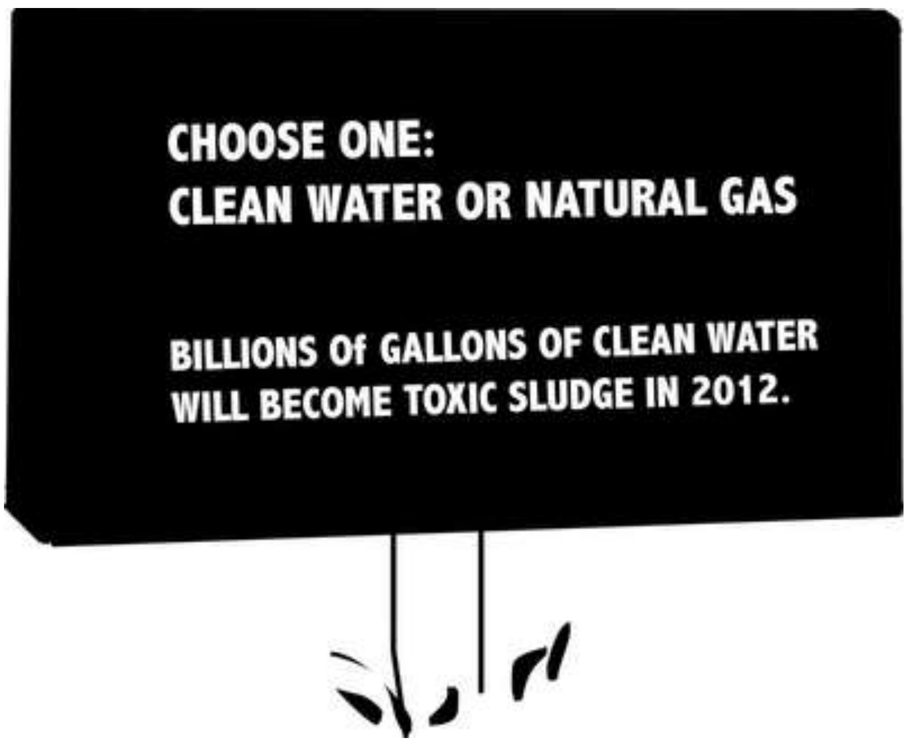
You can't have your gas and drink your water!

Hydraulic fracturing in the context of South Africa's looming water crisis



EMG Water and Climate Change Research Series

Report 6

Liane Greeff

September 2012

EMG
Environmental Monitoring Group

Author: Liane Greeff

Cover image: Nin Andrews, Fracking billboards

Environmental Monitoring Group (EMG)
10 Nuttal Road
Observatory
7925
Cape Town
South Africa
021 788 9924
www.emg.org.za

Acknowledgements

I would like to thank Jonathan Deal and Professor Gerrit van Tonder for their outstanding work in highlighting the potentially devastating implications of fracking for South Africa's water resources, and to thank Jessica Wilson of EMG for supporting this research.

EMG gratefully acknowledges Swedish Society for Nature Conservation (SSNC) and Heinrich Böll Foundation (HBS) for supporting our water and climate change programme.

Contents

1. Introduction **5**

2. State of South Africa's energy **7**

3. State of South Africa's water resources **8**

4. Climate change and fracking **10**

5. Hydraulic fracturing **10**

5.1 Stages in the fracking process *12*

5.2 Analysis of the impact of fracking on water *13*

Water requirements 13

Fracking fluids 14

Groundwater contamination 16

Surface water and land contamination 21

Wastewater management 22

Misclassification of hazardous waste as brine 23

Transport of chemicals and fracking fluid waste 23

Injection into depleted gas wells or deep strata 23

Earthquake activities associated with fracking 23

6. Regulatory capacity to manage fracking in South Africa **24**

7. Mitigation **26**

8. Legal issues **27**

9. Recommendations **28**

9.1 Overarching recommendations *28*

9.2 Research recommendations *29*

9.3 Governance, policy and legislation recommendations *31*

9.4 Public Participation and transparency recommendations *34*

10. Conclusion **34**

11. References **36**

Physical units:

1 m^3	1 cubic meter = 1,000 litre
1 ML	1 Million litre = 1,000m^3
1 Mm^3	1 Million m3 = 1,000,000m^3
1 Wh	1 Watt-hour
1 GWh	1 Giga Watt hour = 1,000 MWh
1 km	1 kilometre

1. Introduction

South Africa is facing a conundrum between its documented energy crisis, its fast-approaching water crisis, the global climate change crisis and the development imperative needed to remedy socio-economic issues of poverty, crime and unemployment. It is estimated that we are currently using 98% of South Africa's available water resources (Blignaut and Van Heerden, 2009), and that the deficit between available water and water demand will be 17% by 2030 (Greenpeace, 2011).

This essay is not about climate change, it is about water and the implications of fracking for South Africa's very scarce water resources. In a nutshell, South Africa cannot afford the quantity of water that is used in the fracking process and which is effectively removed from the water cycle as it is transformed into a toxic cocktail mixed with radioactive substances. Further, we do not have the legal framework for dealing with hydraulic fracking as it requires different regulation from existing energy resources. Petroleum Agency SA (PASA) is the only body with oversight and its job is to promote petroleum extraction in South Africa, indicating a significant conflict of interest. Even if we did have the legal framework, we do not have the expertise or the regulatory capacity to manage an industry notorious for its ecological violations. This is especially true when compared with the United States, which has far more capacity but is not managing to contain water contamination and environmental pollution. In some states in the US, there are only enough inspectors to check each well once every five years which means it can leak for 4.5 years without being noticed.

It is ironic that the government is embracing hydraulic fracking with its known impacts on underground water resources, at the same time as acid mine drainage (AMD) from gold and coal mines is surfacing all over Gauteng and Mpumalanga and making local water resources undrinkable for local communities. An indicative example is the Mpumalanga town of Carolina, whose local dam and water treatment works was contaminated with dangerous levels of heavy metals associated with AMD. Locals won a court case ordering the municipality to provide them with clean water. It is also ironic that Shell, the company promising us safe fracking, was during the week of writing this paper (August 2012) fined $5 billion for its massive oil spill in the Niger Delta and ran the *Noble Discoverer*, an oil drilling ship, partially aground in the Arctic. Promises of safety are lies and if we listen to them we are fools.

The word 'nexus' has recently found itself in the spotlight. In October 2011, the German Government hosted the international Water, Food and Energy Nexus Conference in order to ensure that decisions in one sector were not taken independently of the impacts in another sector. All three issues – water, food and energy – are vital for human survival. Of particular importance for South Africa is that our government needs to manage the energy footprint of water as well as the water footprint of energy, and that the footprints of both water and energy development do not preclude our ability to grow food. The *World Economic Forum Global Risks Report 2011* states: 'any strategy that focuses on one part of the water-food-energy nexus without considering its interconnections risks serious unintended consequences' (World Economic Forum 2011:7)

South Africa would do well to heed this warning. Embarking on hydraulic fracturing in an area covering 20% of South Africa's total land mass will have serious unintended consequences for both water and food security. The severity of these consequences are beginning to surface with the proliferation of research material coming out of the US, the UK, Europe and more recently, South Africa. Despite these warnings, the Minister of Energy publicly stated that 'shale gas under the Karoo is a blessing from God' and that it would be wrong for us to not use the resources that God left us with (SAPA, 2012). The lifting of the moratorium on exploration subsequently took place on 7 September 2012 (Roelf, 2012). If exploration is successful, the production phase will virtually be automatic. The lifting of the moratorium took place despite warnings from leading scientists that fracking with toxic chemicals will have catastrophic results of unknown proportion that will affect future generations of South Africans, and that the current problem of AMD 'is a small problem compared to [fracking] in 50 to 100 years' (Van Tonder, 2012).

Politicians and decision makers need to better understand the water-energy nexus in order to make better decisions in the future than they have in the recent past. A recent example of the South African government downplaying the water-energy nexus is that of the approval and construction of the Medupi coal-fired power station in Limpopo, where both the issue of water supplies and the impact on water resources from the power station itself and from associated mining, were minimised. A World Bank Inspection Panel criticised the World Bank's support of Medupi because the implications of water extraction and pollution were ill considered (World Bank Inspection Panel, 2012).

The market is increasingly being seen as an ineffective approach to decision making – at the macro scale, measuring the wealth of a country using GDP ignores whether that GDP is derived sustainably or through consuming or destroying the natural environment. In terms of evaluating the contributions of fracking to the South Africa economy, profits – which are largely private and taken out of the country – are a very poor indicator. Focusing on profit ignores the multitude of externalities, which are the costs or benefits of the economic activity that are not borne by the oil and gas companies but by private individuals, communities, taxpayers and future generations. The externalities in the case of fracking include road transport and associated damage to national, provincial and local road networks, air pollution, water pollution, waste disposal, health care for diseases such as cancer, leukaemia, and silicosis, which can be fatal, and loss of existing jobs in the agriculture and tourism sectors.

2. State of South Africa's energy

Energy is vital for most human activities and is critical to the social and economic development of our economy. One of the key objectives of the Department of Energy is 'to ensure energy security, which in essence is about ensuring availability of energy resources and access to energy services, in an affordable and sustainable manner while minimising the associated negative impacts of its use' (DMR Website, July 2012). An integrated energy plan (IEP) was published in 2003 and preliminary work has started in 2012 on a second one, which aims to provide a roadmap of the future landscape of energy policy and technology development to guide future energy infrastructure investments. Fracking is such a new technology to South Africa that it has not been included in previous planning processes and has involved little public participation to date. More recently, it has been included in both the draft National Development Plan (November 2011) and the revised National Development Plan (August, 2012) as an increasing contributor to South Africa's energy mix.

Our energy crisis resulted in the South African government building two additional coal-fired power stations – Medupi and Kusile. Kusile alone will add a further10% to South Africa's annual greenhouse gas emissions, and both will lock South Africa into 50 years of coal-based energy, thereby taking us further and further away from the emissions reductions targets required by science to keep global warming below 2˚. According to a recent report by Greenpeace (2011) entitled 'The True Cost of Coal in South Africa', the real scandal is that 'if the same amount of attention and resources were applied to renewable energy, we could develop five times Kusile's proposed power generation capacity from clean energy sources with only 30% of Kusile's external costs'.

It is within this context that the new-to-South Africa technology – hydraulic fracturing – is placed. The emphasis of the pro-fracking brigade is that methane gas burns much cleaner than coal and therefore fulfils a bridging role – a needed step between current dirty coal and future cleaner energy sources. This argument might well make sense if the full life-cycle analysis of methane gas versus coal found it to be much cleaner, if there was a clearer strategy of how it is bridging a high-to-low carbon path for South Africa, and if there were limits set on the total amount of fossil fuel we in South Africa can extract. Instead, evidence suggests that if one takes escaped methane emissions into account – the gas that is released by fracking but is not captured – fracking is worse for climate change than coal.

Additionally, there are no limits in South Africa on the amount of energy to be exploited – we are looking at coal plus gas plus hydropower from neighbouring countries, plus wind and solar. Our greed knows no limits. The methane gas from fracking would be in addition to Kusile and Medupi's emissions, as well as the large reserves of conventional gas sources off the west and east coasts of Southern Africa, and therefore our carbon emissions will increase substantially at a time when predicted climate change is the biggest threat to human survival and development. This is corroborated by researchers from the Tyndall Centre for Climate Change, who state unequivocally that exploiting even a fifth of UK's shale gas resources, which is significantly less than South Africa's predicted resources, would prevent the UK from meeting its climate change emissions target (Harvey, 2011).

Currently, 90% of our energy comes from coal and only 2% from renewable energy (Greenpeace, 2011). On the positive side, the South African government is providing much more support and incentives for wind and solar energy and indications are that we will meet the target of producing 10,000 GWh from renewable sources of energy by 2013. Both solar and wind energy require virtually no water to run and are ideal for Karoo conditions. Renewable energy specialists fear that if government follows large-scale gas production, it will act as a deterrent to the development of true renewables. This has been found to be true in Ohio in the US, where cheaper energy prices and the focus on fossil fuels have been bad news for the renewable energy industry. Two wind farms have faltered, one of the state's prominent solar manufacturing companies laid off half its workforce, and the chairman and founder of a second solar company resigned, leaving a skeletal staff and big debts. Another company that supplied bolts to wind turbine manufacturers was declared bankrupt. According to Eric Burkland, president of the Ohio Manufacturers' Association (Schneider, 2012: 1), 'the energy picture has changed dramatically – the price of electrical power is low. The price of natural gas is low. It's changed the thinking on all alternative technologies. It's affecting solar. You could say it's taking the wind out of wind.' This has devastating implications for climate change.

3. State of South Africa's water resources

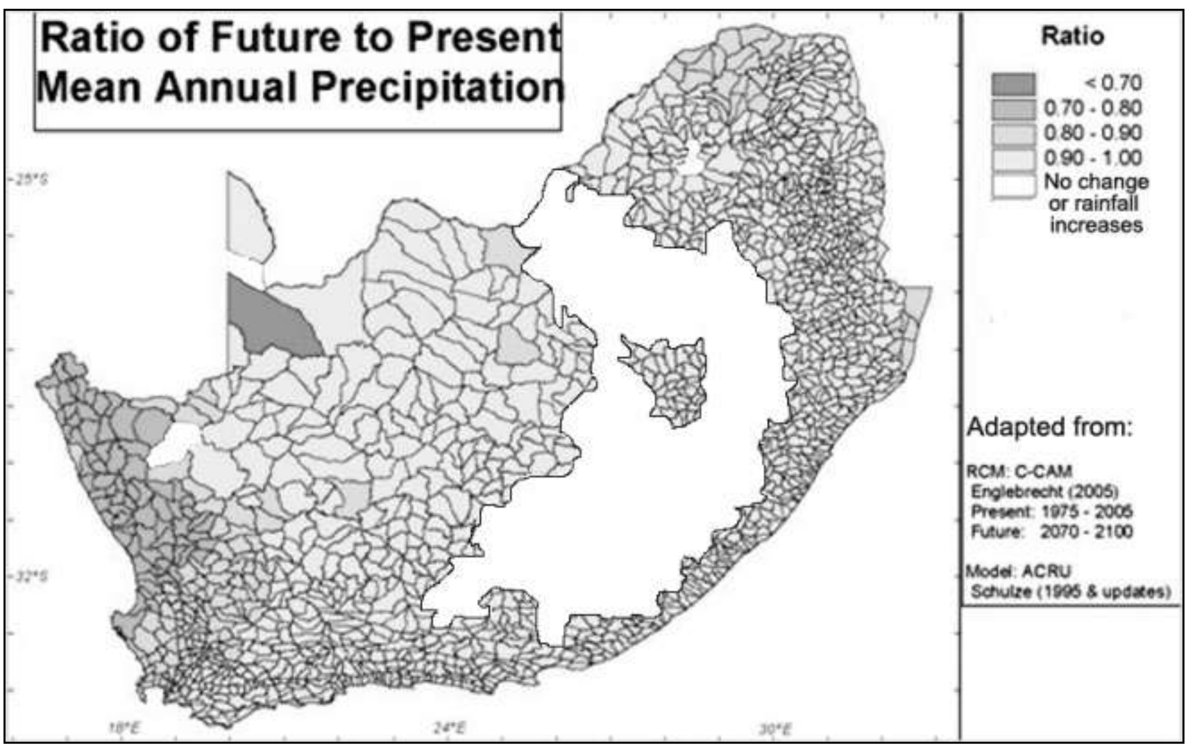
South Africa is classified as a water scarce country with a mean annual runoff of just over 49 000 Mm^3 of water, utilisable groundwater exploitation potential of about 10 000 Mm^3 per annum during non-drought conditions, and 25% than this less during drought conditions. In 2009, the Water Research Commission brought out the Water Resources of South Africa 2005 Study which undertook, for the first time, an integrated assessment of South Africa's surface water, its underground water resources and its water quality. The results revealed South Africa to have even less water than previously estimated and raised concerns that water shortages are on the horizon. According to the project director, Mr Brian Middleton: 'Our assessment of surface water resources, for example, shows that we have 4% less than we estimated in the 1995 study'(Nomqhuphu, 2009: 1), which is significant when available water resources have virtually run out. Surface water was used mostly in larger urban areas while groundwater was found to be used in about 75% of the country, mostly in small towns and villages.

This is particularly true of the Karoo, which is heavily dependent on groundwater resources. In a video interview Julienne du Toit (July, 2012), a researcher based in the Karoo, quoted a Department of Water Affairs study showing that 37 of 50 towns in the

Karoo depend entirely on ground water, 10 depend on a combination of groundwater and surface water and only three towns – Craddock, Adelaide and Cookhouse – depend only on surface water. This means that 94% of the towns in the Karoo depend on groundwater and could be affected by fracking. She said there is an erroneous perception that fracking is just a farmers' problem but in fact, whole towns could be devastated, and 'Carolina could happen all over the Karoo'.

Another vital factor that needs to be taken into consideration is that ground water is seen as the source to meet future water needs, as all the surface water is already allocated. Thus, Du Toit concludes, it's disturbing that fracking could cause so much damage to our future water supplies.

The scenarios associated with climate change paint an even bleaker picture with respect to South Africa's water resources. According to Colvin, Le Maitre and Archer (2010), climate change projections for South Africa are expected to include changes in the amount and variability of rainfall and increases in air temperatures, which will lead to increased evaporation, with a net effect of decreasing the amount of water in our rivers and stored in the ground. They conclude that these changes are critical in light of the fact that South Africa is already using almost all of its available water resources.



This is clearly shown in the map above, showing that rainfall is expected to decrease in all the shaded areas. This, in turn, is likely to result in reduced river run-off as well as decreased ground water recharge. Further impacts on water resources linked to climate change include increased incidences of drought and flooding, and increased risk of water pollution linked to erosion, disasters and algal blooms (Colvin et al. 2010).

4. Climate change and fracking

Shale gas is largely made up of methane, which has the chemical composition CH_4 – each molecule of methane consists of four hydrogen atoms and one carbon atom. It is the second most significant greenhouse gas contributing towards climate change. The argument that shale gas makes a good transition fuel rests solely on the fact that the gas burns more cleanly than coal. The greenhouse gas emissions of shale gas depend on two things – the carbon dioxide that is released when the gas is burnt, and the methane gas which escapes as a result of the fracking process. According to US researchers (Howarth et al, 2011; Black, 2012a), the footprint of shale gas is at least 20% greater than coal and perhaps more than twice as great on the 20-year horizon, and is comparable over 100 years. Fugitive emissions are estimated to be in the region of 8%.

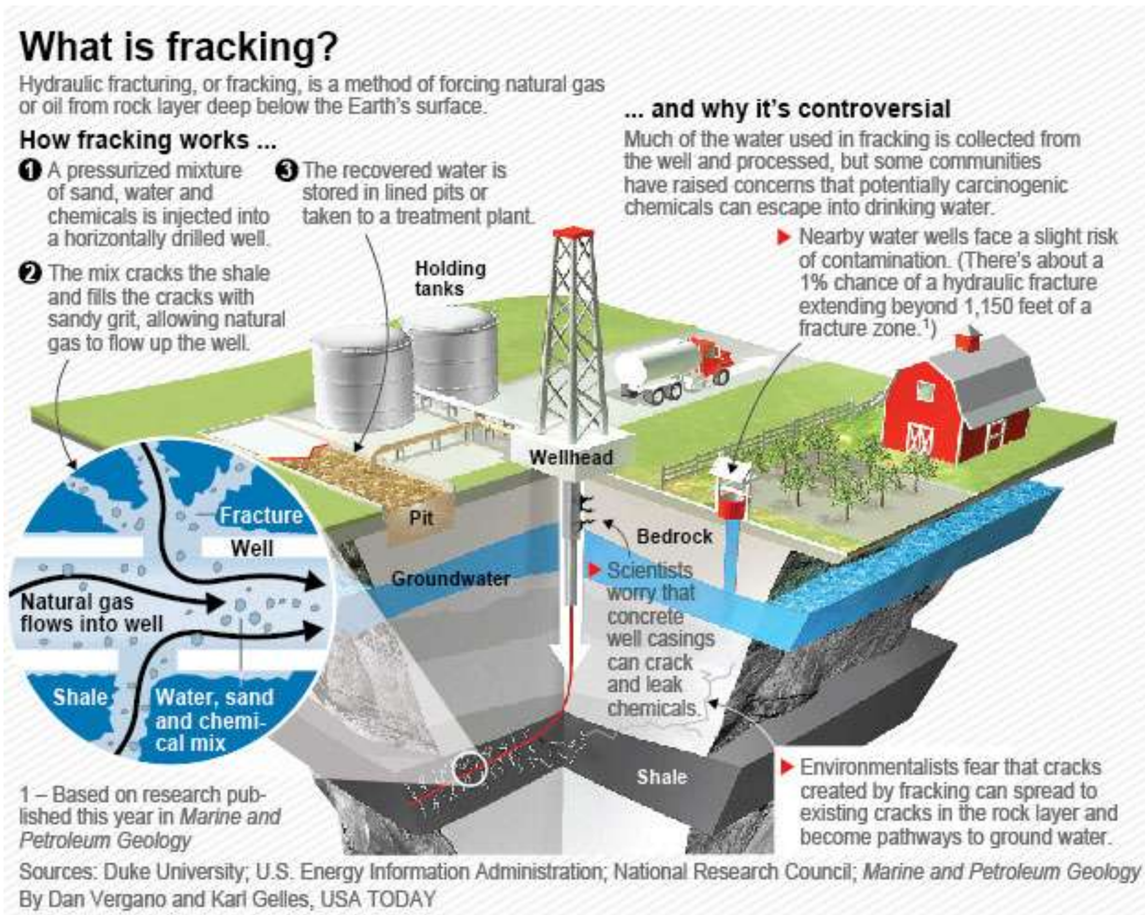
The lead author Robert Howarth reported that 'shale gas may indeed be quite damaging to global warming, quite likely as bad or worse than coal' (Black 2012a). Howarth cautioned that if gas is used for transportation fuel, even higher fugitive methane emissions that escape during the refuelling process are likely. This is particularly relevant in terms of climate change as methane has a global warming potential 23 times that of CO_2.

Fracking is a very energy-intensive process. More and more researchers are calling for a full life-cycle analysis of the fracking process and greenhouse gas emissions due to high percentages of fugitive emissions as well as all the energy required to drill for gas, to clean huge volumes of water both before and after fracking, and the energy use of all the trucks required at all stages of production. In another study (Inman, 2012), researchers found that by changing from coal directly to non-fossil fuel energy sources – such as wind and solar – it would result in a much sharper cut in the warming trajectory, with temperature changes 57–81% lower. If the switch was made from coal to gas, the figures were much lower – in the 17–25% range. They conclude that if we invest more in natural gas in the near term, 'it puts new investment money in the fossil fuel industry and expands the size of its political force' (Inman, 2012). Therefore, we should focus our investment on renewables right now.

5. Hydraulic fracturing

Hydraulic fracturing known as 'fracking' refers to the process in which fracking fluid – a mixture of approximately 99% water and sand plus 1% chemicals – is injected into wells under high pressure to create cracks and fissures in shale rock formations and thereby to improve the oil and gas production of the wells.

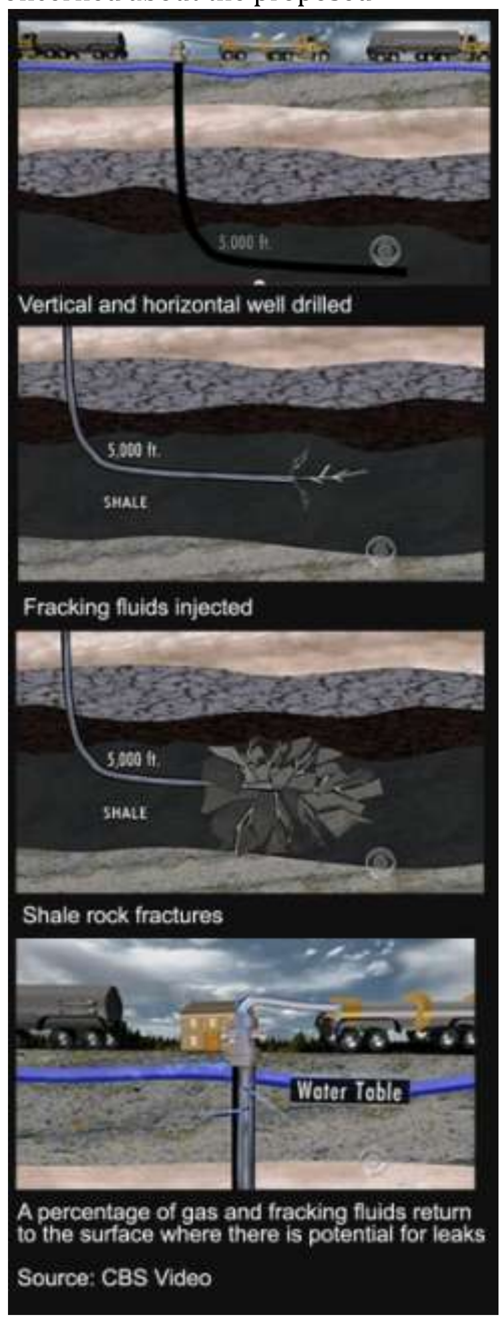
Shale is a sedimentary rock which is formed from deposits of mud, silt, clay and organic matter, and is considered relatively impermeable which means that liquid and gaseous material can't pass through the rock. Therefore, the mostly methane gas locked inside can only be released through breaking the rock open, hence the high-pressure fracking process.



Source: Vergano, D. 2012. USA Today

The process of fracking was virtually unknown in South Africa until the past two years, when a number of companies – most notably, Royal Dutch Shell, Falcon Oil & Gas, Sasol and Bundu Oil – applied for rights to 'frack' in South Africa. Other companies, like Norway's Statoil, US-based Chesapeake and Anglo American, have applied more recently. The areas under applications constitute 20% of South Africa's land mass, though some authors estimate it to be closer to 40%. The potential area extends over most of the Karoo Formation, and includes significant portions of the Western Cape, Northern Cape and KwaZulu-Natal and almost all of the Free State. There are also concerns about fracking in other parts of South Africa, for instance, a number of farmers in Mpumalanga province are mobilising against plans by the Umbono Company to mine gas on 27 farms in the Vaal River feeder area.

Environmentalists in KwaZulu-Natal (Ashe, 2012) are concerned about the proposed fracking in the Southern Drakensberg area, crossing into the Free State and Eastern Cape, where the headwaters of several big rivers have their source, such as the Mkomazi and Umzimkulu Rivers. If these rivers are contaminated it might threaten KwaZulu-Natal's future water supply, especially water for the City of Durban.



5.1 Stages in the fracking process

Fracking involves drilling a vertical well to a depth of 2–6 km until the shale formation is reached and then drilling horizontally for up to 5 km. There are a number of steps in the fracking process (Chesapeake Energy, 2012):

1. Water, sand and chemicals are pumped at high pressures down the wellbore.
2. The liquid goes through perforated sections of the wellbore and into the surrounding formation, fracturing the rock and injecting sand or proppants into the cracks to hold them open.
3. Experts continually monitor and gauge pressures, fluids and proppants, studying how the sand reacts when it hits the bottom of the wellbore, slowly increasing the density of sand to water as the fracturing progresses.
4. This process may be repeated multiple times in 'stages' to reach maximum areas of the wellbore. When this is done, the wellbore is temporarily plugged between each stage to maintain the highest water pressure possible and get maximum fracturing results in the rock.

5. The fracturing plugs are drilled or removed from the wellbore and the well is tested for results.
6. The water pressure is reduced and fluids are carried up the wellbore for disposal or treatment and re-use, leaving the sand in place to prop open the cracks and allow gas and oil to flow.

5.2 Analysis of the impact of fracking on water

Concerns around the range and severity of impacts that fracking has already had on water resources and the potentially catastrophic consequences it could have on future water resources is evidenced by the proliferation of research material becoming available – largely from the US, which is the first country to commercially exploit shale gas, as well as from South Africa, Canada and the United Kingdom.

The impacts of fracking on water can be divided into a number of distinct categories, which vary in terms of locale, severity and time scales. They include (Cooley and Donnelly, 2012; Bosman, 2012; Hartnady, 2012):

- Water requirements
- Groundwater contamination
- Wastewater management
- Truck traffic associated with water transport
- Surface spills and leaks
- Stormwater management

Water requirements

Huge quantities of water are required for the hydraulic fracturing process. Different authors estimate between 5 and 29 ML of water being needed per well, with the average per well (not per fracking incident) estimated at 20 ML. The number of wells on a pad varies considerably – from around 6 to 32, and there are a number of pads in a development. If the exploration phase is successful, the gas production phase could result in the development of over 10 000 wells. The actual number is unknown.

Hartnady calculated that if 10 000 wells are developed, the total water demand would be in the range of 50 000 to 200 000 ML. Fracking would thus become a serious competitor for water, requiring as much as four times the current annual usage of the groundwater in all three of the Shell exploration areas (Hartnady, 2012; Umvoto, 2012).

The Karoo is a semi-arid region in South Africa. It was named by the early Khoisan people, and Karoo means 'the land of thirst'. Most of the area depends on groundwater as the only source of water for domestic, agriculture and livestock watering purposes. It would be very difficult to source the large quantities of water that fracking requites, and indeed Shell has undertaken not to compete with local users for scarce water resources. Instead, a number of potential alternative water sources have been put forward, include seawater, abstraction from deep aquifers, re-using municipal wastewater or even importing AMD from the gold reef areas of Johannesburg (Bosman, 2012). Seawater, however, cannot be used for fracking unless it is treated first as the particles interfere with the chemicals used in the fracking process.

Even though Shell has undertaken not to compete with existing users, there is a broader, more long-term issue at stake, namely, that big industry is locking up 'future water' or water that is currently not needed (Wilson, 2012), but which will soon be the cheapest alternative available. In the future, waste water may be the only resource that municipalities can tap into to augment supply.

All this water has to be transported, largely by truck, and this can result in 1 500 to 2 500 truckloads travelling from the water source to each well. The contaminated fracking fluids that return up the well will need to be disposed of and this is also likely to involve large-scale transportation by truck.

Fracking fluids

During the high pressure fracking process, the shale rock is broken open through creation of fractures and pathways for the gas to move through. To keep these cracks and fissures open to continually mine the gas over a longer period of time, a sand and chemical cocktail is added to the water. The chemicals are to ensure the sand is carried in the fluid, and the sand is to ensure that the cracks in the shale rock – which are between 0.1 mm and 3 mm thick – remain open.

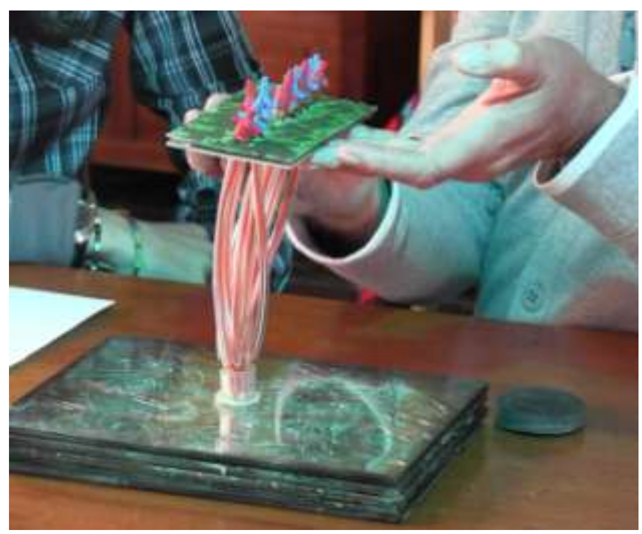
The composition of fracking fluids vary considerably according to the specific conditions underground and also according to industry's research. In the USA, industry does not have to provide full disclosure of chemicals used in the fracking process because of trade secret exemptions. There is also a bizarre US Federal law which exempts the underground injection of fracking fluids from regulation (Tyndall Centre for Climate Change Research, 2011).

In terms of percentage, chemicals comprise between half and 2% of the total fracking fluids. When you take into account the volume of fracking fluids involved, the amount of chemicals released into the ground is staggering. According to the Tyndall research, a single six-well pad will require 1–3.5 million litres of chemicals for the first fracking operation (excluding additional chemicals needed for subsequent fracks). They conclude that based on 1.25–3.5 pads per/km^2, the chemicals needed per km^2 of shale development in the UK would be 3 780–12 180 tonnes. All these chemicals are transported by road.

Van Tonder (2012) explained this same concept more simply using a model of the above ground and below ground scenarios. In the photo on the right the top level section is the surface level with ten wells. Tubes representing each well on the well pad go down vertically for 2–5 km, and then turn in a horizontal direction for another 1–3 km (though some go as far as 5 km. The record in the US is 7 km drilled horizontally).

According to Van Tonder, in a typical US example, where there are ten boreholes on a well pad, one can frack an area of 3 km x 1 km, which gives an area of 300 ha. The thickness of the fracked area is about 100 m. The process is to frack the rock open with a number of small explosions, which results in fractures like shattered glass, with each crack being between 0.1 mm and 3 mm in diameter. The photo on the right shows the same concept using a different diagram.

For each borehole the amount of chemicals used is equal to 4 000 bags of fertilizers of 50 kg each. So for the ten boreholes in the model above covering 300 hectares, the amount of chemicals used is equal to 40 000 fertilizer bags of 50 kg each. The aim of the fracking operation is mostly to increase the permeability of the rock so that water and gas flow more easily. When it is fracked with 700 bars of pressure, there is an exponential flow-back of contaminated water and gas. In the beginning it is very high flow-back, and within a year it is down to 20% and then it reduces further to 10% for between ten and 20 years. The amount of flowback water after the initial period is 300 l/day. When the production stops the borehole is closed using very high quality cement seal, but even this cement cannot be guaranteed not to



crack within 50 to 100 years, thereby creating preferential pathways for the remaining gas and water to escape.

According to Van Tonder, the area represented by the shattered glass in the bottom photograph has been transformed by the fracking process into a water-bearing layer and therefore becomes an aquifer. This means that contaminated water can move from one area to another area within the aquifer within in a number of days, whereas if it had remained unfracked, it would have taken 50 000 years to do so.

Over 600 chemicals are known to be used in the fracking process but due to the non-disclosure clauses it is difficult to know exactly what they are and where they are used. Each fracking operation requires a different cocktail of chemicals. Researchers (Tyndall Centre for Climate Change Research, 2011; Bosman, 2012) examined a list of 260 chemicals that was provided by New York State. Their analysis revealed that of the 260:

- 15 substances are listed in one of four priority lists of substances requiring immediate attention
- 6 are present in list 1 of priority substances, identified by the European Commission as substances requiring immediate attention because of their potential effects to man or the environment (acrylamide, benzene, ethyl benzene, isopropyl benzene, naphthalene, tetrasodium ethylenediaminetetraacetate)
- 1 is currently under investigation as persistent, bio-accumulative and toxic (PBT) (naphthalene bis (1-methylethyl))
- 17 are classified as being toxic to aquatic organisms
- 38 are classified as being acute toxins
- 8 are classified as known carcinogens, such as benzene and acryl amide, ethylene oxide, and various petroleum-based solvents containing aromatic substances
- 6 are classified as suspected carcinogens
- 7 are classified at mutagenic
- 5 are classified as having reproductive effects

Depending on the site, 15–80% of the fracking fluids injected in the ground are covered as flowback water, and the remaining 20–85% of the fracking fluids remain underground (Bosman, 2012).

Groundwater contamination

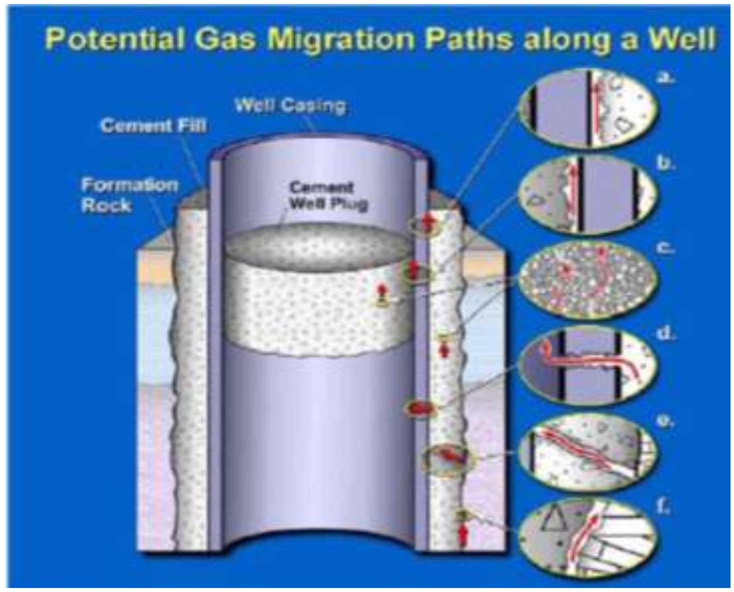
Contamination can takes place in a number of quite distinct ways:

- methane gas migrating from active wells to nearby water sources
- fracking fluids that return up the well as part of the fracking process, which can potentially leak, contaminating surface water or aquifers, or

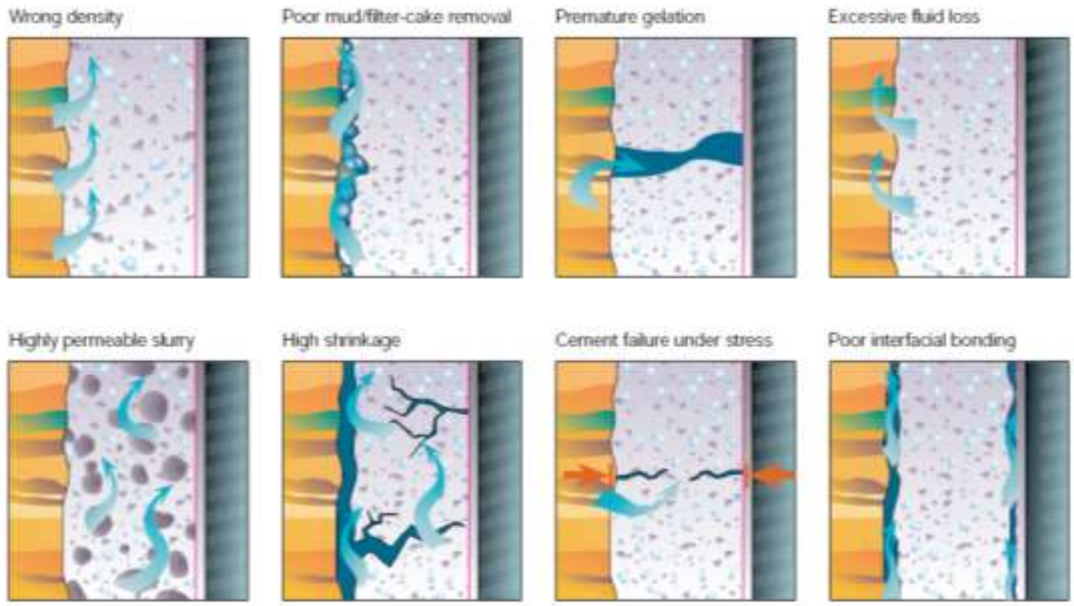
- the more recently exposed potential for contamination from deep-water fracking fluids and produced water migrating towards the surface along preferential pathways, such as dolerite dykes.

Each of these is discussed below in more detail.

Contamination caused by well casing and cement flaws and failure



Bosman (2012) states that establishing a tight seal between the well casing and the shale formation can be technically demanding, particularly in the horizontal sections of a gas well. The diagram alongside documents the potential gas migration paths along a well, and through the well plugs (Bosman, 2012).
Hartnady (2012: 14) quotes a 2005 report by Fleckenstein et al that states: '…Cement has little tensile strength of its own and fails in tension before lending significant support to the casing. The assumption of no contact between the cement sheath and borehole is unrealistic, but illustrates the *dangers to cracking the cement sheath by generating a high internal pressure in casing*, especially during casing pressure tests after cementing.' Hartnady concludes that the assumption of no contact between the cement sheath and the borehole is unrealistic as gas can easily escape up the casing or outside the casing in the fractured zone.



The diagram above, from Bonett and Pafitis (1996: 37) is quite dated but shows potential causes of gas migration pathways through cement, including wrong density, poor mud/filter-cake removal, premature gelation, excessive fluid loss, highly permeable slurry, high shrinkage, cement failure under stress and poor interfacial bonding.

Bosman added that even if a good cement bond is established, the fracturing process involves repeated cycling of hot and cold fluids and pressure changes, which can cause potential paths for leakages to occur. Several researchers remind us that Haliburton, the company which operates many of these wells, was responsible for testing the cements seals at the BP rig in the Gulf of Mexico. The Macondo well blow-out was caused by loss of control over gas influx into the well through faulty casing and the cement seal (Hartnady, 2012).

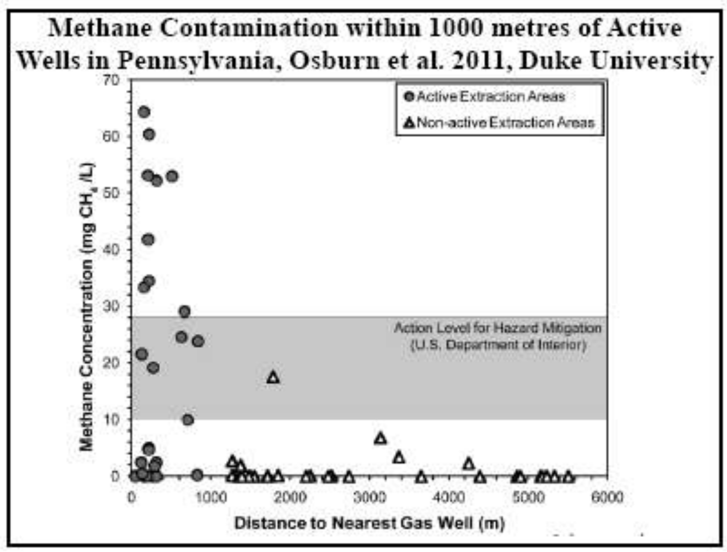
Van Tonder reiterated that the greatest concern currently is the faulty fracking boreholes, more specifically the cement annalus situated between the casing and the rock formation. He states that if there are 50 000 well pads, there must be at least 50 000 boreholes and each of these boreholes must be considered a potential preferred pathway for fracking chemicals, diluted formation elements and methane. He asserted that the greater the number of boreholes, the greater the risk of pollution will be.

Contamination through naturally occurring or induced fractures close to aquifers

When there are naturally occurring or induced fractures close to water-bearing formations, fracking fluids can migrate along them, which can contaminate the water source. Bosman states that as fractures can extent up to 1 000 m in any direction and formations being fractured can vary from 80 m to over 5 000 m below the ground, it is possible that a fracture can occur naturally or be induced. Additionally, the horizontal portion of the well is not sealed, which means it doesn't stop the fracking fluids from migrating. It is therefore vital to have detailed mapping of underground aquifers and the distance between them and the shale formations (Bosman, 2012).

Methane contamination

A peer-reviewed study by Osborne and colleagues (Jackson et al., 2011) about the methane contamination of drinking water associated with fracking provided the first systematic evidence of this in areas where fracking is occurring. Their analysis of 60 private water wells found that thermogenic (from a deep source) methane concentrations 'were found to be 17 times higher on average in areas with active drilling and extraction than methane of near-surface biogenic origin in non-extraction areas, with some drinking-water wells having concentrations of methane well above the "immediate action" hazard level'. This methane contamination is seen graphically in videos of the town of Dimock's drinking water on fire. As a substance, methane remains unregulated and there appear to be no peer-reviewed research papers available on its health impacts, through asphyxiation is known to occur and methane is very explosive.



Upward migration of fracking fluids over time

A peer-reviewed paper by Tom Myers (2012) in the journal *Groundwater* highlights the potential for fracking fluids to migrate through preferential pathways to underground aquifers, and indicates that this migration could be exponentially accelerated through the process of fracturing the underground rock formations. The publication of the Myers paper served as a wake-up call for South African geologist, Prof Gerrit van Tonder, from the University of the Free State Institute for Groundwater Studies, who stated in an interview (Du Toit, 2012b) that: 'Myers maintained there was a very slow movement upwards of deep water, a cycle taking tens of thousands of years. But, he said, the holes drilled into the shale became preferential pathways, which means the fracking fluids left underground could rise up to contaminate aquifers in as little as a few hundred or even a few tens of years. This started me thinking about the Karoo. It also made me remember the exploration holes drilled by the gold companies on my father's Free State farm. Water rose up in them and was still warm at the surface.' Van Tonder added that the prevalence of numerous hot water springs – about twenty – in the Karoo is another indicator of the movement of hot water from deep underground to the surface, as was the evidence that 'exploration holes' drilled by Soekor were 'artesian', which refers again to the vertical movement whereby water rises to the surface under internal hydrostatic pressure.

Van Tonder and his colleague Fanie de Lange undertook research with the primary aim of proving whether or not there exists an upward vertical flow gradient between the deep layers in the Karoo and the top fresh-water aquifer. The authors proved without any doubt that an upward vertical flow gradient exists, and that fracking fluids which are left underground will migrate over time to the surface and will contaminate shallow ground-water aquifers or surface water.

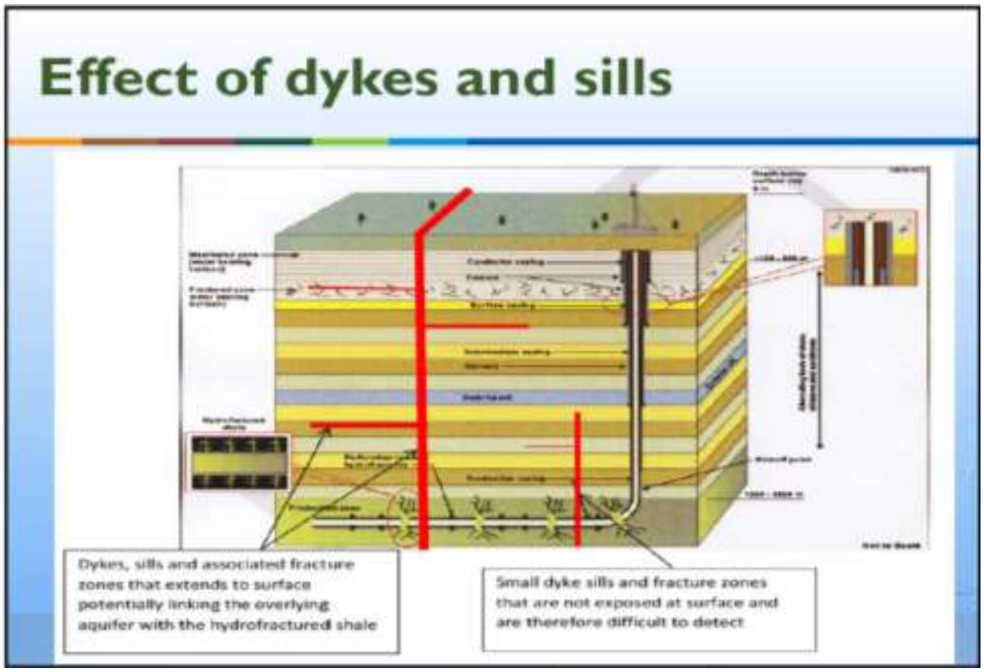
In the typical US example of a fracking well pad with ten wells drilled in an area covering 300 ha referred to previously, Van Tonder estimated that the amount of contaminated water remaining underground after the well pad is abandoned would be equivalent to 6 000 Olympic-sized swimming pools. When these numbers are extrapolated to the whole of South Africa, one can get an idea of the scale of the fracking operation: if 10% of South Africa was fracked over the next 50 to 100 years, this would result in 40 million Olympic-sized swimming pools of contaminated water underground, all of which wants to migrate upwards.

In an interview (2012) Van Tonder was asked how hydraulic fracking compared with the current AMD crisis, and he replied that it was far, far worse. In the case of the AMD, the water table is rising and it is not the same case of upwards migration of contaminated water.

Effects of dykes and sills

According to Van Tonder, the Karoo shale field is notable for being one of the only shale fields in the world to contain so many dolerite dykes, which dramatically increases the potential for preferential pathways and the upward movement of fracking fluids and produced water.

In the diagram below the dykes, sills and associated fracture zones that extend to the surface form a potential link between the overlying aquifer and the fractured shale. Subsurface dykes, sills and fracture zones are difficult to detect.



(Bosman, 2012)

Surface water and land contamination

Prof Ingraffea (The Ecologist TV, 2010) quotes the estimate of the Pennsylvania Department of Environmental Preservation (or Protection) that 'there is one serious environmental concern for every 150 wells drilled to date. You do the math; if we are talking hundreds of thousands of wells we are doing hundreds or thousands of spills'. He warns that it is an impact that is currently accumulating, and that within ten years the results will be clear.

Surface contamination can result from the following (Tyndall, 2011; Hartnady, 2012):

- Spillage, overflow water ingress or leaching from mud
- Spillage of concentrated fracturing fluids during transfer and final mixing with water
- Spillage during drilling
- Spillage of flowback fluid during transfer to storage
- Leakage or overflow from storage ponds/evaporation pits
- Pipeline and casing breakage
- Spillage of flowback fluid during transfer from storage to tankers

Wastewater management

Disposal or recycling of fracking fluids which are acidic, corrosive, carcinogen and likely to contain radioactive materials (thorium, radium and uranium) is another area of concern over potential surface-water contamination.

Drilling the wells results in tonnes of drilling mud per well pad, which typically gets stored and then transported offsite.

Additionally, each well generates 1 300–23 000 m^3 of flowback fluid containing water, chemicals, and subsurface contaminants, which can include naturally occurring radioactive materials (NORMs), toxic organic compounds and heavy metals (Tyndall, 2011). This needs to be temporarily stored or transported to waste water treatment works where it is treated and released back to surface streams. Other ways to manage fracking waste water is to inject the fluids into depleted gas wells or deep strata, to recycle and re-use waste water as fracking fluid, to spread it on roads for dust suppression or to store it in evaporation pits.

All of these options include risks, especially in South Africa where we lack the capacity to treat existing municipal sewage and AMD. It is highly questionable that in the short term we can develop capacity to manage high volumes of toxic waste. We also lack the regulatory and monitoring capacity to keep track of the toxicity levels of fracking fluids.

A recent study by Rozell and Reaven (2012) of Stony Brook University concluded that current methods for wastewater disposal associated with fracking in the Marcellus Shale region in the US put drinking water at risk. They compared five pathways of water contamination: transportation spills, well casing leaks, leaks through fractured rock, drilling site discharge and wastewater disposal. They found that the highest potential contamination risk was from wastewater disposal, which was several orders of magnitude higher than the other pathways as 77% of operators in the study did not recycle or reuse the water due to the high cost of separation and filtration. Instead, they transported the contaminated water to wastewater treatment facilities and dischargedit into streams. The authors stated that even in a best-case scenario, 'it was likely that an individual well would release at least 200 cubic metres of contaminated fluids' (Rozell and Reaven, 2012: 1382). In the worst case scenario, this figure jumped to 13 500 m^3.

The authors argue that municipal wastewater treatment facilities in the US are not designed to handle fracking wastewater, which contains high concentrations of salts or radioactivity two or three orders of magnitude above drinking water standards. This has resulted in high salinity and dissolved solids in Appalachian rivers associated with the disposal of wastewater from the Marcellus Shale *after* standard wastewater treatment.

This has been corroborated by evidence presented by Volz (Rozell and Reaven, 2012) indicating that industrial wastewater treatments may also release effluent in excess of drinking water standards into natural water systems.

Van Tonder explained that since the Karoo Shale was formed in marine conditions, its salt content can be ten times that of the ocean, as well as it potentially containing radioactive materials. This requires regulators to control the surface disposal of fracking waste water much more stringently, which in turn will increase the costs of disposal.

Misclassification of hazardous waste as brine

A report released from Ohio in July 2012 (Ecowatch, 2012) indicates that results of a sample of brine from fracking operations should be considered hazardous, contrary to its current status as non-hazardous. According to Professor Ben Stout of Wheeling Jesuit University, who did the analysis, the sample included arsenic and barium levels that exceed the standard for acceptable drinking water concentrations by 370 and 145 times, respectively, as well as alpha particles indicating elevated levels of radioactivity. A partial review of Ohio's Division of Natural Resources inspection records on 116 injection wells from 2000–2011 reveals a legacy of brine spillage in at least 12 Ohio counties. In many cases, no remediation occurred because brine is not classified as hazardous waste.

Transport of chemicals and fracking fluid waste

In addition, spillage can occur from transport accidents. Northrup (The Ecologist TV, 2010) raised concern about the huge volumes of fracking fluid travelling around the US countryside in tanker trucks. He argues that if only one tanker truck has an accident and the fracking fluids end up in a river, it would destroy the river.

Injection into depleted gas wells or deep strata

This practice is known to cause earthquakes and contributes to the concerns raised by Myers and Van Tonder regarding the upwards migration of fracking fluids.

In Ohio officials confirm that tremors are almost certainly caused by wastewater injection into the ground. As municipal water treatment plants are not designed to deal with radioactive fracking fluids, deep injection is thought to be a safer option. The volumes of water are significant and, according to Pennsylvanian authorities, over 1.5 million barrels of waste was sent to injection wells in Ohio in the second half of 2011 (Carr Smyth, 2012).

Earthquake activities associated with fracking

The link between fracking and earthquake activity is well documented. Hartnady (Nkabinde, 2012) warned that the Karoo has lots of potential earthquake epicentres, and that we should learn from the hydro seismic events in Oklahoma where earthquake activity increased from an average of 30 small earthquakes a year to over 1 000 a year since 2010.

According to Sneed et al (2012) of the United States Geological Survey, earthquakes affect Earth's intricate plumbing system, and hydro-geologic responses to earthquakes include water wells becoming turbid and dry or beginning to flow, formation of new springs or increasing discharge, and well- and surface-water quality becoming degraded as a result of earthquakes. An increase in earthquakes in areas where fracking is taking place adds further concerns regarding contamination by fracking fluids and cement failure due to earthquake activity.

6. Regulatory capacity to manage fracking in South Africa

In the past 15 years local authorities in South Africa have experienced a seven-fold loss of engineers and technologists, which has resulted in the collapse of infrastructure and maintenance programmes, widespread demand-management failures and water treatment failures. According to Herold (2009, 13), this is 'a major national crisis that threatens the life-blood of the country'. These findings were supported by the Water Dialogues Process findings in South Africa (Galvin, 2009). There is a huge dearth of skills to manage our water resources at all levels of government, but especially at the local authority level, and this, Herold says, threatens to destroy the very fabric of organisations such as the DWA, water boards and major metros.

Herold (2009), in his lecture on the water crisis in South Africa, detailed the loss of essential skills, decaying infrastructure and deteriorating water quality as inter-related water crises in addition to the mismatch between supply and demand. Over the last decade and a half the municipal sector has lost six-sevenths of its engineers and technicians, rendering most outlying municipalities impotent to deliver even the most rudimentary services. The erosion of maths and science education in secondary schools is also throttling the professional education pipeline, which threatens an even bigger skills deficit crisis in the future. Recommendations are to improve capacity in local authorities through active recruiting and improvement in service conditions in order to retain staff more effectively.

The US has a much stronger oil and gas industry and it is not keeping up with the regulation needed. According to McKibben (2012), the overmatched regulators 'can't even keep an accurate count of the number of wells' and are having a hard time coping with waste products – especially since the political power of the industry just keeps growing. Michael Jacobson, associate professor at Penn State's School of Forest Resources, says having regulations in place is critical, but since this technology is relatively new the regulations are evolving, resulting in a 'regulate as you go along' approach.

In their review of institutional arrangements within the water sector, Water Dialogues South Africa found that from the mid 1990s there has been insufficient capacity to staff municipalities well or to provide extended services, and that this has been exacerbated by the flight of skills, massive municipal reconfigurations, and an inability to keep staff. They conclude that building capacity is probably the single most critical challenge facing the water and sanitation sector as it underlies everything that the sector does or should do. Even though skills development has been cited in many fora, there is a lack of achievement in addressing this challenge.

Another aspect of regulation that has not surfaced much in the South African debate is the need to protect gas workers through appropriate regulations. According to the biggest US labour organisation, the AFL-CIO (McQuillen, 2012), hydraulic fracturing is harmful to workers and should be monitored by the federal government, particularly as the oil- and gas-extraction industry has a much higher death rate than for other US workers. During the period from 2003 to 2009, the industry had an annual occupational fatality rate of 27.5 per 100 000 workers compared with 3.9 per 100 000 for all US workers. This is more than seven times higher. Fatality rates are higher when there is an increased number of active drilling and workover rigs. The deaths were attributed to highway motor vehicle crashes (29%), workers being struck by tools or equipment (20%), explosions (8%), workers caught or compressed in moving machinery or tools (7%), and falls to lower levels (6%). Death due to disease seem to be excluded from these statistics but in the fracking industry there are high levels of exposure to crystalline silica, which puts workers at risk of silicosis and lung cancer as well as exposure to harmful carcinogenic chemicals.

A report by the Energy Institute of the University of Texas, 'Separating fact from fiction' (2012), looked at both the regulation and enforcement in the shale gas industry. They found that surface spills of fracturing fluids appear to pose greater risks to groundwater sources than hydraulic fracturing itself, and that whilst blowouts – uncontrolled fluid releases during construction or operation – rarely occur, subsurface blowouts appear to be under-reported.

While the report found that existing regulations for the oil and gas industry sufficed in the US, three areas of particular concern required revised regulations – disclosure of hydraulic fracturing chemicals, proper casing of wells to prevent aquifer contamination, and management of wastewater from flowback and produced water. There are still gaps in the regulation of well casing and cementing, water withdrawal and usage, and waste storage and disposal. The report argued that regulations should focus on the most urgent issues, such as spill prevention.

With respect to enforcement of regulations the report found it to be highly variable between states in the US, particularly when measured by the ratio of staff to numbers of inspections conducted. Enforcement actions also tended to focus on surface incidents rather than subsurface contaminant releases, perhaps because they are easier to observe.

Bosman (2012), in her analysis of South Africa's capacity to manage, monitor and enforce mitigation of fracking impacts, identified a number of different government departments at both the national and provincial levels that are responsible for ensuring compliance with relevant statutes such as the National Water Act (Act 36 of 1998), National Environmental Management Act (Act 107 of 1998) and the Minerals and Petroleum Resources Development Act (Act 28 of 2002)– including the Petroleum Agency of South Africa, DWA, DEA, three provincial departments for the environment, Department of Health, Department of Agriculture and the Department of Trade and Industry. Due to the vastly different mandates of these departments, Bosman concluded that 'harmonised and coordinated compliance and enforcement monitoring will be almost impossible'.

In South Africa, there is much concern about the current state of water management. Havemann, the lawyer working with Treasure the Karoo Action Group, has said that even if there is perfect regulation, South Africa lacks the capacity to enforce compliance. He cites as an example that 79% of the posts of South Africa's water police, the Blue Scorpions, are vacant. It is impossible to regulate without the necessary combination of people and skills.

7. Mitigation

The scale of fracking, the quantities of water and toxic water involved, air pollution impacts and the industrial activities and transport associated with fracking mean that the impacts are significant, irreversible and will change the nature of the Karoo landscape for the foreseeable future.

The technology is still in its infancy and its learning curve is very steep. Whether or not South Africa embarks on fracking, it would do well to delay the process in order to benefit from the US experiences and from the development of improved technologies. One example is the development of waterless fracking technology by GasFrac Energy Services, which uses propane – one of a group of liquefied petroleum gases with the molecular formula C_3H_8 – instead of water (Cooper, 2012). The propane is injected into the well together with sand and chemicals under pressure, and when the pressure is off, the propane transforms into a vapour and returns to the surface where it can be separated and reused. Benefits of this approach include reduced water consumption and contamination, reduced truck traffic and increased well production, but the cost is 50% higher than for water-based fracking and is likely to render fracking uneconomical in South Africa.

Another technological improvement is the use of 'green' fracking fluids, a relative term used to describe the less toxic chemicals that can be used. This does not affect the radioactivity of the waste water produced. Van Tonder (2012) has indicated that even without the fracking fluids the process would still be disastrous for South Africa.

The second area of potential mitigation is the use of improved technologies available that can capture fugitive methane emissions and reduce it from the current estimate of 8% of the methane gas escaping into the atmosphere. As methane has such a significant climate-change footprint, reducing escaped gas would reduce the greenhouse gas impact of fracking, but it would not negate it.

A vital area in which mitigation is paramount is that of waste water treatment. This is highlighted by researchers Rozell and Reaven as being several orders of magnitude more likely to result in water contamination than transportation spills, well casing leaks, leaks through fractured rock, and drilling site discharge. Thus they recommend that regulators focus much more attention on improving the quality of the treated wastewater that gets returned into river systems. Specialists, however, say that, due to the contaminants and the salinity levels, it is not possible to treat the contaminated waste water to a level where it is no longer harmful to the environment.

A common practice in the US of dumping huge quantities of waste water into abandoned wells needs to be fully understood in terms of its potential for bringing on earthquakes as well as the upwards migration of subterranean water, as highlighted by Myers (2012) and Van Tonder (2012).

Mitigation of impacts requires stepping up capacity within government structures to make wise decisions, to develop appropriate policies and regulations and to enforce these regulations, as well as improved levels of cooperation between different ministries and different levels of government. Institutions such as the Water Research Commission should be undertaking research now to guide future decisions.

8. Legal issues

A number of laws aim to protect South Africa's water and environment. In terms of the National Environmental Management Act, there are a number of Principles of Sustainable Environmental Management which must be complied with in all actions of all organs of state (Bosman, 2012). These principles include an integrated approach, a risk averse and cautious approach that takes into account the limits of current knowledge about the consequences of decisions and actions, and the polluter pays principle. Bosman highlights the reference in NEMA to the 'best practicable environmental option', which is the 'option that will provide the most benefit or cause the least damage to the environment as a whole, at a cost acceptable to society in the long term as well as the short term' (Bosman, 2012). Fracking would not qualify in this regard.

In Section 21 of the National Water Act, a water authorisation can be given for consumptive or non-consumptive water uses if the user can provide evidence that the water use will be an 'efficient and beneficial use of water in the public interest'. According to Bosman, fracking in its current form cannot be regarded as a sustainable use of water that will meet this criterion, and authorisation should therefore not be granted. This is particularly true, Bosman adds, where the proposed water use will affect the reserve needed for basic human needs and aquatic ecosystems, and for sole-source ground water resources. She states that if 'there is any suspicion that an activity may potentially detrimentally affect the quality of quantity of this water resource, then water uses by this activity cannot be authorised'. Taking the significant pollution threats into account, this implies that fracking is arguably illegal in South Africa.

9. Recommendations

During the writing of this essay, the South African Cabinet lifted the moratorium on shale gas mining, a decision which they based on the report by a Department of Mineral Resources task team established to investigate the pros and cons of fracking. This committee made the recommendation to grant 'conditional approval of hydraulic fracturing under the current regulatory framework' (Department of Mineral Resources, 2012). The executive summary of the report is available online.

The recommendations below have been broadly categorised into

- overarching;
- research;
- governance, policy and legislation; and
- public participation.

9.1 Overarching recommendations

Need for undertaking strategic environmental assessments to guide development at the policy, planning and programme levels

Fig (2012) has highlighted the need for robust strategic environmental assessments to guide development in each of the areas designated for fracking and prior to the granting of any production rights in South Africa. Indeed, the whole issue of whether South Africa should follow the fracking development path or the renewable energy path should be undertaken as a strategic environmental assessment that allows full public debate and deliberation, the underpinnings of true democratic process. The water implications of the alternative development options should be at the heart of the strategic environmental assessment.

Need for science to inform policy

Prof Chris Hartnady believes that the greater issue is that policy is preceding adequate scientific study, which could inform the impacts of fracking on water and rural livelihoods and indeed confirm whether a full cycle analysis of the greenhouse gas emission associated with fracking makes it any cleaner than other fossil fuels (Hartnady, 2012). To this end he believed it essential that the moratorium on fracking remained in place while scientific studies took place. Instead, the Cabinet has approved the exploration phase while undertaking research.

Analyse the implications of the lifting of the moratorium

It remains very unclear what the lifting of the moratorium on fracking means for South Africa and what safeguards are in place to mitigate the worst environmental impacts of the fracking process. For instance, are development rights effectively automatic if gas is found? What zoning laws are in place (such as the Cape Land Use Planning Ordinance) and should these be extended to other provinces? How will the water licenses be decided? What rights do landowners have? Who carries the burden of proof for contamination of water resources? All of this and more needs to be understood in much greater detail. Civil society has an important supportive and watchdog role in ensuring best practice is implemented in South Africa

9.2 Research recommendations

Undertake a comprehensive water-energy audit of the fracking process compared to alternative energy development options

Wise decision-making processes must simultaneously address the challenge of sustaining both these essential resources. This is especially true for South Africa – a country facing critical shortages of both energy and water, and while the recent focus has been on energy there are indications that it is South Africa's water shortages that will most hamper future growth.

Research a full life-cycle analysis of the climate change implications of the fracking process

Climate change is arguably the greatest threat to humanity and it is essential that we fully understand the climate change potential of greenhouse gas emissions associated with the entire hydraulic fracturing process, including the high percentage of fugitive methane emissions, all the energy required to drill for gas, to treat huge volumes of water both before and after fracking, and the energy used for all transport required at all stages of gas production and distribution. With this knowledge, we can evaluate South Africa's current and future contribution to climate change under the different development scenarios and make an informed choice.

Research into the upwards migration of fracking fluids

The Executive Summary of the DMR report highlights the fact that we know little about the hydrogeology of the Karoo Basin and the 'effects of dolerite intrusions, kimberlite fissures and existing fracture systems are relatively unknown and further investigations and modelling are required' (DMR, 2012: 6). They do, however, assert that 'fracking fluids are immobile under normal conditions with no "drive" once the fracking operation has been completed'. This is exactly contrary to Professor Van Tonder's assertion that once fracking operations have been completed, the shale formation is transformed into a water-bearing aquifer layer where the fracking fluids can move at much faster rates than before fracturing – at the rate of decades versus hundreds of thousands of years. Van Tonder believes the contamination of South Africa's water resources will be evident in 50 to a hundred years' time.

Research the implications of using toxic chemicals in the fracking fluids

Health implications of the known toxic chemicals used in the fracking process are vast and include cancers, birth impacts, death etc. Van Tonder reiterated in his video presentation that, due to the upwards migration of fracking fluids that remain in the shale formation, under no circumstances should the companies be allowed to include any hazardous chemicals in the fracking fluid cocktail. He added that even without the fracking fluids the fracking water would still contaminate underground water resources due to the highly saline and potentially radioactive nature of the deep strata and underground water resources. This needs to be fully understood.

Develop the research programme of the Water Research Commission to guide policy and implementation with respect to fracking

The Water Research Commission should play a valuable role in safe-guarding South Africa's water resources through targeted research programmes on water and fracking, to guide policy and decision making and inform the development of monitoring, regulation and mitigation standards, as well as disaster management scenarios.

Develop detailed understanding of the underground geology of areas and aquifers

Bosman (2012) has highlighted the urgent need for detailed geological research in the regions where fracking could go ahead, with a particular emphasis on the location of underground aquifers, and the distances between them and the shale formations. This needs to take place before any fracking processes are permitted.

Understand the life cycle of fracking wells and what it means for monitoring, mitigation and long-term rehabilitation, and the costs thereof

It is understood that concrete has a limited life span. It might be a 100 years, but ultimately shale gas casing and cementation will fail. Stevens (2012) answered the question: "would the cement and steel casings in the Karoo inevitably deteriorate and fail over time, resulting in the upward migration of fracking fluids to ground water zones?' by saying that the short answer is 'yes – sometime in the future the casing/cement in the wellbore may undergo mechanical and/or chemical failure', but that functional failure is highly unlikely in the near future. We have learned through the AMD issue that problems remain after the economic benefits of a resource have been exploited. We need to develop mechanisms to prevent this happening with respect to fracking.

9.3 Governance, policy and legislation recommendations

Adopt the precautionary principle

The overarching message is to adopt the precautionary principle. This is supported by the SA National Environmental Management Act, which states that where there may be harm to the environment, a risk-averse and cautious approach must be taken. Despite the Cabinet's lifting of the moratorium in South Africa, processes should be in place to enable the moratorium to be re-instated if research or practice indicates that the multitude of environmental and water concerns are valid.

Fracking has been banned completely in France and Bulgaria and in the US state of Vermont. In July 2012, France's Environment and Energy Minister, Delphine Batho, confirmed that France has no intention of lifting its ban on shale gas exploration because of continued concerns over its environmental impact. She said that the government clearly and distinctly maintains the ban 'because nowhere in the world has it been proven that this exploitation can be done without significant environmental damage and important health risks'. The Governor of Vermont, Peter Shumlin, said fracking contaminates groundwater and the science behind it is 'uncertain at best'.

Strong regulation and enforcement

The Royal Society and Royal Academy of Engineering in the UK brought out a joint report detailing the need for strong regulation and best practice. According to Sir John Beddington, 'the UK regulatory system is up to the job for the present very small scale exploration activities, but there would need to be strengthening of the regulators if the government decides to proceed with more shale gas extraction' (Black, 2012b). In particular they recommend the following:

- Comprehensive monitoring of methane in water and the atmosphere before, during and after operations
- Use of an independent well examiner empowered to carry out onsite inspections on demand
- Better co-ordination between the various government agencies involved

Researchers from Duke University (Jackson et al, 2011) specified six recommendations to improve public confidence in shale-gas extraction. These recommendations include the following:

- Initiate a medical review of the health effects of methane

- Construct a national database of methane, ethane, and propane concentrations and other chemical attributes in drinking water
- Evaluate the mechanisms of methane contamination in drinking water
- Systematically sample drinking water wells and deep formation waters
- Study disposal of waste waters from hydraulic fracturing and shale-gas extraction
- Refine estimates for greenhouse-gas emissions of methane associated with shale-gas extraction

Need for an independent regulatory body with a focus on environment and water resources

There is an urgent need for an independent regulatory body in South Africa. Currently, we have PASA, which has as its mission 'to promote, facilitate and regulate exploration and sustainable development of oil and gas in South Africa' on behalf of the South African government (PASA, 2012). In terms of its strategy, PASA is committed to:

- increase exploration and production activities in SA
- regulate the exploration and production environment
- acquire, archive and enhance all petroleum exploration and production data
- ensure a viable and sustainable agency

Only one of out of its 12 values references the environment, stating that it has an 'active regard for the natural environment,' which PASA states it shows by monitoring environmental compliance, participating in activities aimed at creating awareness and preserving the environment and promoting responsible exploitation of our natural resources. This is a clear conflict of interest: the regulator of exploration and exploitation is also the promoter of petroleum exploitation.

Strengthen the role of the Department of Water and Environment Affairs in monitoring and evaluation of fracking, especially with respect to the granting of water licenses

There is an urgent need to strengthen the capacity of the Departments of Water and Environmental Affairs to play a more meaningful role in regulation of gas exploration and production. As stated above, the roles of permitting, monitoring and regulation need to be separated from PASA.

The Department of Water Affairs is the custodian of South Africa's water resources and therefore needs to oversee the following:

- Where water used for fracking will be sourced
- Implications for other water users
- Water treatment

- Chemicals used
- Wastewater treatment and disposal
- Contamination of rivers and aquifers
- Disaster management
- Implications of seismic activity
- Monitoring of wells
- Compensation for communities affected by water contamination
- Billing the Gas Industry for the cost of all water-related externalities

Ensure that the oil and gas industry pay the costs of all externalities and enforce the polluter pays principle

The extraction of shale gas may be relatively cheap due to the oil and gas companies only paying for production costs and not for any of the environmental externalities. This includes paying the true cost of water, appropriate waste disposal, road maintenance and the construction of new roads, health care for those negatively affected, as well as clean-up costs for air, land and water pollution. The polluter pays principle is included in Section 2 of the National Environmental Management Act.

Agree that legal frameworks for burden of proof and compensation need to be in place before any fracking takes place

The recent experience of Carolina – where communities had to go to court in order to get the municipality to fulfil its obligation to provide their constitutionally guaranteed right to water – highlights the vulnerability of communities when things go wrong and water becomes contaminated. As predictions indicate that things will indeed go very wrong in both the short term and the long term, the burden of proof must rest with the oil and gas companies – meaning that they need to prove they did not contaminate the land or water. Also needed are negotiated compensation agreements that cover both the short-term period of thirty years when the companies are still operational, as well as the long-term potential impact due to water contamination from upward migration of fracking fluids and cement casing failure.

Develop clear legislation on fracking and the protection of groundwater and the control of wastewater disposal

South Africa does not have the appropriate legislation to deal with the scale of the potential impact of fracking on our underground water resources from both the fracking process and the impacts associated with wastewater disposal. This needs both new legislation and the capacity to implement, regulate and enforce. In particular, experience from the US highlights the need for regulators to control the surface disposal of fracking waste water much more stringently than they have done so to date, which in turn will increase the costs of disposal.

Assess the paucity of technical staff with the required capacity to monitor, evaluate, regulate, and manage etc. the hydraulic fracturing process in South Africa

It is imperative that we do not fool ourselves into believing that we have the human or technical capacity to manage the hydraulic fracturing process in South Africa.

9.4 Public Participation and transparency recommendations

Initiate public debate to analyse fracking and its implications for South Africa, which an inclusive multi-stakeholder process could help inform

Increasing opposition to fracking is coming from rural Karoo communities, environmentalists, large-scale and small-scale farmers, water specialists etc. This was evidenced by an anti-fracking rally in August 2012 in Nieu-Bethesda in the Karoo, which included scientists, small-scale farmers, motorbike riders calling themselves 'Bikers against Fracking' and local school children, who called on the government to be a good role model. All this debate points to the need for a much larger public debate to take place in South Africa, and highlights the potential role an **inclusive multi-stakeholder process** could play in informing this debate.

Both The Water Dialogues South Africa and the South African Initiative on the World Commission on Dams Process are examples of positive multi-stakeholder processes which enabled people from diverse backgrounds and opinions to develop a common conversation. Too often, people with different perspectives only engage in arguments. At the very least a scoping process should be undertaken in order to canvas the views of all the stakeholders in South Africa, especially the rural communities of the Karoo who have largely been left out of the debate.

Full public disclosure of wastewater disposal and chemicals used in the fracking process should be mandatory

We need to have full public disclosure of any and all chemicals that are used in the fracking process. Even though Shell has undertaken to disclose chemicals in South Africa, it appears that this would not be public disclosure.

10.Conclusion

It is fitting to end this paper with a reflection from UNEP. During the last week of the Rio+20 Conference held in June 2012, UNEP launched its state of the planet report, the Global Environment Outlook 5, which included a review of 90 key treaties. Only four out of 90 showed ‘significant progress’, 40 showed some progress, ‘little or no’ improvement was detected for 24 (including climate change) and further deterioration had been recorded for eight of these goals. As a species on a finite planet, we are not doing very well. Achim Steiner, the head of UNEP, recommended that we look beyond GDP to a new international indicator of progress, and suggested the implementation of the Inclusive Wealth Indicator – the IWI – which covers not only produced capital, human capital and natural capital, but also critical ecosystems.

South Africa was one of 20 countries evaluated according to the IWI, and was one of four found to have a negative score, indicating that we are on an unsustainable path. Water and environmental specialists in South Africa strongly conclude that the large-scale implementation of fracking in South Africa will just take us further and faster along this unsustainable and thirsty path to a climate change future we do not want and which we cannot afford – economically, socially or environmentally.

11.References

Ashe, B. July 2012. Telephonic interview.

Black, R. 2012a. Shale gas 'worse than coal' for climate. BBC News, 12 April. Available at http://www.bbc.co.uk/news/science-environment-13053040.

Black, R. 2012b. 'Fracking' safe with strong regulation report says. BBC News. 28 June. Available at http://www.bbc.co.uk/news/science-environment-18611647

Blignaut, J. and Van Heerden, J. 2009. The impact of water scarcity on economic development initiatives. *Water SA* (35)4: July.

Bonnett, A and Pafitis, D. 1996. Getting to the root of gas migration. *Oilfield Review* 8(1) (Spring 1996): 36–49.

Bosman, C. 2012. Can it be fracking sustainable? Proposed shale-gas extraction in the context of integrated water resources management. Presentation at the WISA Conference, Cape Town, May 2012.

Carr Smyth, J. 2012. Ohio earthquakes: Officials say tremors were 'almost certainly' caused by wastewater injection 03/ 9/12 Huffington Post. http://www.huffingtonpost.com/2012/03/09/ohio-fracking-earthquakes-cause-determined_n_1334808.html.

Chesapeake Energy. 2012. Simplified steps in hydraulic fracturing. Available at www.hydraulicfracturing.com.

Colvin, C, Le Maitre, D and Archer, E. 2010. Climate change and water resources: Altered water availability and increased societal risk. In Department of Science and Technology, *South African risk and vulnerability atlas*. Available at http://www.rvatlas.org/download/sarva_atlas.pdf.

Cooley, H and Donnelly, K. 2012. Hydraulic fracturing and water resources: Separating the frack from the fiction. Available at www.pacinst.org/reports/fracking/full_report.pdf.

Cooper, Dave. 2012. Waterless fracking is Alberta firm's answer to environment issues. http://www.edmontonjournal.com Department of Energy. 2012. http://www.energy.gov.za.

Department of Mineral Resources. 2012. Investigation of hydraulic fracturing in the Karoo Basin of South Africa: Executive summary. Available at http://www.info.gov.za/view/DownloadFileAction?id=174015.

Du Toit, J. 2012. Video interview. EcoDoc Africa.

Du Toit, J. 2012b. Confessions of a fracking defector. *Daily Maverick*. Available at http://dailymaverick.co.za/article/2012-06-15-confessions-of-a-fracking-defector.

EcoWatch. 2012. First ever fracking wastewater test in Ohio reveals stew of hazardous toxins. Available at http://ecowatch.org/2012/first-ever-fracking-test/.

Energy Institute. 2012. Separating fact from friction in shale gas development. Available at http://energy.utexas.edu.

Fig, D. 2012. Fracking issues require new laws. *Mail and Guardian*. Available at http://mg.co.za/article/2012-08-09-fracking-issues-require-new-laws.

Fleckenstein, WW, Estes, AW, Rodriguez, WJ, Berger, A, Sanchez, FJ. 2005. Cement casing: The true stress picture. AADE-05-NTCE-14. Paper presented to the American Association of Drilling Engineers Annual Conference, Dallas, Texas, April 5–7.

Galvin, M. 2009. Straight talk to strengthen delivery in the water services sector: The Water Dialogues-South Africa synthesis report. Available at http://www.waterdialogues.org/south-africa/overall.htm.

Greenpeace. 2011. The true cost of coal in South Africa. Available at http://www.greenpeace.org/africa/en/News/news/The-True-Cost-of-Coal/

Hartnady, 2012. Environmental impacts and geophysical risks of shale-gas development. Presentation at Shale Southern Africa Conference. Available at http://issuu.com/erinbosendesign/docs/hartnady_2012_shalesaconference-v120314.

Harvey, Fiona. 2011. Shale gas push 'would wreck UK's climate change targets'. *The Guardian*. Available at www.guardian.co.uk/environment/2011/nov/23/shale-gas-climate-change-targets.

Herold, CE. 2009. The water crisis in South Africa. 14th Des Midgley Memorial Lecture, SANCIAHS. Available at http://www.dbsa.org/Blog/Lets%20talk%20water%20with%20DBSA1/The%20water%20Crisis%20in%20South%20Africa.pdf.

Howarth, RW, Santoro, R and Ingraffea, A. 2011. Methane and the greenhouse-gas footprint of natural gas from shale formations. A letter. Available at http://www.sustainablefuture.cornell.edu/news/attachments/Howarth-EtAl-2011.pdf.

Inman, Mason. 2012. Natural gas a weak weapon against climate change, new study asserts. National Geographic News. Available at http://news.nationalgeographic.com/news/energy/2012/03/120314-natural-gas-global-warming-study/.

Jackson, RB, Rainey Pearson, B, Osborn, SG, Warner, NR and Vengosh, A. 2011. Research and policy recommendations for hydraulic fracturing and shale-gas extraction. Center on Global Change. Duke University. Durham. N/C. Available at www.nicholas.duke.edu/cgc/HydraulicFracturingWhitepaper2011.pdf.

McKibben, B., 2012. Why not frack? *The New York Review of Books*. Available at http://www.nybooks.com/articles/archives/2012/mar/08/why-not-frack/?pagination=false.

McQuillen, W. 2012. Fracking regulations needed to protect gas workers, AFL-CIO says. Available at http://www.bloomberg.com/news/2012-05-22/fracking-regulations-needed-to-protect-gas-workers-afl-cio-says.html.

Myers, T. 2012. Potential contaminant pathways from hydraulically fractured shale to aquifers. *Ground Water*. Available at http://onlinelibrary.wiley.com/doi/10.1111/j.1745-6584.2012.00933.x/abstract.

Nkabinde, S. 2012. Geologist warns of fracking risks. *Business Report*, 27 March. Available at http://www.iol.co.za/business/business-news/geologist-warns-of-fracking-risks-1.1264278.

Nomqhuphu, W. 2009. A latest SA water study reveals less water than estimated. Water Research Commission Press Release. Available at http://www.wrc.org.za/News/Pages/AlatestSAwaterstudyrevealslesswaterthanestimated.aspx

Petroleum Agency SA (PASA) 2012. Company Profile. http://www.petroleumagencysa.com/About_Us/company_profile.aspx

Roelf, W. 2012. S. Africa lifts moratorium on shale gas exploration. *Reuters*. Available at http://www.reuters.com/article/2012/09/07/safrica-gas-idUSL6E8K739020120907.

Rozell, D and Reaven, S. 2012. Water pollution risk associated with natural gas extraction from the Marcellus Shale: Risk analysis. Available at http://onlinelibrary.wiley.com/doi/10.1111/j.1539-6924.2011.01757.x/full

SAPA. 2012. Shale gas is from God, says minister. *Fin24.* Available at http://www.fin24.com/Economy/Shale-gas-is-from-God-says-minister-20120518.

Schneider, K. 2012. US fossil fuel boom dims glow of clean energy. Environment 360. Available at http://e360.yale.edu/feature/us_fossil_fuel_boom_dims_glow_of_clean_energy/2511/.

Sneed, M, Galloway, DL and Cunningham, WL 2012. Earthquakes: Rattling the earth's plumbing system. U.S. Geological Survey Fact Sheet 096-03. Available at http://pubs.usgs.gov/fs/fs-096-03/.

Stevens, B. 2012. Shale gas casing and cementation will fail, but when? Available at http://oilprice.com/Energy/Energy-General/Shale-Gas-Casing-and-Cementation-Will-Fail-but-When.html.

The Ecologist TV. 2010. True cost of America's gas rush. Available at http://www.youtube.com/watch?v=nCyHS7fKmXI.

Tyndall Centre for Climate Change Research. 2011. Shale gas: a provisional assessment of climate change and environmental impacts. University of Manchester. Available at http://www.tyndall.ac.uk/sites/default/files/tyndall-coop_shale_gas_report_final.pdf.

Umvoto Africa. 2012. Scientist warns of environmental, geophysical risks of shale gas development. Available at www.moneyweb.co.za/mw/content/en/moneyweb-health-and-science?oid=565565&sn=2009+Detail.

Van Tonder, G. 2012. Video interview. EcoDoc Africa and Ejolt-CCS.

Vergano, D. 2012. Natural gas gold rush: Is your state next? *USA Today*. Available at http://www.usatoday.com/news/nation/story/2012-05-29/fracking-environment-gas/55845708/1.

Wilson, J. 2012. Electronic correspondence.

World Bank Inspection Panel. 2012. Overview Inspection Panel investigation report South Africa – Eskom Investment Support Project (EISP). Available at http://siteresources.worldbank.org/EXTINSPECTIONPANEL/News%20And%20Events/23204926/EISP_Overview_IP.pdf.

World Economic Forum. 2011. Global risks report 2011. Sixth edition. An initiative of the isk Response Network. Available at http://reports.weforum.org/global-risks-2011/.