The banks of all water systems should be covered by dense forests. The science behind this is that the roots of the trees retain water. When the water-table subsides, the roots of the trees slowly release water. Hence, a pond surrounded by trees will never run dry. The foliage of the trees also minimizes evaporation."

"Lakeside and Riverside Plantations" (16th March 1988, Kolkata)

"For afforestation programmes to be successful, surface water must be conserved. This can best be accomplished by increasing the water capacity of existing storage systems and building new systems. The cheapest and easiest method of creating new water storage systems is to construct small-scale ponds and lakes."

"Integrated Farming" (20th February 1988)

"Irrigation is also an important aspect of farming. As a principle, subterranean water should not be used for irrigation purposes. Subterranean water should not be disturbed, otherwise the level of the water-table will drop, leading to an acute shortage of water. The best system is to collect surface water. The rainwater, even from light showers, should be collected where it falls. If the huge reserves of water under some deserts are harnessed, it may do more harm than good. It is always better to conserve surface water.

"Water conservation, irrigation and afforestation are essential for desert reclamation. In the Thar Desert of India, a canal has been constructed to bring water from the Ganges to irrigate the land. The Ganga Nagar area has been reclaimed and is now producing large quantities of wheat. The canal can be extended even further into the desert. Conserving surface water is the best method of irrigation and is preferable to exploiting underground water reserves."

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Sarkar, P. R., *Discourses on Prout* (DOP). AM Publications, First English Edition, 1993. This book is a series of six discourses given in English at the First Conference of Proutists, 17-22 October, 1959. (Note: These discourses are also contained in *Prout in a Nutshell*.)

Sarkar, P.R. *Ideal Farming*, (IF). AM Publications, 1990. This book is a compilation of discourses on farming.

Sarkar, P. R., *The Electronic Edition of the Works of P. R. Sarkar* (ElEdit). AM Publications, Version 7.0, 2006. (Note: All the discourses and books by P. R. Sarkar included in the above reference list are also available in this electronic edition. ElEdit Version 7.0 contains the most recent translations available of all Sarkar's discourses and books.

Note: In the following endnotes, a space may have been inserted into some URLs in order to facilitate formatting. If a URL does not work, check for the insertion of a gap.

Endnotes

[1] Prout (the Progressive Utilization Theory) is the socio-economic theory developed by the Indian philosopher, Prabhat Ranjan Sarkar (1921-1990). For an introduction to the social philosophy of Sarkar see in this volume, "The Biopsychology of Cooperation" by Michael Towsey. For an introduction to Sarkar's economic proposals see also in this volume, "The Three-Tier Enterprise System".

[2] Here Sarkar has adopted the terminology of the Indian system of administrative subdivision. Rural *Districts* are divided into *Blocks* and the *Blocks* into *Villages* (the smallest administrative unit). In urban areas, the District is divided into *Municipalities* (or City Councils) and the *Municipality* into *Wards*. This system was inherited from the years of British administration and consequently has similarities to administration in Australia and New Zealand where a Local Government Area is the equivalent of an Indian block. See http://en.wikipedia.org/wiki/Administrative_divisions_of_India for more detail on India's current system of administrative units which, it should be noted, is not entirely similar to that proposed by Sarkar.

[3] The Wentworth Group is a group of high profile and authoritative scientists concerned for the environment. They make reports and issue statements, particularly concerning water management, which carry considerable weight in Australian policy making debates. http://www.wentworthgroup.org/, link valid 20 December 2009.

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[8] Hamilton, Clive. *Scorcher: the dirty politics of climate change*. Black Inc. 2007.

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[13] Lawson (2002) as cited in *Water Demand Management* (2006) Ibid.

[14] Adams, Shar. "Water shortage man-made", *The Epoch Times*, 20-26 September 2006, p 1.

[15] Ibid.

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[22] Fullerton, 2001 Op Cit. p 86

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[28] From Black, Op. Cit., p 12, who cites *H2O*, *Guardian Special Supplement*, 23 August 2003.

[29] Chalmers, Emma. "Labor floats plan to harvest stormwater". *The Courier Mail*, Monday 2 July 2007, p 2.

[30] Eutrophication is the process by which pond and lake waters become enriched (polluted) with mineral and organic nutrients, thereby promoting a proliferation of plant life, especially algae. This reduces dissolved oxygen content, lowers water quality and kills other plants and fish.

[31] Farmhand Foundation. *Talking Water: An Australian Guidebook for the 21st Century*. Farmhand Foundation, 2004. ISBN 0-9751235-0-5.

[32] White, 2000 Op. Cit.

[33] Endersbee, Lance. *A Voyage of Discovery: An earthshaking revelation of what is happening to our planet*. Self published via Monash University Bookshop, Australia, 2005. http://www.monash.edu.au

[34] Adams, Philip. *A dissident view of water and warming*. Late Night Live, ABC National Radio, 11 December 2006, http://www.abc.net.au/rn/latenightlive/stories/2006/1808528.htm, link valid 18 December 2009. The Australian scientist Vale Lance Endersbee (1925-2009) was no stranger to controversy. He was a climate change sceptic and a supporter of the Citizens Electoral Council of Australia whose approach to climate change is the adoption of nuclear energy.

[35] http://rio.twdb.state.tx.us/publications/reports/GroundWaterReports/GWReports/R360AEPC/Ch15.pdf

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[47] http://www.solarsailor.com/media_water_061012.htm, link valid 20 December 2009.

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[49] http://www.skysails.info, link valid 20 December 2009.

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[51] http://www.qwc.qld.gov.au/Projects+-+South+East+Queensland+Water+Grid and http://www.cottonwoodwater.org/indirect_potable_reuse.htm

[52] Responding to public concern, the Queensland Water Commission has published a brochure listing the seven barriers in its intended plan to recycle water for domestic consumption:

- Barrier 1: Source control – to prevent harmful chemicals from entering the water cycle in the first place.
- Barrier 2: Wastewater treatment plant – a settling pond and biological reactor that removes most solids, organic matter, etc. After this point, the water could be used for outdoor irrigation.
- Barrier 3: Microfiltration – low-pressure membrane filtration to remove bacteria. This technology is already used in the manufacture of beverages.
- Barrier 4: Reverse Osmosis – a high pressure filtration process that removes salts, viruses and organic pesticides. The same technology is used in desalination plants.
- Barrier 5: Disinfection and Advanced Oxidation – uses ultraviolet light and peroxides to remove any remaining organics compounds.
- Barrier 6: Natural Environment – water is returned to storage dams or aquifers in readiness for final treatment.
- Barrier 7: Water treatment plant – the existing standard water treatment and sterilization.

According to the same Queensland Water Commission brochure, "Purified recycled water has been used to safely replenish drinking water supplies in North America and Africa for decades and more recently in Europe and Asia. Long-term studies have shown no adverse effects."

[53] Sarkar, P. R. *Prama.* AM Publications, 1987.

[54] Ransom, 1998 Op. Cit.

[55] Ransom, 1998 Op. Cit.

[56] The ruling Queensland Labor Party's promotion of the Traveston Dam against widespread opposition caused the sitting Labor member for the area, Andrew McNamara, to lose his seat in the subsequent State election on 21 March 2009. See "Traveston issue blamed for ousting McNamara", *The Sunday Mail*, 22 March 2009, p 9. At the time of publication the dam was finally stopped by the Federal Minister for the Environment on environmental grounds.

[57] ECO, Issue #04, Nov-Dec 2006, Sunshine Coast Environment Council, http://www.econews.org.au, link valid 20 December 2009.

[58] The *power scaling law* expresses this idea in precise language. For the mathematically minded a function obeys the power scaling law when the logarithm (log) of the count of X (where X in this case is reservoirs of a particular volume) plotted against the log of X (the reservoir volume) is a falling straight line over three or more orders of magnitude.

[59] For example, neurons in the brain are inter-connected according to a power law. Genes inside cells regulate each other according to a power law. It is also a property of social systems – the distribution of business sizes and the connectivity of the internet follow a power law.

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[61] *Large Dams In India – Temples Or Burial Grounds?* (2004). http://www.zmag.org/content/showarticle.cfm?ItemID=6272

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[68] Leaman, 2005 Op. Cit., p 50.

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[70] At the Institute of Sustainable Futures, http://www.isf.uts.edu.au

[71] Black, 2004 Op. Cit.

[72] Leaman, 2005 Op. Cit. p 48.

[73] Leaman, 2005 Op. Cit. p 48.

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[77] Fullerton, 2001 Op Cit.

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[117] Sarkar (IF), p 94.

[118] Sarkar (IF).

[119] For a more detailed discussion of Sarkar's approach to a cooperative rural sector, see Michael Towsey, "The Three-Tier Enterprise System" in *Understanding Prout*, *Volume 1*, 2010.

[120] Sarkar (IF), p 9-10.

[121] Sarkar (IF), p 94.

[122] Sarkar (PE).

[123] Leakey, Richard and Lewin, Roger. *Origins – What New Discoveries Reveal about the Emergence of our Species and its Possible Future*, pp 9-10, E. P. Dutton & Co., 1978. ASIN: B000IV25Q8.

[124] "Farmers launch tree-felling protest", *The Australian*, 3 July 2007.

[125] UN, United Nations. *Millennium Development Goals*. United Nations, NY, USA, 2003. http://www.developmentgoals.org/Education.htm

[126] National Parks and Wildlife (NPWS 2007), New South Wales, Australia. http://www.nationalparks.nsw.gov.au/npws.nsf/Content/Home

[127] Alexandra, J and Riddington, C. "Redreaming the rural landscape". *Futures* **39** pp 324-339, 2007.

[128] 80% of Australian farmers are 64 or older. See http://www.foodconnect.com.au/

[129] Towsey, Michael. "The Three-Tier Enterprise System", in *Understanding Prout, Volume 1*, Proutist Universal, 2009.

[130] Leaman, 2005, Op. Cit.

[131] As quoted in Bailey, Richard. *An Introduction to River Management*. The Institution of Water and Environmental Management, 1991.

[132] Water Resource Plans result in many glossy brochures! See, for example, a variety of reports associated with the WRP for the Mary River Basin published by the Southeast Regional Water Planning Group, Department of Natural Resources and Mines (Queensland), April 2003.

[133] The five are:

- National Water Commission, a statutory authority within the Department of Prime Minister and Cabinet (PM&C).
- Office of Water Resources, an agency within PM&C.
- Department of Agriculture, Forestry and Fisheries (DAFF).
- Land and Water Australia, a statutory authority within DAFF.
- Department of Environment and Heritage.

Each of these separate bodies administers a range of different programs including the National Water Initiative, the National Action Plan for Salinity and Water Quality, and the Murray-Darling Basin Initiative. Although these programs address similar problems, they have different structures, different departments, different Ministers, different accountability mechanisms and different timelines. The Australian Labor party has said it will create a single Federal Government Agency to administer all Commonwealth water programs using the argument that Australia's water crisis is a national problem that demands a coordinated national response.

[134] Roberts, Greg. "Farmers fume over Cubbie station 'gift' of water license". *The Australian*, 10 July 2008.

http://www.theaustralian.news.com.au/story/0,25197,23996542-5013404,00.html, link valid 20 December 2009.

[135] Wentworth Group of Concerned Scientists. *Accounting for Nature: A Model for building the National Environmental Accounts of Australia*. April 2008. Downloadable from http://www.wentworthgroup.org, For a good introduction to the model, see also Peter Cosier, *Accounting for Nature*, Fenner Conference on the Environment, 10-12 March 2009, Canberra.

[136] http://www.environment.gov.au/archive/biodiversity/toolbox/templates/pubs/habitat-hectares.pdf, link valid 23 December 2009.

[137] http://www.abc.net.au/rn/backgroundbriefing/stories/2008/2392756.htm, link valid 23 December 2009.

[138] Ibid.

[139] This is the distinction between the deep ecology and the utilitarian approaches to environmental management. See http://en.wikipedia.org/wiki/Deep_ecology, link valid 23 December 2009.

[140] Jesson, Bruce. *Only Their Purpose is Mad – The money men take over New Zealand*. The Dunmore Press, 1999. ISBN 0 86469 343 5.

[141] Fullerton, 2001 Op. Cit. p 29.

[142] Fullerton, 2001 Op. Cit. p 29.

[143] Cruver, Brian. *Enron – anatomy of greed*. Arrow Books, 2003.

[144] Towsey, Michael. "The Three-Tier Enterprise System", in *Understanding Prout, Volume 1*, Proutist Universal, 2009.

[145] Fullerton, 2001 Op. Cit. Chapter 2.

[146] Leaman, 2005 Op. Cit. p 134.

[147] Warren, M. Article in *The Australian*, 21-22 October 2006, p 6.

[148] Lane, Sabra. *Fear of no water forces councils to draw up tough contingency plans*. Australian Broadcasting Report, 2007. http://www.abc.net.au/am/content/2007/s1907815.htm, link valid 20 December 2009.

[149] Barber, Marcus. "A Drop in the Ocean for Foresight Practitioners: What the Future May Hold for Fresh Water Usage and Availability throughout the Globe". *Journal of Futures Studies*, **11**(3) pp 61-78, 2007.

[150] http://www.waterfootprint.org/, link valid 20 December 2009.

[151] Black, 2004 Op. Cit.

[152] Black, 2004 Op. Cit. p 136.

[153] See, http://en.wikipedia.org/wiki/Community-supported_agriculture. An inspiring film *The Real Dirt on Farmer John* documents the resurrection of a family farm through its conversion to a CSA model.

[154] http://www.foodconnect.com.au/

[155] Alexandra, J and Riddington, C., 2007 Op. Cit.

[156] Alexandra, J and Riddington, C., 2007 Op. Cit.

[157] Fullerton, 2001 Op. Cit. p 133, emphasis added.

[158] Bussey, Marcus. "Mapping Neohumanist Futures in Education", Chapter 1 in *Neohumanist Educational Futures*, editors Sohail Inayatullah, Marcus Bussey and Ivana Milojevic, Tamkang University Press, 2006. ISBN: 986-7385-63-2.

[159] Sarkar, P. R. *The Liberation of Intellect: Neohumanism*. AM Publications, 1982.

[160] Knudtson, Peter and Suzuki, David. *Wisdom of the Elders*, Bantam, 1999. ISBN-10: 0553372637. Emphasis added by this author.

[161] Alexandra and Riddington, 2007 Op. Cit.

[162] Smith, Robyn. *The Story: Caring for Country*, Australian Broadcasting Corporation., 1998. http://www.abc.net.au/science/slab/country/story.htm.

[163] Alexandra and Riddington, 2007 Op. Cit.

[164] Goodman, A.S. *Principles of Water Resources Planning*. Prentice Hall, NJ. 1984. ISBN: 0-13-710616-5.

[165] Fullerton, 2001 Op. Cit. p 261.

[166] http://en.wikipedia.org/wiki/Great_Artesian_Basin.

[167] Fullerton, 2001 Op. Cit. p 37.

[168] Fullerton, 2001 Op. Cit. p 83.

[169] Fullerton, 2001 Op. Cit. p 87. See http://www.globalwaterpolicy.org/books.html for reviews of Sandra Postel's books, *Rivers for Life*, Island Press, 2003, and *Pillar of Sand: Can the Irrigation Miracle Last?*, W.W. Norton, 1999.

[170] www.greens.org.au, link valid 20 December 2009.

[171] Sarkar (IF).

[172] Sarkar (PN18).

[173] Sarkar (PE).