Acceptance Speech for the Habitat Council Conservation Award
Cape Town Environmental Centre, 10 October 2009

Crisis in our Rivers! What Crisis?

Prof. Anthony Turton
Director: TouchStone Resources (Pty) Ltd
&
Centre for Environmental Management: University of Free State

There has been much debate in the public media over the last year about the so-called "water crisis". Much of this has been fuelled by the Eskom collapse in 2008 and the whole debate can be summed up by saying there are two poles being represented in the media. On the one hand there are a few scientists – not too many – who are warning of an impending problem, while on the other hand there is the government that is vehemently denying that any crisis exists. In between these two poles you have a confused population, who are uncertain who to believe and more importantly, what to do about making right that which is clearly wrong.

So is there a crisis in our water resource management?

I do not like the word "crisis", but my vocabulary does not give me any word that better describes what I am seeing unfold around me, so let me use an analogy to explain where we are as a nation. Think of us all sitting in a large commercial jet airliner and we are flying at cruise altitude across the Himalaya mountain range. We know there are very high mountains out there, but we have faith in the pilot and more importantly, in the technical systems that have been developed over long periods of time that all combine to make flight across these mountains safe. Then suddenly we hear from a stewardess that we have lost our technical systems. Note, we have not heard from the pilot yet, only from the stewardess, who seems a little agitated, but tells us all not to worry. So now we are flying across the highest mountains in the world and we have been told that the technical systems are down. Is this a crisis?

Well yes and no. Yes, it is clearly a crisis, because we know we are in a dangerous place, so we need to do something different in order to again make us safe. But no, we have not yet smashed into the mountain, so we are all still alive and that is obviously good. Now the analogy becomes interesting. Should we all get excited and demand from the Captain that he does something about this crisis? Or should the Captain spend all of his energy convincing us that everything is going to be all right? Or should the Flight Engineer attack the Stewardess for telling us about the problem, denying that it actually exists? All of these actions are valid responses, but none of these actions will take evasive measures in time for us to avoid smashing into the mountain. The prudent approach would thus be for the Captain and his full crew, to accept that there is a problem and then take appropriate evasive action, either by turning around, or by flying to a higher altitude.

Now apply this to our national rivers. We can spend all of our energy on blaming the messenger and trying to discredit them and thus destroy the message – and still slam into the mountain; or we can convert our collective energy into light rather than heat and apply our minds to finding a solution – and thus avoid slamming into the mountain. It is our choice.

This is where we are as a nation. Our rivers are under severe pressure and to explain why this is I need to revert back to some fundamentals. The core problem relates to the thing we call the hydrological cycle, which is shown in Figure 1. Water is a flux, moving in time and space, as it has done from the very beginning of the Earth, billions of years ago. The water you used to brush your teeth this morning went through a dinosaur kidney 65 million years

ago. It is this hydrological cycle that defines one critical parameter upon which the development potential of the entire African continent is predicated – the conversion of precipitation into runoff. Precipitation is water that falls as rain, snow, dew and fog. Once it has fallen, a few things happen to that water. A small fraction percolates into the ground and becomes soil water. A slightly larger fraction trickles over the ground and becomes what is known as runoff, which we see as water in rivers. The largest fraction is lost to evaporation, either directly from the earth, or *via* the leaves of vegetation in a process known as transpiration. Together this is called "evapotranspiration". The map presented in Figure 2 shows the global conversion of precipitation to runoff broken down by continent. It will be noted that Africa has the lowest conversion ratio in the world, with a paltry 20% of the total rainfall eventually becoming water in a river, and thus available for economic development.

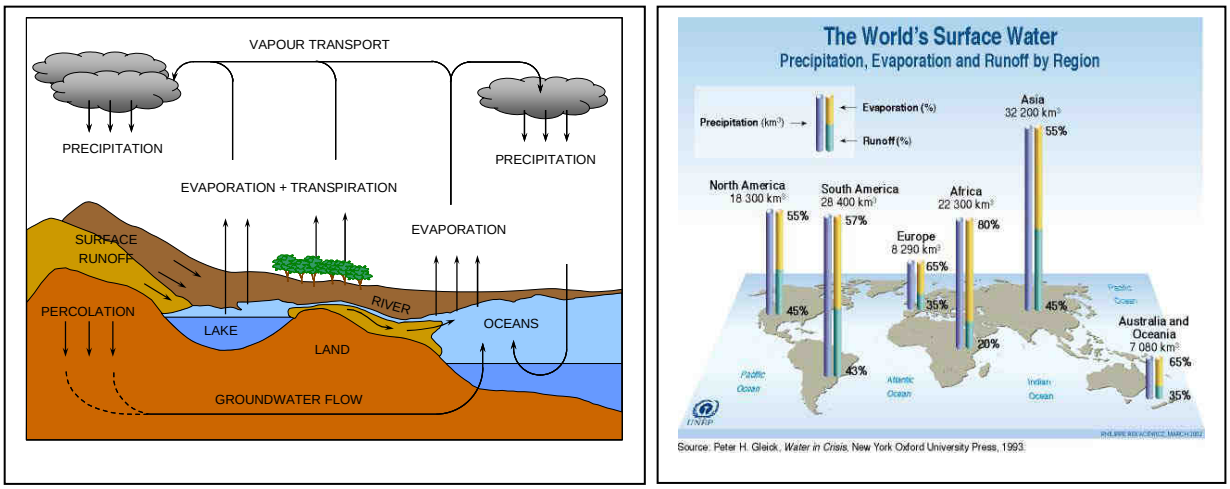

Figure 1 (left) shows the hydrological cycle that moves water around the planet as a flux. Figure 2 (right) shows the conversion ratio of precipitation to evaporation and runoff as a continental average.

From this it is evident that Africa has started off with a hydrological disadvantage, because a staggering 80% of the total volume of water that falls from the sky is lost almost immediately to evaporation. It is evaporation that is the limiting factor to our economic development; and it is this problem that we need to understand as a nation. Let us now get closer to home. South Africa has 19 Water Management Areas (WMA's), which cover the entire country. Each of these are hydrological management units based on a specific river basin, portion of a river basin, or set of river basins that can be managed as a coherent unit. About two thirds of the total country lies in river basins that are shared with neighbouring countries, of which four are the most important – the Orange, Limpopo, Incomati and Maputo. By far the most important river basin in South Africa in terms of economic development is the Orange, so let us focus for a moment on that system in order to gain a better understanding of the issue. The Orange River basin is shared between four countries – South Africa, Lesotho, Botswana and Namibia. The conversion ratio of precipitation to runoff in the whole basin is a meagre 5.1%, but in the South African portion of that basin it is a pathetic 3.4%[1]. Now it becomes interesting. Think of the total volume of water left in the Orange River after evaporation as being equal to 100%. Now think of the total volume of all of the dams that have been built in the entire river basin. This gives us a ratio of river flow to storage and it helps us to grasp the vulnerability we confront as a nation as we approach that point of total resource capture – when 100% of the flow equals 100% of the storage capacity – at which time there is no flow left. In the South African portion of the Orange River basin, the combined volume of dams

equals 271.3% of the average annual flow. This means that we have almost captured three times the total average flow of the river, which is an astronomical number. Technically we refer to this as basin closure, because we have captured more of the resource than is available on a reliable basis, and overall allocation exceeds the actual volume that has been trapped behind dams.

So can we continue to build dams in that system? The answer is a clear no. The solutions to the past problems are no longer appropriate to the future problems. We cannot use today's science based on yesterday's knowledge to solve tomorrow's problems. This is the crisis. We have no new innovative thinking. We have no crucible of ideas being nurtured by society from which new thinking will emerge. If we believe Albert Einstein then we must accept that the level of ingenuity needed to solve a problem, exceeds the level of ingenuity that created the problem in the first place[2]. This means that we, as a nation, will need to mobilize more ingenuity with which to develop new solutions than the combined ingenuity that created all of those dams, all of those mines, all of those water transfer schemes and all of that industry if we are to manage the finite limitation that a rainfall to runoff ratio, or a runoff to storage ratio, imposes on us as a nation.

Let us now focus on another of our major river basins, the Limpopo, because from there we learn another valuable lesson. In that system we have a unique set of conditions that combine to give us a completely different set of problems that will need yet another set of innovative solutions, if we are to continue to grow our economy and give every citizen a quality of life that is better than what they experienced under Apartheid rule. In the Limpopo we have a low conversion of precipitation to runoff similar to the Orange, *but* we also have malaria as an endemic problem. Why is this significant? To answer that we first need to understand some fundamental numbers. The total population that depends on a given resource is the indicator we need to illustrate this specific problem. Work done by a famous Swedish hydrologist by the name of Prof. Malin Falkenmark[3] in the 1980's developed an indicator that has come to be known as the Water Crowding Index (WCI). This was based on a global study that looked at every country in the world, using what she called a "flow unit" of one million cubic metres of water as a standard measure. She then assessed the level of technology in each country, assuming that the capacity to mobilize technology would be part of any future solution. From this massive study a baseline emerged and that number was 1,000 people per flow unit, which represented the upper limit of the number of people that local water supply can sustain. Anything above a value of 1,000 represents an elevated level of risk; and the value of 2,000 represents what Falkenmark called "the Water Barrier" beyond which no viable economic development was possible, short of massive injections of technology, the likes of which she had not yet seen in her global study. This concept has been applied to South Africa by Prof. Peter Ashton and his team[4] and they have developed a WCI for the four major river basins that South Africa shares with neighbouring states. Of these the Limpopo manifests as the worst case with a WCI of 4,219 in 2000; and a staggering WCI of 4,974 by the year 2025. This means that the Limpopo River is our worst case scenario in terms of water crowding, so what is happening there serves as a foretaste of what will probably happen in the rest of the country *if we do nothing by pretending that everything is all right*.

Why is the malaria problem relevant in this specific case? Stated simplistically, we have an extremely high WCI in the Limpopo River basin (assuming the work by Ashton and his team is valid), and we have malaria that is being controlled by the application of DDT. We know that DDT is an endocrine disrupting chemical (EDC); and we know from published peer-reviewed research that a high correlation exists between the application of DDT as a control

measure and the birth of babies with deformed genitalia[5] (either being born with both male and female organs, or with abnormalities associated with what we can broadly call gender-defining organs) and we also know that this is affecting male fertility[6]. We also know that sewage treatment plants are not removing the female hormone oestrogen[7], which we know is going back into river systems in various locations across the country. We know that many of these dysfunctional sewage works are located in rural areas[8], some of which are in the Limpopo Province. The common denominator is the Limpopo area and abnormalities associated with gender arising from EDC's such as the use of DDT to control malaria.

Now let us look at other rivers in order to gain an understanding of the overall complexity of the problem we are dealing with. The National Water Resource Strategy (NWRS) is the official government planning document. In terms of that document there are 19 WMA's, each with a different set of characteristics as manifest in the year 2000, which is shown in Table 1.

Table 1
Reconciliation of the Requirements for and Availability of Water as it Existed in 2000. (All volumes given in millions of cubic metres per year ($10^6 m^3 yr^1$). (Source: adapted from the National Water Resource Strategy, 2004:38[9]).

WMA	Reliable Yield	Transfers In	Local Requirements	Transfers Out	(Shortfall) Surplus (+)
Limpopo	281	18	322	0	(23)
Levuvhu/Letaba	310	0	333	13	(36)
Crocodile West & Marico	716	519	1,184	10	41
Olifants	609	172	967	8	(194)
Incomati	897	0	844	311	(258)
Usutu to Mhlatuze	1,110	40	717	114	319
Thukela	737	0	334	506	(103)
Upper Vaal	1,130	1,311	1,045	1,379	17
Middle Vaal	50	829	369	502	8
Lower Vaal	126	548	643	0	31
Mvoti to Umzimkulu	523	34	798	0	(241)
Mzimvubu to Keiskamma	854	0	374	0	480
Upper Orange	4,447	2	968	3,149	332
Lower Orange	(962)	2,035	1,028	54	(9)
Fish to Tsitsikamma	418	575	898	0	95
Gouritz	275	0	337	1	(63)
Olifants / Doring	335	3	373	0	(35)
Breede	866	1	633	196	38
Berg	505	194	704	0	(5)
Total for Country	**13,227**	**-**	**12,871**	**170**	**186**

Acceptance Speech for the Habitat Council Conservation Award
Cape Town Environmental Centre, 10 October 2009

Note that in the year 2000 we had a national surplus of 186 million cubic metres (mcm) of water, which is a small number when compared to the deficits I am now going to present to you. In a nutshell, South Africa had allocated around 98% of our total water resource in 2004, and we have simply run out of the stuff.

Let me now focus on four of these WMA's, which I have selected simply because they each tell a different story and thus they each pose a different problem for the future. These four WMA's are – the Upper Vaal (chosen because it sustains the bulk of our national economic development), the Crocodile West & Marico (because it sustains a significant portion of our mining economy but it also drains the Gauteng Province), the Berg (because it sustains the local economy of Cape Town and environs), and the Mvoti to Umzimkulu (because it sustains the industrial and agricultural areas along the coast of Kwa Zulu Natal from Richards Bay to Port Shepstone). The NWRS starts off with the data presented in Table 1 and then makes use of two different scenarios with which to predict the future. These scenarios factor in diverse aspects such as the capacity to transfer water into or out of the WMA, future population growth, urbanization, level of economic development and suchlike. Two scenarios are used, called the Base Scenario (low growth) and the High Scenario (high growth). The numbers for each of these four WMA's are as follows:

- The Upper Vaal manifests as a water deficit of 42 mcm in 2025 in terms of the Base Scenario; and a water deficit of 764 mcm in terms of the High Scenario. The future solution here is likely to be reuse of mine effluent for industrial process purposes while building more transfers in from the Lesotho Highlands.
- The Crocodile West & Marico manifests as a water surplus of 125 mcm in 2025 in terms of the Base Scenario; and a water surplus of 335 mcm in terms of the High Scenario. This is one of the few WMA's that will not be in deficit and the reason is illuminating – this increased flow is from sewage returns out of Gauteng, so water quality will be the major challenge here.
- The Berg manifests as a water deficit of 67 mcm in 2025 in terms of the Base Scenario; and a water deficit of 508 mcm in terms of the High Scenario. The future solution here is likely to be desalination for potable purposes and recycling of sewage effluent for industrial and agricultural water.
- The Mvoti to Umzimkulu manifests as a water deficit of 423 mcm in 2025 in terms of the Base Scenario; and a water deficit of 788 mcm in terms of the High Scenario. The future solution here is likely to be desalination for potable purposes in areas along the coast, supported by recycling of sewage effluent for industrial and agricultural water.
- The total national situation for the year 2025 in terms of the NWRS manifests as a water deficit of 234 mcm in the Base Scenario; and a water deficit of 2,044 mcm in terms of the High Scenario. Compare this to the meagre surplus of 186 mcm that existed in the year 2000 shown in Table 1.

So much for water expressed as a quantity, where I have clearly shown that as a nation we are running with a gas tank on empty. We have simply used all of the water we have and what we do next will literally determine whether we have a future at all. So what about water quality? We know that there is a general deterioration of water quality across the whole country with three generic forms of pollution – radiological, biological and chemical. Radiological pollution in the form of radioactivity is associated mostly with gold mining activities and is generally found downstream of tailings dams[10]. We also know that the Witwatersrand Mining Basin is closing down as we know that decant of radioactive acid mine drainage (AMD) is

scheduled for January 2012 from the South West Vertical Shaft in Benoni[11]. We also know that this will contribute about 5% of the flow of the Vaal River but 25% of the salts load, so the impact will be catastrophic and something akin to South Africa's own Chernobyl. We know that the mining companies are protecting their interests by developing a plan that will externalize the cost of remediation by selling this treated mine effluent to Rand Water[12]. This is a pressing problem and the choice we make as a nation will literally seal our fate. The argument is complex and it is easy to mislead both the government and public about what needs to be done. My view is that we can only solve this by having an open public discussion and by appointing a panel of wise people to advise the Minister about what her next move should be. I believe the public has the right to know that the current proposed solution will have 11 million people drinking this water in the near future, without having been given a choice as to whether they are prepared to do this in the first place. I am on record as saying that because we cannot remove 100% of the toxins 100% of the time, it will be imprudent to use anything but the very best quality water as feedstock into a potable water reticulation system. I am also on record as saying that I believe we must sell this water as industrial process water, on which we can base a new beneficiation-styled economy in the post mine closure phase.

However my personal views are irrelevant if nobody in a position of authority is prepared to listen to them.

On the biological side the biggest source of contamination is from dysfunctional sewage works. These produce phosphates and nitrates and these nutrients cause the blooming of cyanobacteria, which produce a toxic substance known as microcystin. This is chemically similar to rinkhals venom; and while no research has been done in South Africa on human health impacts, we know that there are many health risks, including cancer, based on research conducted elsewhere[13]. This is a looming crisis of note if we look at trends in the level of microcystin. The Finnish government becomes excited when the level is 10 micrograms per litre. The Americans are more resilient, because they become concerned when levels exceed 60 micrograms per litre. The average of the worst five dams in South Africa is 10,000 micrograms per litre, spiking at 16,000 micrograms per litre, and we apparently show no concerns for this as a nation, even though there is no known antidote for microcystin poisoning. Some indications are that other biological contamination can be expected in the form of bacteria and viruses that have escaped in partially treated sewage. In this regard partial treatment is sometimes more damaging than no treatment at all, simply because partial treatment removes only the weaker pathogens, leaving the stronger and more virulent to multiply. Very little scientific work has been done on this specific issue in South Africa so we can only speculate, but it is not inconceivable to anticipate drug-resistant pathogens such as Hepatitis emerging from highly contaminated rivers in the near future. This is speculation, but is based on simple logic, and is thus a possibility, if not a probability. There has been some mention in the media of flesh eating bacteria occurring in some of the lagoons along the KZN coastline, but again the research has not been done, so we remain in the dark about specific cause and effect. If we apply logic then this is not an impossibility, given that we know the rivers in that area to be highly stressed, and we also know that lagoons lie downstream and thus we can expect a cumulative impact arising from the combined abuse of rivers manifesting in that one single terminus – the lagoon. A river is a linear entity, so what happens upstream, combines to impact downstream.

On the chemical side, the major problem in my professional opinion is related to EDC's, which South Africa has a very limited capacity to do anything about. Given that we are so

water constrained, we have in effect lost our national dilution capacity, and this means that EDC's will be concentrated in our overloaded rivers and will start to recycle throughout society. It is not improbable to anticipate a higher prevalence of EDC manifestation in the near future, most likely to be located in river systems with a high WCI and a low capacity to process sewage effluent. If malaria is endemic in a specific area with these characteristics, then the probability of increased EDC manifestation will become exponentially higher, simply because our persistent use of DDT in the face of global trends, means that we have many thousands of tons of the chemical in circulation that will remain in the environment for decades to come, even if we stop using it tomorrow. Very little research has been done on this and our national capacity is highly constrained. In my view this should become a national priority with a high level of funding and urgency attached to it.

What we do not know is the effects of anti-retroviral medication entering the river systems. Here our state of knowledge is such that we know with a high level of confidence that medication passes through the human body in partially metabolized form. We also know, specifically from the work on EDC's[14], that some of this medication has endocrine disrupting capabilities, and we know from the work on oestrogen that these hormones are not removed by current sewage and water treatment processes. We also know that one outcome is an alteration to biochemical processes that collectively define gender, at least in animals if not in humans[15]. We also know that South Africa has a high level of HIV and so we can assume that a high level of ARV use is taking place. We can thus assume that this is entering some of the river systems, probably in those with an extremely high WCI, simply because we know that under such conditions poverty prevails, and therefore under such conditions local authorities are weak and consequently sewage treatment facilities are likely to be inadequate. We do not know if this partially metabolized ARV will have any detrimental effect on people and the environment. Here we are simply flying blind as a nation.

That is a brief overview of our rivers and now we can ask the question – is there a crisis?

To me the crisis lies in the fact that there is simply no capacity to debate these issues without major ramifications for the messenger. We return to the analogy of the aircraft where the messenger is the Stewardess who is reprimanded by the Flight Engineer. What we need is robust public debate informed by quality science that is trusted by a wide sector of society. What we do *not* need is sensationalism, or a media frenzy, because that drives mass panic. We also do *not* need finger pointing or blame, either for the messenger, or for the government. Remember, the aircraft in which we are all sitting has lost some of the technical systems, but it has not yet smashed into the mountain, so every second we waste in bickering over who is right and who is to blame, means we are one second closer to that final inevitable collision that will become the ultimate judge of who was right or wrong.

So the crisis lies in our persistent denial that there is a problem. It lies in the pitiful fact that we are dooming future generations to the misery of poverty by failing to recognize that what we have done thus far can no longer be done in the future, simply because the assumptions on which previous solutions were based are no longer valid. Sadly it lies in the probable truth that we will start to see more manifestations of EDC's across the board. This means a national propensity to androgyny for future generations, specifically if they were conceived in areas of high risk such as in the Limpopo River basin.

The crisis also lies in our inability to develop new solutions. If we take microcystin as an example, then we have the highest levels in the world. If we accept that solutions are needs-

driven, then we cannot expect to import these solutions, simply because other countries do not have that problem and are thus have no need to develop solutions. We will have to develop our own solutions and that will need science, engineering and technology of the very highest order, if we are to have a realistic chance of doing this. Our solutions will have to be radical and different, but also well thought through and innovative. I cannot see government solving these problems on their own – they are simply too complex for any one institution to resolve – so I see a future in which partnerships emerge from which innovative thinking is spawned. I therefore see a future in which a new form of public-private partnership becomes the norm, probably with sewage treatment being passed on to a new type of public enterprise that can do what has to be done if we are to halt the collapse of these vital processes.

I thank you for the award you have chosen to give me. While the last year of my life has been extremely difficult, I have tried not to waver in my quest for scientific integrity and respect for the public's right to know about issues that affect their daily lives so directly. While I was still serving as a Fellow in the CSIR, I tried to remain true to the mandate given by Parliament, and in that quest I have never wavered. I believe that our young democracy deserves to be deepened, and I believe that a sense of nationhood needs to be inculcated at every available opportunity, but I also believe that the common threat of water scarcity and the implications arising from this one simple fact can be the vehicle that binds us together. We need to support government as they grapple for solutions and we need to understand that in a fledgling democracy we will sometimes make mistakes, so we, as a nation, need to become forgiving when these mistakes harm us as individuals, as happened to me. Forgiveness is a powerful thing, for it allows us to heal and move on, but more importantly mistakes allow us to learn, so we must not be afraid of making them.

But above all else we need to realize that we are all sitting in this aircraft flying over the Himalayas and some of our technical systems have just gone down, so every second we waste trying to hide this one simple truth, is one second closer to us slamming into the mountain. We need a robust Captain with a steady and unwavering hand on the stick. We need wise advisors of great integrity who can help that Captain to make the rapid decisions he will need to make, in order to take evasive action. We also need the passengers to have faith in what is happening in the cockpit, as these evasive measures are taking place, because mass panic can hasten our demise. Yet, in final measure, we need to accept that the public – in this case the passengers in the stricken airliner – have a right to know what is happening, and so we must never fail them in this legitimate need. Good quality information serves all parties and results in good quality decision-making, and surely, we as South African citizens, deserve only the very best of all of these things.

I thank you all.

---

[1] **Ashton, P.J., Hardwick, D. & Breen, C.M.** 2008. Changes in water availability and demand within South Africa's shared river basins as determinants of regional social-ecological resilience. In: **Burns, M.J. & Weaver, A.v.B.** (Eds.) *Advancing Sustainability Science in South Africa*. Stellenbosch: Stellenbosch University Press. Pp 279 – 310.

[2] **Homer-Dixon, T.F.** 1994. The Ingenuity Gap: Can Developing Countries Adapt to Environmental Scarcity? In *Population and Development Review*. Vol. 21, No. 3; 587-612; **Homer-Dixon, T.F**. 1996. Environmental Scarcity, Mass Violence and the Limits to Ingenuity, in *Current History*. No. 95; 359-365; **Homer-Dixon, T.F.** 1999. *Environment, Scarcity and Violence*. Princeton, NJ: Princeton University Press; **Homer-Dixon, T.F.** 2000. *The Ingenuity Gap*. London: Jonathan Cape.

Acceptance Speech for the Habitat Council Conservation Award
Cape Town Environmental Centre, 10 October 2009

---

[3] **Falkenmark, M.** 1986. Fresh Water – Time for a Modified Approach. In *Ambio*, Vol.15, No. 4; 192-200; **Falkenmark, M.** 1987. Water Related Limitations to Local Development: Round Table Discussions, in *Ambio*, Vol. 16, No. 4; 191-200; **Falkenmark, M.** 1989. The Massive Water Scarcity now Threatening Africa: Why isn't it Being Addressed? In *Ambio*, Vol. 18, No 2; 112-118; **Falkenmark, M.** 1989. Vulnerability Generated by Water Scarcity, in *Ambio*, Vol. 18, No. 6; 352-3; **Falkenmark, M., Lundqvist, J. & Widstrand, C.** 1990. *Water Scarcity - an Ultimate Constraint in Third World Development.* Tema V, Report 14: Department of Water and Environment Studies, University of Linköping; **Falkenmark, M.** 1991. Rapid population growth and water scarcity: the predicament of tomorrow's Africa, in **Davis, K. & Bernstam, D.** (Eds) *Resources, Environment and Population.* New York: Oxford University Press pp 81-94; **Falkenmark, M. & Lindh, G.** 1993. Water and Economic Development. In **Gleick, P.H.** (Ed.) 1993. *Water in Crisis: A Guide to the World's Water Resources*. Pp 80-91. New York: Oxford University Press; **Falkenmark, M.** 1994. The Dangerous Spiral: Near-future Risks for Water Related Eco-conflicts. In **ICRC.** 1994. *Water and War. Symposium on Water in Armed Conflicts.* Pp 10-28. Montreux, 21-23 November 1994. Geneva: International Committee of the Red Cross (ICRC); **Falkenmark, M. & Lundqvist, J.** 1995. Looming Water Crisis: New Approaches are Inevitable. In **Ohlsson, L.** (Ed.) 1995. *Hydropolitics: Conflicts over Water as a Development Constraint.* Pp 178-212. Zed Books: London.

[4] **Ashton, P.J., Hardwick, D. & Breen, C.M.** 2008. Changes in water availability and demand within South Africa's shared river basins as determinants of regional social-ecological resilience. In: **Burns, M.J. & Weaver, A.v.B.** (Eds.) *Advancing Sustainability Science in South Africa*. Stellenbosch: Stellenbosch University Press. Pp 279 – 310.

[5] **Bornman, M.S., Delport, R., Becker, P., Risenga, S.S. & de Jager, C.P.** 2005. Urogenital birth defects in neonates from a high-risk malaria area in Limpopo Province, South Africa. *Epidemiology*. (16)5. S126 – 127.

[6] **Aneck-Hahn, Natalie H., Schulenburg, Gloria W., Bornman, Maria S., Farias, Paulina & de Jager Christiaan.** 2007. Impaired Semen Quality Associated with Environmental DDT Exposure in Young Men Living in a Malaria Area in the Limpopo Province, South Africa. *Journal of Andrology*, Vol. 28. No. 3: 423-434.

[7] **Slabbert, J.L., Venter, E.A., Verslyke, B., Versonnen, B. & Arijs, K.** 2005. Detection of estrogenic activity in South African surface waters and sediments using a recombinant yeast screen. Twelfth International Symposium on Toxicity Assessment, Skiathos, Greece, 12-17 June; **Slabbert, J. L., Venter, E. A., Motsepe, A. & Moletsane, M.** 2007(a). Method development for biochemical procedures related to estrogen and androgen screening of water and sediment samples: 2002-2003. Biological/biochemical methods and the establishment of *in vivo* techniques for the detection of endocrine disruptors in water systems: 2003-2005. In **Burger, A.E.C**. (Ed.), 2007. *Implementation of a Research Programme for Investigating Endocrine Disrupting Contaminants in South African Water Systems.* Vol. 2, Appendixes 3A+B. WRC Report No. 1402/1/07. Pretoria. ix + 34 pages; **Slabbert, J. L., Venter, E. A., Moletsane, M., van Wyk, J. H., Schillack, V., Aneck-Hahn, N. H. & Marais, P.** 2007(b). An investigation into the occurrence of steroidal hormones (estrogens) in sewage effluent using biological/biochemical and chemical techniques: 2003-2005. In **Burger, A.E.C.** (Ed.), 2007. *Implementation of a Research Programme for Investigating Endocrine Disrupting Contaminants in South African Water Systems.* Vol. 2, Appendix 3C. WRC Report No. 1402/1/07. Pretoria. v + 20 pages; **Slabbert, J. L., Venter, E. A., Moletsane, M., van Wyk, J. H., Blaise, C. & Aneck-Hahn, N. H.** 2007(c). An investigation of the estrogenic activity in water from selected drinking water treatment processes. Report to the Water Research Commission by CSIR Natural Resources and the Environment. Report Number 1532/1/07. xvii + 52 pages.

[8] **SAICE.** 2008. Presentation to Parliamentary Portfolio Committee on Water Affairs and Forestry. Cape Town. 4 June 2008. Cape Town: South African Institute of Civil Engineers (SAICE).

[9] **NWRS.** 2004. *National Water Resource Strategy.* Pretoria: Department of Water Affairs and Forestry (DWAF). http://www.dwaf.gov.za/Documents/Policies/NWRS/Default.htm

[10] **Coetzee, H.** 1995. Radioactivity and the Leakage of Radioactive Waste Associated with Witwatersrand Gold and Uranium Mining. In **Merkel, B. J., Hurst S., Löhnert E.P. & Struckmeier W.** (Eds.) Proceedings Uranium Mining and Hydrogeology 1995, Freiberg, Germany: *GeoCongress* **1**. – 583 S.; Köln (von Loga; ISBN 3-87361-256-9); **Coetzee, H., Venter, J. & Ntsume, G.** 2005. *Contamination of Wetlands by Witwatersrand Gold Mines – Processes and the Economic Potential of Gold in Wetlands. Council for Geosciences Report No. 2005-0106*. Pretoria: Council for Geosciences; **Coetzee, H., Winde, F. & Wade, P.W.** 2006. *An Assessment of Sources, Pathways, Mechanisms and Risks of Current and Potential Future Pollution of Water and Sediments in Gold-Mining Areas of the Wonderfonteinspruit Catchment.* WRC Report No. 1214/1/06. Pretoria: Water Research Commission; **Wade, P.W., Woodbourne, S., Morris, W.M., Vos, P. & Jarvis, N.W.** 2002. *Tier 1 Risk Assessment of Selected Radionuclides in Sediments of the Mooi River Catchment. WRC Project No. K5/1095*. Pretoria: Water Research Commission; **Winde, F. & Van Der Walt, I.J.** 2004. The Significance of Groundwater-Stream Interactions and Fluctuating Stream Chemistry on Waterborne Uranium Contamination of Streams – A Case Study from a Gold Mining Site in South Africa. In *Journal of Hydrology*, 287. Pp 178-196.

---

[11] **Golder.** 2009. *Environmental Impact Assessment: Western Utilities Corporation Mine Water Reclamation Project. Golder Report No. 12064-8755-1*. Johannesburg: Golder Associates.

[12] **Naidoo, B.** 2009. Rising Tides: Massive Acid Mine Drainage Project Stimulus for Local Beneficiation, in *Creamers Mining Weekly*. July 31 – August 6. Pp 8 & 9; **Noseweek**. 2009. Joburg's Poisoned Well. *Noseweek* Issue No. 118. August 2009.

[13] **Oberholster, P.J., Botha, A-M. & Grobbelaar, J.U.** 2004 *Microcystis aeruginosa*: Source of toxic microcystins in drinking water. *Africa Journal of Biotechnology* 3: 159-168; **Oberholster, P.** 2008. *Parliamentary Briefing Paper on Cyanobacteria in Water Resources of South Africa. Annexure "A" of CSIR Report No. CSIR/NRE/WR/IR/2008/0079/C.* Pretoria. Council for Scientific and Industrial Research (CSIR); **Oberholster, P.J. & Ashton, P.J.** 2008. *State of the Nation Report: An Overview of the Current Status of Water Quality and Eutrophication in South African Rivers and Reservoirs.* Parliamentary Grant Deliverable. Pretoria: Council for Scientific and Industrial Research (CSIR).

[14] **Genthe, B. & Steyn, M.** 2007. *Parliamentary Briefing Paper on Endocrine Disrupting Chemicals. CSIR Report No. CSIR/NRE/WR/IR/2008/0079/C.* Pretoria. Council for Scientific and Industrial Research (CSIR).

[15] **Lyons, Gwynne.** 2008. *Effects of Pollutants on the Reproductive Health of Male Vertebrate Wildlife – Males Under Threat*. England: CHEM Trust Available online at www.chemtrust.org.uk