The Down Under water experience

Jasper Verberk

Introduction

I'll start this article with the warmest July month ever recorded in the Netherlands. At the end of July I read on my Dutch internet news source (see Website 1) that in the month of July the water consumption in the Netherlands was 1,5 times the normal consumption in July as result of the heat stroke. Consumption figures of several water companies were given. At the bottom of this news item the following sentence caught my attention "Waternet, het bedrijf dat drinkwater levert aan Amsterdam kon het dagverbruik voor de maand juli niet aanleveren" or in English "Waternet, the utility supplying water to the city of Amsterdam, was not able to produce the daily consumption in the month of July". In Australia it is unthinkable that a water utility is not able to produce up to date figures on water consumption, daily rainfall and capacity of the reservoirs. Websites of Australian utilities are updated daily with these figures. The consumers visit these websites (see Websites 2, 3, 4, 5) frequently to see what the level of water restrictions is and to find out the allocated days for sprinkling their garden that week.

Furthermore, every day at the end of the news report on television in Sydney and in all local news papers overviews are presented of the water consumption of the different suburban areas, dam capacities, rain fall figures (currently and in the last 5 years) and so on.

And water is even a hot topic in the news and politics. Political parties have eminent water paragraphs in their election program and a special secretary of the PM for water has been announced to deal with interstate water related problems. On television attention is paid to the water problems on prime time by documentaries and discussion programmes. Water has been the lead story on most papers in the last spring as it is a topic that affects all Australians. Since October 2006 all major cities have water restrictions. Why all this attention, what's going on? Is it as problematic as it is? And what is the reaction of the Australian water utilities to the water crisis?

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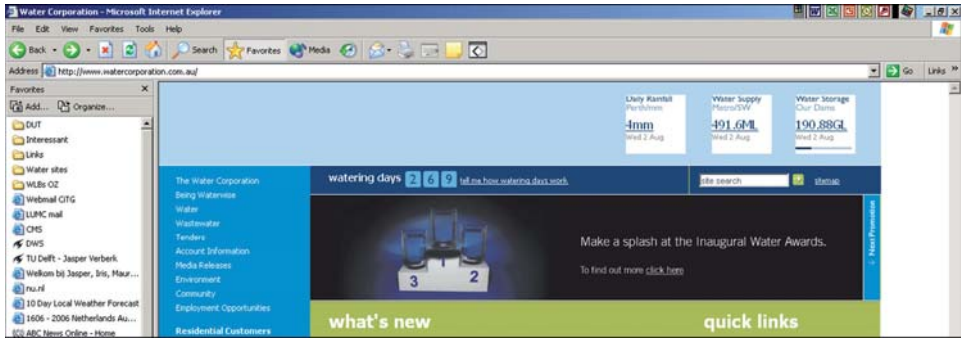

Figure 1 - Example of website of Australian water utility with on top of the site information about yesterday's reservoir levels, consumption and rainfall and street numbers indicating who is allowed to water the garden.

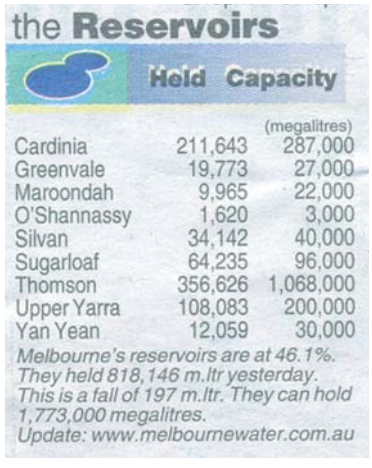

Figure 2 - Figures on water levels in reservoirs close to Melbourne

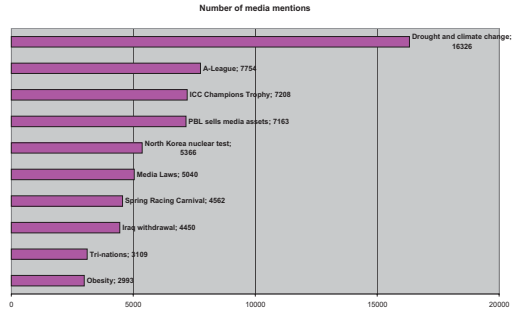

Figure 3 - The week's top 10 Australian issues, October 21-27 (Source Media Monitor)

Water consumption

Water availability

Australia is a large country with an unique water resources situation. Australia is a continent of extremes: of geography, climate, population distribution and water resources. It is the driest inhabited continent on Earth, with highly variable rainfall patterns. This variability means that Australian communities frequently face water supply and water quality problems.

Only 12 percent of the annual rainfall over Australia results in runoff into streams and rivers or soaks into and is retained in the ground. The rest is returned to the atmosphere directly by evaporation or from vegetation through the process of transpiration. This results in Australia having only one per cent of the water carried by the world's rivers despite having five per cent of the world's land area. The long term

When I arrived in September 2005 in Australia I expected a sunny hot country, where everyone is dressed in shorts and walking on thongs. This last expectations about the Australian "fashion" was true, however the spring of 2005 was very wet with even some floodings in the Adelaide area. This had not happened in the last 100 years! The year 2006 on the other hand was dry. I cannot remember any substantial rainfall since April 2006. In the month of October 2006 only 1 mm of precipitation was recorded, compared to a normal yearly average of 50 mm. Also when driving through the country it was obvious that the land was dry. The grass is everywhere yellow coloured and the number of bushfires was already high in October. The fire season even started 1.5 month earlier than normal because of these very dry conditions. I myself didn't experience that there was a drought. Water was always running from the tap. Even when the restrictions came into place in October there was always sufficient water.

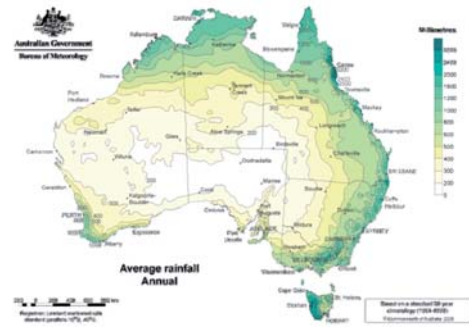

Figure 4 - Average annual rainfall in Australia (Bureau of Meteorology, http://www.bom.gov.au/cgi-bin/climate/cgi_bin_scripts/annual-monthly-rainfall.cgi)

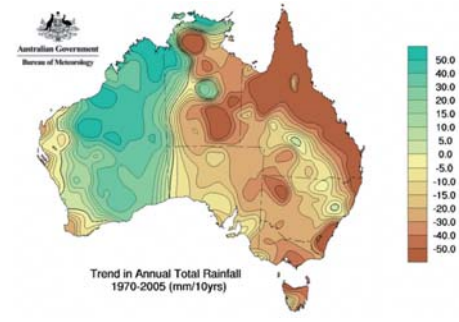

Figure 5 - Trend in annual total rainfall period '70- '05 (Bureau of Meteorology, http://www.bom.gov.au/cgi-bin/silo/reg/cli_chg/trendmaps.cgi)

average annual rainfall over Australia is estimated to be 455 millimetres. However, this hides the very variable rainfall pattern across the continent as indicated in figure 4.

Besides large fluctuations in rainfall over the country also large variations in rainfall over the years exist as a result of climatological weather phenomena like el Niño and la Niña. In recent years the rainfall has been considerably lower than the average values as indicated in figure 5 and many regions in Australia are dealing with a severe drought.

Australia is currently (anno 2006) experiencing the worst drought in 1,000 years. The yearly rainfall is half the average rainfall. All cities have started with water restrictions and some cities even are running out of water in the very near future. The water levels in the reservoirs are low (see Websites 6, 7), some reservoirs are even under the critical level. Some rural communities in Victoria have run out of water and the inhabitants are getting every two weeks water by trucks, the so called water carting (see Website 8).

The inflow in the Murray-Darling basin, the largest catchment area in Australia, is record low. Since the water year started on July 1 only 10% of the average inflow has reached the Murray-Darling basin. Also the reservoir and river levels everywhere in the country are historical low. Even some reservoirs have become totally dry and the pictures in the newspaper and on the television of the low water levels in the river Murray are dramatic.

Water consumption

Australians are large domestic water consumers. On average they use 315 liter drinking water per person per day for domestic use (Water account Australia 2000-01, 2004). The people in Northern Territory use most water, almost 600 lpppd, while the people in New South Wales are moderate consumers with only 277 lpppd. It has to be mentioned that in the Northern Territory and Tasmania there is an abundance of water and no water restrictions are in place, while in all the other states water restrictions

Table 1 - Water use by households 2000-2001 (Water account Australia 2000-01, 2004)

Location	NSW	Vic.	Qld	SA	WA	ACT	Aust.
Bathroom	26	26	19	15	17	16	20
Toilet	23	19	12	13	11	14	15
Laundry	16	15	10	13	14	10	13
Kitchen	10	5	9	10	8	5	8
Outdoor	25	35	50	50	50	55	44
Total	100	100	100	100	100	100	100

When I signed my rental agreement I was told that the first 200 kL (in Australia they use kL in stead of m^3) of water use would be paid by the land lord. I did a quick calculation, based on my Dutch water consumption of 125 lpppd, and concluded that this was a fair deal. My family would at maximum consume 150 kL a year. The first night we slept in our new house at 0.00 hour I was woken up by a strange noise. I quickly found out that the sprinkler system was in use. For an hour the lawn was watered. The same noise was nticed again at 6.00 a.m. Again the sprinkler system started. This all resulted in a huge water consumption. In the end I used far more than 200 kL a year, the final volume of water was 350 kL or a daily use of 250 lpppd.

are in place. Most of the water is used outdoors for watering the garden. In normal years the garden takes around 35% of the consumption, although in hot, dry summers this figure can be as high of 90% in some parts of the country.

The average price of water is $ 0.42 per kL for the first 125 kL, ranging from $ 0.42 per kL for the first 125 kL in Adelaide and Perth to $ 0.98 per kL in Sydney. The capital cities price is in the upper bound and some cities have inclining block tariffs (see table 2). As a result of the low price of water there is no incentive for Australians to limit their water consumption.

Taking into regard these low cost of water it is not strange to understand why there is a huge opposition against expanding treatment by the state governments. Increasing the treatment will result in very large investment costs and thus a large increase in drinking water price. With the low current cost a doubling of the price can easily be expected. Furthermore the realisation time for building a drinking water plant is most probably longer than the lifetime of the state government. Water related projects have a life span longer than the life span of the average politician. So the successive government will have the benefits of investments made by the previous government.

Water demand

At the time of writing of this article the Australian population just popped the 20.5 million inhabitants mark (see Website 9). As summarised in figure 6, the Australian Bureau of Statistics projects that the population of Australia will increase by five million more people to reach 25 million in 2032. Moreover, they estimate that the nature and rate of population growth will not be uniform. Most notably, the population of the Brisbane-Moreton region is projected

Table 2 - Tariff charges for water consumption

Town/City	Price per kilolitre ($)	Fixed charge ($)	Annual bill for 250 kL consumption ($)
Adelaide	0.42: < 125 kL	135	312.5
	1.00: > 125 kL		
Brisbane	0.84	100	310
Sydney	0.98	76.55	
Melbourne			
- City West Water	0.80	84.44	283.99
- South East Water	0.81	35.88	238.23
- Yarra Valley Water	0.78	59.12	253.05
Perth	0.42: < 150 kL	149	278.8
	0.67: 151 – 350 kL		
	0.91: 351 – 550 kL		
	1.20: 551 – 950 kL		
	1.50: > 950 kL		
Canberra	0.43: < 175 kL	125	279
	1.05: > 175 kL		

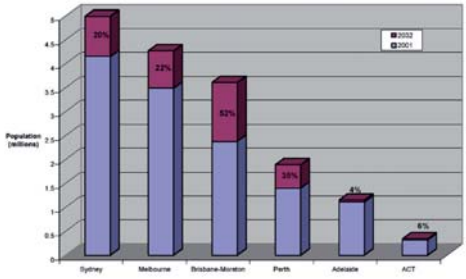

Figure 6 - ABS population estimates for 2001 and projections for 2032.

Figure 7 - Signs indicating level of water restrictions.

to increase by 53%, Perth by 35%, and Sydney and Melbourne are projected to increase by 20% and 22% respectively. Little growth is projected for Adelaide (4%) and the ACT (6%) (Australian Bureau of Statistics projections 2003).

Considering the decreasing rainfall in most of the country (15% in the Eastern States and South Australia) and the increasing population in these same areas it is not difficult to see that the Australian water utilities faces some real challenges in providing sufficient water to their customers in the future.

How to deal with this increasing demand?

There are different solutions to deal with this increasing demand, some are behavioural solutions, others are technical solutions.

Behavioural solutions

In times of extreme drought (as in the last decade) most cities introduce water restrictions. This means that the use of water is limited for some periods of time of the day and for some actions. In general there are 5 levels of restriction (although not in all states). An overview of the meaning of the different level of restrictions, the current restrictions and reservoir levels in the major cities can be found on: https://www.wsaa.asn.au/frameset2.html. The level of restrictions is triggered by the amount of water in the drinking water reservoirs. Once it drops underneath a certain level tougher restrictions come into place.

Much information is given by the water utilities about the restrictions on their websites, on television and radio and in schools. See for example the “our water our future” website (see Website 10), or the “save water” website (see Website 11).

In Australia the water utilities spent an enormous amount of time and effort in water education. By telling people what they can do to limit their water use the water utilities hope that the daily consumption will be limited. On all websites of the water utilities calculations of your daily water consumption can be made and methods to decrease your consumption are given (see Websites 12, 13, 14). Furthermore, water saving games are developed for young children to make the aware of the precious water. Also much publicity is given to smart water inventions.

The population of Australia is still increasing rapidly. Besides this, also the number of people living in a house is decreasing. Australians also spent more money on a second house away from the city. In the different trips I made in South Australia it was clearly visible that in the coastal communities around Adelaide many people build their second house. All these new development areas have to be supplied with drinking water. The drinking water is sometimes transported over a distance of more than 800 km. All pipelines to transport water to remote areas are made of steel, are placed above ground and water temperature can go up to 40 degrees. In Western Australia even temperatures of 50 degrees are found in the Kalgoorie pipeline and special heat shields have been designed to limit the water temperature increase. Of course it is questionable if the transport of water over these vast distances is a sustainable solution.

Figure 8 - Cartoon in paper after announcement of water restriction level 3 in Adelaide.

Not surprisingly the dual toilet is originating from Australia. Also the time shaving shower timers are getting much attention at the moment (see Website 15).

There is a large societal control of the water restrictions as neighbours report each other when they are using water not on the appropriate day. Furthermore, several cities have appointed special water patrols. These are officers patrolling the city, looking for households wasting water and also to educate people on water use. Heavy fines are given when people don't comply with the restrictions. In Adelaide those who fail to comply with restrictions will be issued with a notice reminding them of their responsibilities. If non-compliance continues, a $315 expiation notice will be issued. Serious and ongoing breaches could result in court action and fines of up to $5,000 for individuals or $10,000 for businesses.

Technical solutions

Besides these more behavioural solutions water utilities, consultants and federal and state government look for technical solutions on how to cope with the lower amount of water available as a direct result for the drought and the in the coming years increasing demand as a result of the population growth. Hereafter just some potential applicable solutions are given. Many more are proposed, like the blue sky projects as towing iceberg from the Antarctic to Australia and shipping water from the

Since October, 21st water was restricted in Adelaide, water restrictions level 2 were in place. I was only allowed to use water outdoors on 3 days of the week. The restrictions are aimed to reduce the water consumption. So I was quite surprised to read in the paper that since the water restriction introduction the water consumption in the Adelaide CBD area has increased. The reason for this increase is that people now are aware that they can not use water every day. Therefore they program their sprinkler installations to water the garden once every day with more than twice the normal amount of water, resulting in an overall water consumption increase. You can say that the introduction of the water restrictions level backfired. Restrictions level 3 will be announced on January 1st 2007, not allowing watering the garden with sprinkler installations but only with a hand hose with special water nozzle.

Kimberleys in giant water transport bags to Perth or transporting water by pipelines from the Ord river in the north of Australia through 4,000 km of desert to Adelaide and Melbourne

Rain water tanks

A simple and practical solution is to use all the rain as effectively as possible. Therefore in rural areas but also in the urban areas people install rain water tanks. This water is very useful for watering the garden, the main water consumer! Several state governments have drafted rebate schedules encouraging people to use rain water tanks.

New dams

Now the country is facing a very severe drought period discussions about building new dams to create reservoirs are omnipresent. Of course it is questionable if this will help as these reservoirs will only fill when rain is falling. Furthermore, it takes a long time before reservoirs are being built and close to the capital cities there are no locations available anymore.

Indirect potable re-use (IPR), direct potable re-use (DPR) or storm water capture

To reuse of water much attention is given in Australia, especially as it makes use of water already in the urban water cycle. Many new suburban development sites already make use of recycled water for non potable use, for example for watering gardens. Reuse by a dual reticulation system is no real option for already existing cities as an expensive second reticulation system has to be constructed. Reuse for potable water consumption receives lots of attention, especially in the towns with severe water restrictions, like Toowoomba (see case study hereafter) and Goulburn. This reuse can be direct or indirect. Indirect potable water reuse means that the waste water is treated and the effluent is led back to the reservoir and undergoes an additional natural treatment. Direct potable reuse means that the waste water is treated and from the effluent of a waste water plant directly drinking water is produced. This is already being done in Singapore in the NEWwater project.

Although there are some severe water restrictions in Australia the general public is not supporting the idea of water reuse for potable use. The Toowoomba case shows that the “not in my back yard principle” is valid. The people in general support the idea of reuse. But as it concerns their public health their opinion is not in favour for reuse.

Desalination

All capital and major cities in Australia are located close to the coast line. 80% of the population is living within 50 km for the coast line. Furthermore, the concentrate can be easily disposed in the sea as long as there are no real treatment solutions for this waste stream. As a result desalination is often mentioned as the solution for Australia’s drinking water availability problems. However, only a few small capacity installations have been built yet converting sweater into drinking water, mostly at tourist locations as Kangaroo Island (capacity 300 kL/d)

Case desalination Perth

The second case study deals with the water shortage in Perth. Climate change has seen the water running into Perth’s dams drop by two thirds in the last seven years. In 2001 water restrictions were introduced. Added tot this a population growth of 1.7% per year and a 20% increase in the amount of water used at home, sketches the contours of the expansion in water treatment needed in Perth. Currently an extra 150 GL a year is expected to be necessary in 2031. Already for decades different options for supplying water to Perth have been considered in several studies. Many studies have been undertaken to see if transporting water from the Kimberleys to Perth is a viable solutions.

At the end of 2006 the largest desalination plant in the Southern Hemisphere has been put in production. This plant has a capacity of 45 GL or 45 million KL a year. To reduce the environmental impact electricity for the plant it was the intention to produce energy by a wind farm. However, the exact location of the wind farm is still under discussion while the membrane filtration installation is already built. As from 2009 the current capacity is not sufficient to supply sufficient drinking water to the customers a second desalination plant with a capacity of 45 GL is in commission at the moment.

Case Indirect potable reuse

Toowoomba is a city in the South East of Queensland, Australia. It is located 132 km west of Queensland's capital city, Brisbane, and two hours drive from the famous Gold Coast and Sunshine Coast beaches. With a population of about 110,000 Toowoomba is Australia's second largest inland city, after Canberra, the nation's capital. The city sits on the crest of the Great Dividing Range, around 700 metres above sea level. The City occupies the edge of the range and the low ridges behind it. Two valleys run north from the southern boundary, each arising from springs either side of Middle Ridge near Spring Street at an altitude of around 680m. These waterways, East Creek and West Creek flow together just north of the CBD to form Gowrie Creek. Gowrie Creek drains to the west across the Darling Downs and is a tributary of the Condamine River, part of the Murray-Darling Basin. The water flowing down Gowrie Creek makes its way some 3,000 km to the mouth of the Murray River near Adelaide in South Australia. Rain which falls on the easternmost streets of Toowoomba flows east to Moreton Bay a distance of around 170 km.

Toowoomba's location in Queensland

Toowoomba's water supply consists of 3 dams (Cooby, Perseverance & Cressbook) with a total capacity of 126,000 megalitres. The city also has underground supplies in fractured basalt, it sits above the eastern edge of the Great Artesian Basin and to the west underground water is available beneath agricultural alluvium. The average rainfall in the period 1998 to 2005 has been 30% below the long term average consistent with a prolonged drought. During March 2006 the surface water storage in the dams fell below 25% of full capacity. As a result water restriction level 4 were announced. These levels mean that only on selected days it is allowed to water the plants outside with a watering can.

The Toowoomba City Council has commissioned several studies on how to deal with the water shortage. Under the direction of Toowoomba's Mayor a potable reuse project was launched. This plan will result in water reclaimed from a sewage treatment plant being returned to one of the reservoirs to provide 25% of the potable water supply for Toowoomba. Consultant reports indicate that after flocculation, ultrafiltration, reverse osmosis and ultraviolet disinfection the product water to be piped to water reservoir will contain 30 milligrams per litre total dissolved solids of an unknown composition and unknown organic compounds. Early 2006 the city council of Toowoomba decided unanimously in favour of the recycling project. However, after hefty protests from the local population the federal government in Canberra decided that a referendum was necessary.

On 29 July 2006 Toowoomba City Council conducted a poll of Toowoomba residents on the proposal to use this multi-barrier filtration system for filtering sewage for drinking purposes. The poll question was: "Do you support the addition of purified recycled water to Toowoomba's water supply via Cooby Dam as proposed by Water Futures - Toowoomba?" 38% of voters supported the proposal and 62% opposed.

The no-voters were asked for their reasons to object to the recycled water plans. The majority of the no-voters was not concerned about the quality of the recycled water. The main concern was the declining imago of the city as the "shit city" in Australia and the resulting unfavourable settling conditions. As a result of the no-vote the highest water restrictions will start soon. Usage of water outside is totally banned and hefty fines apply if people do use water.

The no-vote in Toowoomba has a large precedent for other municipalities and cities in Australia. In several municipalities a poll on the use of recycled water was scheduled, but it is now questionable if these polls will be held. A day after the results of the Toowoomba poll the New South Wales government announced that they will not further investigate the use of effluent for potable use. It is now up to the Premier of Queensland or even to the Prime Minister to organise a poll during the state elections or general elections in 2008, putting the water dilemma high on the political agenda.

An interesting fact is that 3 days Toowoomba poll a survey showed that 60% of the population in South-East Queensland voted in favour of recycled effluent being added to the region's water supplies. The "not in my back yard" principle applies.

Figure 9 - Perth desalination plant (left) and proposed Cervantes wind farm (right)

and Rottnest island (capacity 500 kL/d). As a result the desalination capacity of Australia is only about 1% of the world desalination capacity.

Several water utilities and councils in Australia are investigating the possibilities of desalination to be able to meet the future drinking water demand:

- Gold Coast Water, Tugun QLD, capacity 45 GL/year;
- Perth WA, capacity 45 GL/year
- Sydney NSW, capacity 45 GL/year, tenders were submitted in August 2006;
- Gosford/Wyong NSW, capacity 7.5 GL/year

The Australian drinking water industry

Water utilities

In Australia, the way the drinking water is treated and managed depends on the location. The population is generally clustered in large cities along the coast, vast areas of Australia are only very sparsely populated. As a consequence, there is a huge variation in scale in water-delivery systems. Some water authorities supply populations of more than a million (Sydney Water services four million people in the Sydney region, for example) while many others service as few as several thousand (such as AQWEST, in Bunbury, Western Australia, servicing around 34,000 people). In addition, some local governments run small systems that supply drinking water to as few as 20 people, while about one in six Australian homes use rainwater collected on roof catchments. An overview of all Australian water utilities can be found on the website of WSAA (see Website 15). The large variation in size of the customers served results large differences between companies in water quality related problems, research questions and level of knowledge.

Water sources and drinking water treatment

Groundwater provides about one fifth of Australia's drinking water supplies. Some regions use little or no groundwater, while others rely heavily on this source. The Great Artesian Basin, Australia's largest source of groundwater, provides the only reliable and continuous water supply for much of the arid outback, particularly in Queensland, New South Wales and South Australia.

Most drinking water is originating from surface water. As the Australian cities are almost all located at the coast they make use of large inland protected catchments and reservoirs. The primary focus of the water authorities is on preventing of water contamination in the pristine catchments. The level of treatment is low, compared to the Dutch drinking water treatment. The default surface water treatment is coagulation, flocculation, sedimentation, filtration and eventually followed by MIEX for organic material removal. Finally the water is disinfected by chlorination or chloramination.

Water quality issues

Australia is facing several water quality issues. Some are related to the drought. But most issues are a result of the different treatment philosophy. In Australia the principle of the total system approach is also used to deliver high quality water to the customer. The focus is on protection of the source and disinfection with chlorine/chloramine. As a result the level of treatment is limited. A city like Melbourne treats only 20% of its surface water with filtration, the rest of the water is distributed unfiltered. The main focus of the Melbournian utilities is therefore

Directly after I arrived in Australia is noticed that the water quality was different from the quality in the Netherlands. When I took a shower in the morning the bathroom smelled like a swimming pool. The chlorine added to the water for disinfection was clearly preent. Furthermore, sometimes also a more “ground” or “earthy” smell of the water was noticeable. Especially in the summer time Geosmin and MIB could sometimes be smelled. Both aesthetical observations resulted in buying bottled water from the supermarket. Our house did not have a puri-tap, a point of use filter system. Every week I bought two 10 litre cartons for all the water we are drinking. Even the water we used for making our tea and coffee was bottled water.

on catchment protection and chemical disinfection. Similar observations can be made for other cities. The water quality issues that are important at the moment in Australia are:

- taste and odour/algal blooms/toxins/natural organic matter
- disinfection by products
- particles build-up

Taste and odour/algae blooms/toxins/natural organic matter

Cyanobacteria, or better known as blue green algae, release a large range of secondary metabolites into affected water bodies, causing such adverse effects as taste and odour problems through to acute toxicity. Microcystins and 2-methylisoborneol (MIB) are two commonly occurring cyanometabolites in Australian drinking water sources. Microcystins are highly toxic cyclic peptides, produced as secondary metabolites of cyanobacterial species such as Microcystis, Anabaena and Oscillatoria. MIB, or 2-methylisoborneol, is a non toxic cyanometabolite, producing a musty odor that can be detected by the human nose at very low levels. Both microcystins and MIB are recalcitrant to conventional surface water treatment methods. Even when the algae are removed the toxins can remain in the water. Toxins can be removed with biological sand or activated carbon filtration. As a result of the decreasing rainfall the detention time of water in rivers becomes longer and also the temperature is increased. This results in more and longer lasting algae blooms and associated occurrence of cyanobacteria.

Disinfection by products (THM and NDMA)

Another important water issue are the disinfection by products. As a result of the interaction between natural organic matter and chemical disinfectants numerous unwanted substances are formed, like tri halo methanes (THMs) and N-nitrosodimethylamine (NDMA). In Australia several water utilities use chloramine for disinfection because it is a more stable disinfection product than chlorine. Especially the utilities with extensive transport/distribution systems swapped to using chloramine in order to avoid the occurrence of amoebic meningitis caused by Naegleria fowleri. Naegleria fowleri is a free living amoeba which is common in the environment and grows optimally at temperatures of 35 to 45 °C. Exposure to the organism is believed to be relatively common but infections resulting in illness are rare. Most reported cases of N. fowleri meningitis are associated with swimming in natural surface freshwater bodies, and infection occurs through introduction of the organism into the nasal cavities. Cases are often reported to be associated with jumping or falling into the water, providing conditions where water is forced into the nose at pressure. Cases of disease have also been associated with swimming pools where disinfection levels were inadequate, and inhalation of tap water from surface water supplies that have been subject to high temperatures. The involvement of tap water supplies was first documented in South Australia, where a number of cases occurred in the 1960s and 70s in several towns served by unchlorinated surface water delivered through long above-ground pipelines. About half of the cases in the state did not have a recent history of freshwater swimming, but had intra-nasal exposure to tap water through inhaling or squirting water into the nose.

NDMA is a disinfection byproduct of chloramine that has recently had much attention as it is highly carcinogenic already in low concentrations. Concentrations in Australian drinking water range from 0 to 90 ng/l. At the moment the guideline of NDMA is Australia in discussion and it is expected that it will be 100 ng/l. So for the moment there is no exceeding of the guidelines. However, observed concentrations are close to the guideline.

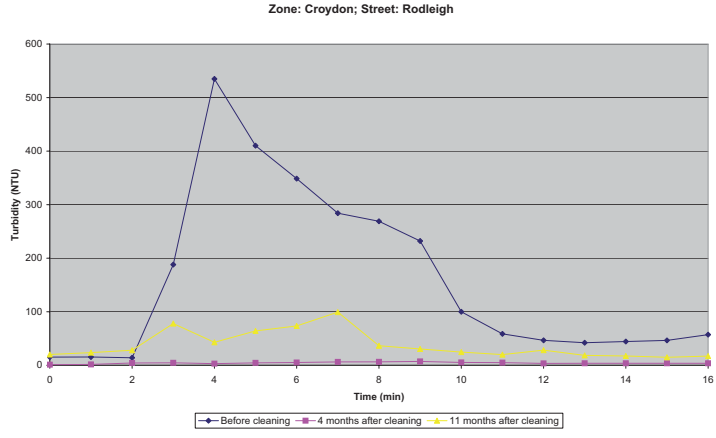

Figure 10 - RPM curves for Rodleigh street in the Croydon supply zone of YVW

Taste and odour problems and occurrence of elevated levels of THMs can be avoided by removing organic material from water. The Magnetic Ion Exchange (MIEX) process has been developed in Australia at the Australian Water Quality Centre in conjunction with Orica Australia and CSIRO to remove dissolved organic matter from water. MIEX is an ion exchange process capable of reducing the level of dissolved organic carbon up to 70-80 percent and colour up to 80% (Drikas *et al*., 2002). At Mt Pleasant, a treatment location close to Adelaide, the first full scale MIEX installation has been built with a capacity of 2.5 ML a day. At the moment there is large interest for MIEX in the United States and also in Europe as it is a cost effective treatment technology that can be easily retrofitted in existing treatment plants.

Water quality complaints

As a result of the limited treatment of drinking water in Australia the particulate and organic load from the production locations to the distribution system is high. In Melbourne the particle load is up to 1 ppm or 1 mg/l, while in the Netherlands this load is 10-100 µg/l. In the Australian Drinking Water Guidelines no guideline for particle loading is mentioned. However, there is a guideline for turbidity. Based on aesthetic considerations, the turbidity should not exceed 5 NTU. If disinfection is required, then a turbidity of less than 1 NTU is desirable at the time of disinfection (ADWG, 2004).

With these high loadings it is not strange that in the distribution system a rapid fouling of the mains takes place. Water quality complaints are high (see table 3) and mains need to be cleaned on a regular basis. Complaints in Melbourne mainly consist of

Table 3 - Water quality complaints (WSAA facts 2004)

Utility	WQ complaints/1000 properties		WQ complaints/1000 km of pipes
	1998/1999	2003/2004	2003/2004
Sydney Water	136.2	1.4	113
Melbourne retailers			
- City West Water	2.5	0.8	61
- South East Water	3.8	2.2	156
- Yarra Valley Water	4.5	5.6	400
Water Corporation	n.a.	20.1	1085
SA Water	2.2	1.1	61
Brisbane Water	9.7	4.8	318

discoloration events, while in Perth and Adelaide complaints are caused by taste and odour.

Water complaints can be avoided by cleaning of mains. However, in a country where water restrictions are in place the water utilities only want to clean the mains when really necessary. To predict where sediment is accumulating in the distribution system a computer model has been developed, called the particle sediment model (PSM). This model is an add-on computer program to the freely available EPANET (Jayaratne *et al.*, 2004). This computer program identifies hot spots in the distribution system where cleaning is most likely. Furthermore Yarra Valley Water, one of the three Melbournian retailers, is using the in the Netherlands developed Resuspension Potential Method in the planning of their mains cleaning programme. In the last 1.5 year over 200 RPM curves have been made, providing much information about the rate of fouling of the mains in relationship to degree of treatment and distribution system properties. The coming time the results of the PSM modelling and RPM measurements will be combined for one the of supply zones of Yarra Valley Water. From figure 10 it can be seen that before cleaning of the main the main was very dirty. 4 months after cleaning the main was still reasonable clean, there was no necessity to clean the main. 11 months after cleaning a clear fouling of the main is observed, the main needs to be cleaned.

Water education in Australia

It will be clear that Australia's water future is challenging. A continuous changing climate, a large expected increase in water demand, a decreasing water volume available for consumption and more stringent guidelines are just a few of the problems that are creating this challenging future. A question you might ask is "how does the Australian educational system respond to these challenges?"

In Australia there are in total 43 universities. Of all these universities 28 are more or less involved in water research, ranging from water reform and environmental policies, global climate change and variability, irrigation, rivers and catchment to urban water (Water Innovation, a new era for Australia, 2004). However, when we look in the educational programmes in some more detail only four universities offer one or more courses on drinking water treatment (Murdoch University, University of New South Wales, University of South Australia and Deakin University).
A direct result of the large number of universities is that the number of students at the faculties is quite small. For example, in the state South Australia (approx. 1.5 million inhabitants) there are three universities. All three universities offer a civil engineering course, resulting in only a low number of first year students in 2005. As a direct result the faculty staff is quite small and the staff members have to give all general civil engineering courses, while at the same time they have to specialise in a certain research area.
The Australian universities rely for a large part on international students. On average 30% of their funding is coming from overseas students, mainly originating from Asia (China, Vietnam, Philippines, India). As said before the educational system in Australia is quite scattered. This has its origin in the large distances between the different capital cities in the country. Students tend from historical reasons to study at the university in their direct neighbourhood. Only a limited amount of inter state students can be found the universities.

To generate a more or less constant research cash flow to the universities, most form consortia with companies. These consortia are always state based, making it possible to get grants from the state government. Examples of these consortia are Curtin Water Research Centre (Water Corporation WA together with Curtin University), SA Water Centre for Water Science and Systems (SA Water and University of South Australia). Drawbacks of these consortia are that the research is aimed at specific local research topics and not all aspects of the water supply processes (source, treatment, distribution systems) are covered.
Several water orientated university groups have since 2004 combined efforts on education (and in the future research) in the International Centre of Excellence in Water Resources Management

(ICE WaRM (see Website 17). This centre provides a national focus and international gateway to Australia's education, training and research expertise in water. ICE WaRM offers a master program in water resources management for (inter)national students and vocational training courses for companies.

Australian drinking water research

The next question to be answered is how the Australian water research responds to the large water challenges. Before 1990 there were only limited national research organisations as a result of the large distances between the different cities. The Australian federal government started in 1990 with a programme to combine the centres in similar research fields in so called cooperative research centres (CRC's). This has proven to be a very effective initiative because since 1990 71 CRCs have started. A study of the Allan Consulting Group on the effectiveness of the CRC programme learnt that "For every $1 spent by the Commonwealth Government on the CRC Programme, GDP is cumulatively $0.60 higher than it would have been had that $1 instead been allocated to general Government expenditure" (The Allan Consulting Group, 2006)
In 1994 several water research organisations decided to successfully apply for a CRC grant. The cooperative research centre for water quality and treatment (CRC WQ&T) (see Website 18) is the leading Australian drinking water research organisation. CRC WQ&T is an unincorporated joint venture between 29 participants representing government, industry and research organisations. The current centre was established in July 2001 under the Australian Government Cooperative Research Centres Program. A formal agreement, known as the Centre Agreement, between the participating organisations defines the contributions of the parties (cash or in-kind) and the nature and scope of the cooperation. The Centre's head office is located at the Australian Water Quality Centre in Adelaide, with parties in all mainland states and territories. The annual funding per year is AU$ 12 million of which AU$ 2.5 million is federal funding. The researchers are located at the participating water utilities, universities and governmental organisations and work in project teams on research topics. The Dutch TTI Water will probably be organised in a likewise system as CRC WQ&T is organised.
In 2008 the current CRC WQ&T will cease to exist. The governing board has decided that CRC WQ&T will not apply for a third grant from the Australian federal government but that it should be able to raise sufficient funds from the water utilities itself. CRC WQ&T should stand on its own legs. Discussions about the new water research centre are in the final stages.

Besides CRC WQ&T there are different state orientated water research centres, mostly hosted at a university and connected with the local water utility. Some of these research centres have ties with CRC WQ&T.

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