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The impact of a developing community on the water quality of an urban river

The influence of a developing community on the water quality of an urban river is illustrated in this article. Testing revealed high chemical, physical and microbiological variables, indicating relatively serious pollution. A pollution cycle exists which can only be destroyed by addressing the socio-economic issues influencing water quality.

Die invloed van 'n ontwikkelende gemeenskap op die waterkwaliteit van 'n stedelike rivier

Die invloed van 'n ontwikkelende gemeenskap op die waterkwaliteit van 'n stedelike rivier word in die artikel aangetoon. Toetse het op 'n groot aantal chemiese, fisiese en mikrobiologiese veranderlikes gedui wat 'n betreklik ernstige besoedelingstoestand aandui. 'n Besoedelingsiklus bestaan wat slegs vernietig kan word deur die sosio-ekonomiese probleme, wat 'n impak op waterkwaliteit het, aan te spreek.

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There is considerable literature on developing communities living and working in poor conditions (cf Hardoy & Satterthwaite 1992; Binns 1996; Morris *et al* 1996; Krige 1997; Schmidt 1998; Agrawal 2001). These communities have to focus their energies on survival and therefore find it difficult to share the developed world's concern for and awareness of the environment. Many socio-economic issues are significantly influenced by the political culture of a community. Its rural or urban orientation may dictate its political affiliation and influence its environmental awareness. Historical events, too may influence a community's behaviour and its response to proposed interventions. Payment for services and expectations of appropriate service levels are typical examples (DWAF 1999). These factors can give rise to problems relating to the water quality of rivers in such communities.

1. Objectives

When the research project from which this paper emerges was undertaken in July 1997, its initial objectives were:

- to investigate the hydrological processes and development of urban rivers and water courses in and around Bloemfontein;
- to determine the impact of urban development on these water courses;
- to establish the water quality of urban rivers and water courses;
- to determine methods/practices to control the microbiological quality of urban runoff;
- to design and implement the control methods/practices identified, and
- to monitor the results.

Only the second and third objectives will be discussed in this paper.

A preliminary survey of the hydrological processes and development of urban rivers and water courses in and around Bloemfontein was carried out during this stage of the project. The river investigated was the Modder River and the water courses were the Fontein Spruit, Bloem Spruit and Renoster Spruit. The Fontein Spruit is a perennial tributary of the Bloem Spruit, which is a perennial tributary of the Renoster Spruit which in turn is a tributary of the Modder River. All previous hydrological and water quality data concerning the river and the water courses were collected and synthesised in order to obtain an understanding of the historical and present water quality. This information was also used to identify any sources of change in the water quality over time and in different parts of the river. As no data on the microbiological status of the water courses were available, a monitoring programme was implemented. The water quality of the three water courses was monitored once a week for a period of four months (August 1997-November 1997), as well as during and after rainstorms in order to establish a wet weather baseline of their microbiological quality. The water courses and sampling sites are indicated in Figure 1.

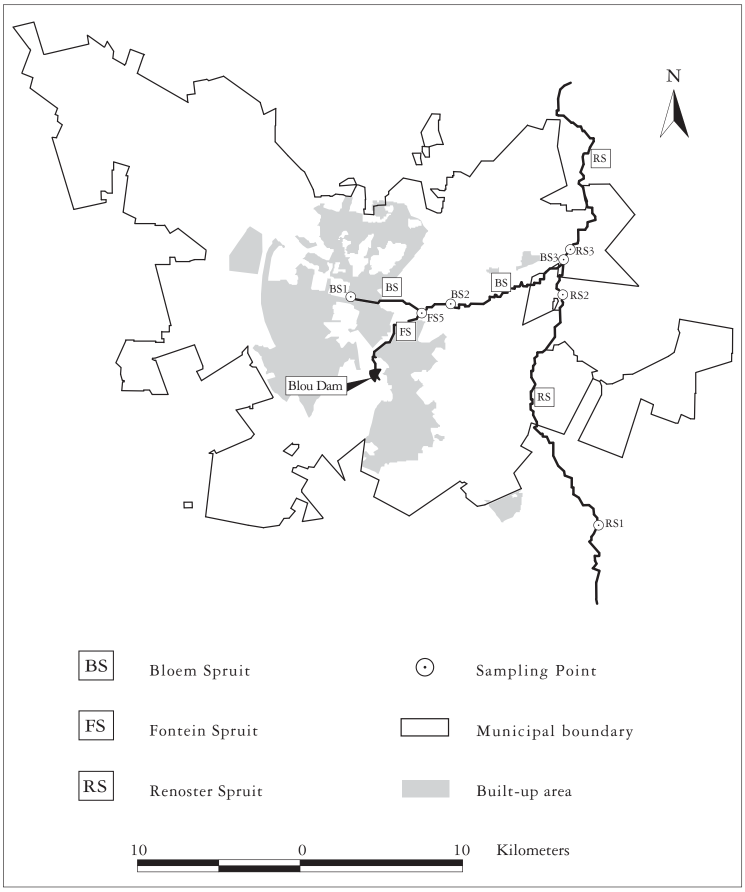
The sampled data were analysed during December 1997, and it was established that the level of pollution of all three water courses was high and the microbiological quality of the water poor. From the data it was clear that the Fontein Spruit could be a possible source of pollution for the other two water courses as the highest values for all three microbiological indicator organisms were recorded there.

In order to determine the source of pollution to the receiving waters of the Fontein Spruit, a pollution assessment of its drainage basin was planned for the first part of 1998. This assessment clearly indicated that the developing community living in the drainage basin had a large impact on the quality of the receiving waters of the Fontein Spruit, reflecting social, economic and physical factors. The study area was thus reduced to the Fontein Spruit catchment. The delineation of this catchment is illustrated in Figure 2.

2. Study area

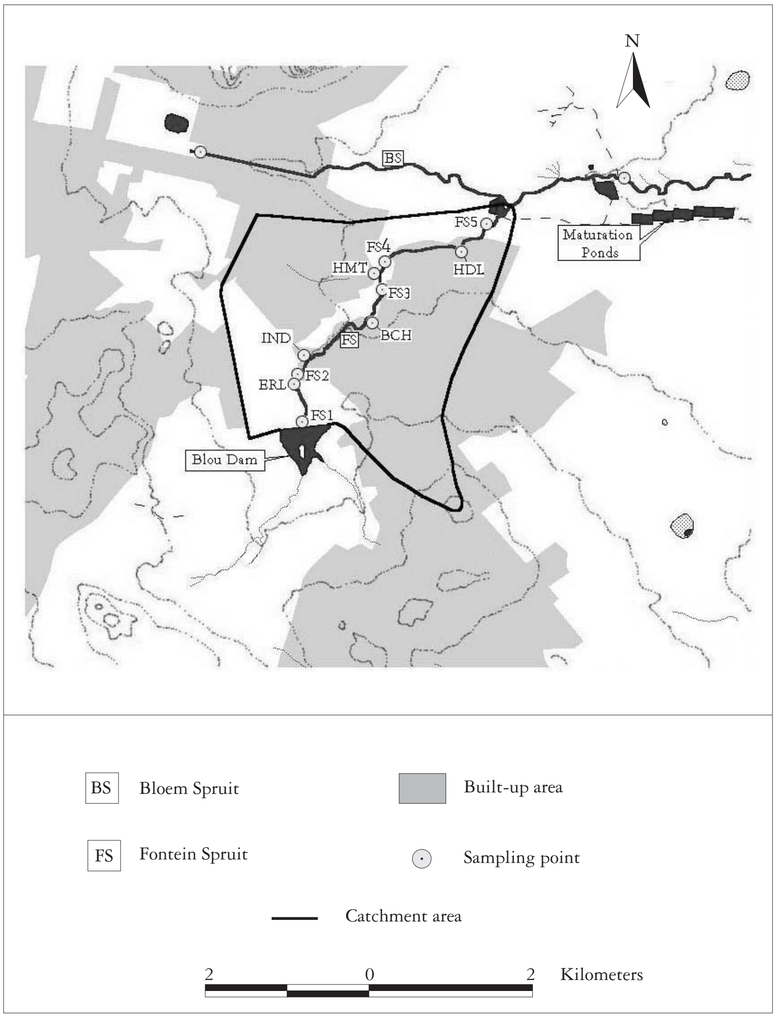
The study area, Mangaung and Heidedal, is located within the municipal boundaries of Bloemfontein about 6km from the CBD. It covers an area of about 35km^2. It is situated on flat land with no topographical disturbances and it is drained by the Fontein Spruit, a small stream which flows intermittently during the summer. The mean annual rainfall is approximately 550mm. The area is a typical example of a mainly black community with a rapid, largely uncon-

Figure 1: Water courses and sampling sites in the Bloemfontein region



trolled growth of low-cost, high-density housing developments. It includes developed, developing and informal sections. The developed sector was planned and is maintained and serviced by the local authority. This sector constitutes the higher socio-economic group of the study area. There is less planning and control in the developing sector and very little in the informal sector, where there are virtually no

Figure 2: The Fontein Spruit catchment area



services or control. These sectors are at middle and low socio-economic levels, respectively (Pretorius 2002: 1-10).

With the abolition of influx control in 1986, Bloemfontein — and especially Mangaung — became a focal point of population growth (Krige 1991). During the period 1986-1994 a variety of informal processes eroded boundaries, the most important of these being the process of land invasion (Krige 1998). This process largely accounts for the fact that, by the end of 1998, the number of stands in Mangaung had increased from 20 270 in 1990 to more than 46 000 (Krige 1998). Approximately 6000 of these stands fall into the developed category and are fully serviced with water, water-borne sewerage and electricity. Waste is removed once a week. The road system in these sectors consists mainly of gravel and dirt roads, except for the main connector roads, which are paved. The additional stands form part of the developing and informal areas. The housing in the informal sections consists mainly of squatter shacks with a skeleton road system, a limited number of communal water supply points and a form of sanitation. However, most of the sanitation systems are in a poor condition, as they are not maintained. Limited formal removal of solid waste takes place (Pretorius 2002: 4-11). Table 1 gives an indication of the level of municipal services in the various residential areas.

Table 1: Level of key municipal services in the various residential areas

Residential area	Service supply	Water	Sanitation	Electricity	Solid waste
Heidedal		YC	WB	FG	MR
Mangaung: formal areas					
Batho		YC	WB	FG	MR
Bochabela		YC	WB	FG	MR
Phameng		YC	WB	FG	MR
Mangaung: informal areas	Zone				
Thambo 1 & 2	1	RDP	BPL	LC	NO
Lusaka	2	RDP	BPL	LC	NO
Maphikela	3	RDP	BPL	LC	NO
Papi Makotoko	4	RDP	BPL	LC	NO
Sekhupi 1, 2 & 3	5	RDP	BPL	LC	NO
Thabo Mbeki 1 & 2	6	RDP	BPL	LC	NO
Peter Mokhaba	7	RDP	BPL	LC	NO

Residential area	Service supply	Water	Sanitation	Electricity	Solid waste
Shuping	8	RDP	BPL	LC	NO
Solomon Mahlanqu	9	RDP	BPL	LC	NO
Isithwalanwe	10	RDP	BPL	LC	NO
Codesa 2 & 3	11	RDP	BPL	LC	NO
Codesa 1	12	RDP	BPL	LC	NO
Joe Slovo	13	YC	WB	FG	NO
Kagisho	14	RDP	BPL	LC	NO
Kathrada 1 & 2	15	RDP	BPL	LC	NO
Erlich Park		HC	WB	FG	MR

Key	HC	House connection	WB	Waterborne
	YC	Yard connection	BPL	Bucket/pit latrine
	RDP	Standpipe @ 150m		
	FG	Full grid	MR	Removal by municipality
	LC	Low current	NO	No removal

Status November 2000; compiled from official figures from the local municipality

3. Methodology

As far as physical and chemical variables are concerned, it was decided to measure those that could provide an indication of the condition of the aquatic environment (conductivity, total dissolved solids, dissolved oxygen, chemical oxygen demand, nitrate, phosphate and orthophosphate) as well as those that could be linked to the survival of micro-organisms (pH, turbidity and temperature). In this study microbiological analysis was limited to faecal coliforms, *Clostridium perfringens* and somatic coliphages. Ten sampling points were identified and monitored twice a month from April 1998 to December 1998. Routine sampling commenced at 08:00 and was carried out on every second Wednesday for the whole sampling period. All the samples discussed in this section refer to surface water grab samples taken at depths of less than 250mm. Replicate water samples were collected in sterile Whirl packs®.

The purpose of the socio-economic survey was to identify the characteristics of the community with regard to environmental awareness and political culture; use and functioning of services; payment for services, and demand for services, in order to determine the impact of these characteristics on the water quality of the Fontein Spruit.

The survey was conducted in the residential sectors of the study area, comprising Erlich Park, Heidedal, three formal suburbs (Batho, Bochabela and Phahameng) and fifteen informal sectors of Mangaung. Since the households in the community do not vary a great deal in terms of income, the study was designed to reflect a measure of municipal service differentiation rather than economic differentiation. To this effect, three distinct survey sectors were identified, as follows:

- The developed sector

In this sector, all infrastructure is in place and the local authority services the area. The number of stands in the study area is 347 and 75 households were included in the survey. The houses are brick, with corrugated iron roof and cement floor. Even though the economic differentiation from the other areas is not great, this sector represents the highest socio-economic group of the study area.

- The developing sector

This sector includes the three formal suburbs of Mangaung as well as a sub-section of Heidedal. The total number of stands in this sector is 6 249. The sector was divided into 11 blocks of approximately equal numbers of households. Fifty houses were randomly selected from each block and a total of 575 households were interviewed during the survey. The houses in this sector are typical municipal houses consisting of two to four rooms. The walls are concrete blocks or mud brick. Most have corrugated iron roofs and concrete floors. The majority of the plots also have backyard houses erected for the purpose of renting out to tenants. Many of these are in a relatively run-down condition.

- The informal sector

This sector is inhabited mainly by people who obtained their stands through land occupation. Information with regard to the number of stands in the informal sector was not available when the field programme was compiled, so 50 households were randomly selected from the 15 informal sections and regarded as a representative sample. There are currently just over 2000 stands in this sector. The type of housing is mainly 'squatter shacks', which are usually cheap and impermanent.

The survey was carried out during July 1999 by ten fieldworkers recruited from residents of the community. They attended a training course a week prior to the survey. The fieldworkers interviewed the member of the household responsible for payment for municipal services. Misinterpretation of the technical terms used on the data capturing form was the main problem experienced during the survey. The fieldworkers were able to explain such terms during the interview, which proved that the training they had received was vital, as incorrect information on the forms could easily have negated the value of the study (Pretorius & De Villiers 2002).

4. Results

4.1 Microbiological quality

It is clear from Table 2 that the figures for all three microbiological indicator organisms are high, thus indicating microbiological pollution.

Table 2: n-Values, geometric means, medians, 95% confidence intervals, and minimum & maximum values for microbiological indicator organisms in storm water draining from residential and industrial sectors (April 1998-November 1998)

Water quality variable		Sampling sites				
		ERL	IND	BCH	HMT	HDL
Faecal coliforms (counts/ 100ml)	n-Values	15	16	9	14	16
	Geometric mean	3.48E+02	7.31E+02	5.34E+04	1.40E+04	1.25E+03
		Log-transformed data				
	Median	2.83E+00	2.67E+00	4.48E+00	4.19E+00	3.34E+00
	95% CI	5.31E-01	5.89E-01	7.96E-01	2.87E-01	3.64E-01
	Min	6.02E-01	1.64E+00	3.43E+00	3.25E+00	1.64E+00
	Max	3.75E+00	5.12E+00	7.51E+00	4.89E+00	4.07E+00
Clostridium perfringens (counts/ 100ml)	n-Values	9	16	8	13	16
	Geometric mean	3.51E+01	5.91E+01	3.73E+02	1.82E+02	5.53E+01
		Log-transformed data				
	Median	1.65E+00	1.83E+00	2.57E+00	2.19E+00	1.78E+00
	95% CI	4.00E-01	2.43E-01	5.13E-01	2.67E-01	2.20E-01

Water quality variable		Sampling sites				
		ERL	IND	BCH	HMT	HDL
	Min	5.38E-01	5.38E-01	1.79E+00	1.54E+00	5.38E-01
	Max	2.50E+00	2.41E+00	3.55E+00	3.45E+00	2.36E+00
Somatic coliphages (counts/ 100ml)	n-Values	1	4	3	8	7
	Geometric mean	4.00E+02	1.68E+02	1.04E+03	1.41E+03	6.56E+02
	Log-transformed data					
	Median	2.60E+00	2.15E+00	2.85E+00	3.13E+00	3.34E+00
	95% CI	2.82E-01	9.22E-01	2.94E-01	9.02E-01	
	Min	2.60E+00	2.00E+00	2.30E+00	2.48E+00	3.01E-01
	Max	2.60E+00	2.60E+00	3.90E+00	3.63E+00	3.96E+00

The high values recorded, particularly at sampling point BCH are cause for concern. When water quality samples were taken at this sampling point during the monitoring phase, blocked and broken sewerage pipes were frequently observed and raw sewage was observed to reach the Fontein Spruit via surface water runoff (Photo 1).

4.2 Chemical quality

4.2.1 pH

pH is an important variable in water quality assessment, as it influences many biological and chemical processes within a body of water and all processes associated with water supply and treatment. The water of the Fontein Spruit is eutrophic due to the excessive photosynthetic activity of algae, which explains its relatively high pH value of 7.9 (Table 3). Photosynthesis lowers the dissolved CO_2 concentration, as well as the carbonic acid, and thus increases the pH (Horne & Goldman 1994).

Photo 1: Pollution at sampling point BCH

Table 3: Medians, standard deviations, and maximum & minimum values of physical and chemical parameters in drainage from residential sections (April 1998-November 1998)

Water quality variable	Sampling sites					
		ERL	IND	BCH	HMT	HDL
PH	Min	7.1	7.5	7.6	6.8	7.5
	Max	8.7	8.6	8.8	8.6	10.6
	Sdev	0.5	0.3	0.4	0.5	0.8
	Median	7.9	7.8	7.9	7.9	8.1
	n-values	16	17	9	14	16
DO (mg/l)	Min	3.8	1.6	0.1	0.8	3.2
	Max	12.6	12.6	12.8	13.5	11.2
	Sdev	3.3	3.9	4.7	4.1	2.4
	Median	7.7	8.7	8.9	7.9	8.9
	n-values	11	11	7	8	11
COD (mg/l)	Min	7.0	4.0	8.0	10.0	20.0
	Max	20.0	47.0	803.0	75.0	203.0
	Sdev	3.8	11.9	257.5	18.6	44.1
	Median	11.5	10.0	44.0	21.5	53.0
	n-values	15	17	9	14	16
NH_4 (mg/l)	Min	0.110	0.073	0.488	0.232	0.134
	Max	0.317	2.904	72.346	3.087	1.330
	Sdev	0.062	0.671	23.087	0.803	0.425
	Median	0.134	0.146	3.318	0.427	0.409
	n-values	15	17	9	14	16
NH_4-N (mg/l)	Min	0.090	0.060	0.400	0.190	0.110
	Max	0.260	2.380	59.300	2.530	1.090
	Sdev	0.051	0.550	18.927	0.657	0.330
	Median	0.110	0.120	2.720	0.350	0.300
	n-values	15	17	9	14	16
NO_3 (mg/l)	Min	0.133	20.457	0.266	0.780	0.602
	Max	2.037	35.500	2.958	0.553	25.700
	Sdev	0.649	3.243	0.918	1.757	8.074
	Median	0.651	29.707	1.993	2.590	8.183
	n-values	15	17	9	14	16
NO_3-N (mg/l)	Min	0.030	4.620	0.006	0.180	0.014
	Max	0.460	8.000	0.668	1.480	5.800
	Sdev	0.146	0.730	0.219	0.397	1.807
	Median	0.147	6.709	0.450	0.585	2.020
	n-values	15	17	9	14	16
PO_4 (mg/l)	Min	0.230	0.100	0.437	0.113	0.309
	Max	2.790	1.545	81.300	1.800	4.250
	Sdev	0.714	0.385	26.345	0.419	1.040
	Median	0.759	0.520	1.933	0.670	1.290
	n-Values	15	17	9	14	16
PO_4-P (mg/l)	Min	0.075	0.058	0.143	0.037	0.101
	Max	0.910	0.504	10.212	0.587	1.387
	Sdev	0.233	0.121	3.187	0.137	0.340
	Median	0.248	0.170	0.631	0.220	0.421
	n-Values	15	17	9	14	16

4.2.2 Dissolved oxygen

Concentrations below 5 mg/l may adversely affect the functioning and survival of biological communities, while those below 2 mg/l may be fatal to most fish. In this study the oxygen concentrations were mostly high, almost supersaturated.

The overall high concentrations (>100%) are indications of algal photosynthesis, as several algal blooms were observed during the monitoring period. The production of oxygen thus exceeded the diffusion rate of oxygen out of the system by photosynthesis. The low concentrations recorded (<3.0 mg/l) in the system can be due either to low oxygen production by the algae if washed out by rainfall, or to high oxygen demand as a result of high organic content in the drainage from residential sections BCH and HMT.

4.2.3 Chemical oxygen demand

In this study the median COD values (Table 3) were reasonably low (<30 mg/l) at three sites, indicating relatively low organic loading. The high concentrations at BCH and HDL, however, indicate pollution by waste water.

4.2.4 Nitrate (NO_3-N)

From Table 3 it is clear that the nitrate concentration measured in the study area was high. Nitrate is normally the most common form of combined inorganic nitrogen in water courses and streams. Inorganic nitrogen is primarily of concern due to its stimulatory effect on aquatic plants and algae. Natural concentrations, which seldom exceed 0.1 mg/l NO_3-N, may be enhanced by municipal and industrial waste water (Chapman 1992). This is further confirmation of waste water pollution via the sampling points, which represent the drainage from the various residential sections.

4.2.5 Ammonium (NH_4)

Ammonia occurs naturally in bodies of water, arising from the breakdown of nitrogenous organic and inorganic matter in soil and water, excretion by biota, and reduction of nitrogen gas (NH_3) by microorganisms (Roos & Pieterse 1994). Unpolluted water contains small quantities of ammonia, usually well below 0.1 mg/l, as nitrogen

(Chapman 1992), while high ammonia indicates an organic load on the system because NH_3 is generated by heterotrophic bacteria as a primary end-product of the decomposition of organic matter. The NH_4-N concentration in the Fontein Spruit (Table 3) was very high, much higher than in unpolluted rivers, which average 0.015 mg/l (Roos & Pieterse 1994). These high NH_4-N concentrations in the Fontein Spruit can be attributed to the drainage from the residential areas of Bochabela (BCH), Batho (HMT) and Heidedal (HDL).

4.2.6 Phosphate (PO_4)

From Table 3 it is clear that the PO_4-P concentration in the Fontein Spruit was very high. Such high concentrations compare with a hypereutropic system and can be due to PO_4-P discharge by human and animal activity in the study area. Human and animal waste contains substantial amounts of PO_4-P.

4.3 Physical quality

4.3.1 Total dissolved solids

In this study the median concentration of TDS ranged from 238 to 633 mg/l. This is four times the average for rivers in Africa (Wetzel 1983). Water with a TDS of >500 mg/l is brackish and can have a negative impact on an aquatic ecosystem.

5. Observations and interpretation of survey results

The local authority provides basic services to the community in the study area. These are regarded as inadequate and underdeveloped. Respondents attribute this to apartheid policies and the community's own culture of non-payment. The greatest concern or problem in the study area is broken or blocked sewer pipes. However, not all residents see sewage as the cause/source of disease in the community. This means that it is of paramount importance to provide education and training with regard to sewerage systems, the effect of blockages and the health risks involved in overflowing sewers. The "fork blocking the drains" situation needs to be resolved by educating community members to remove cutlery from plates before washing them and not to use toilets to flush leftovers. Other major causes of pipe blockages are the alternatives used in place of toilet paper. These include page from telephone directories, newspaper, cardboard, woollen material and sometimes even plastic bags. The use of these alternatives results primarily from poverty. The simple solution would be for the municipality to supply toilet paper, in much the same way as the refuse removal services provides refuse bags. The part of the study area that has a refuse service appreciates it. However, the number of informal dumps is unacceptable. The perception is that dumps are created because skips are "too far away" and "move around a lot", so people do not use them. They also get full quickly and are too high for children. Children taking rubbish to the skip would thus rather dump it as they are eager to go and play. Rubbish lying around, whether dumped garbage or litter, is the main reason for blocked stormwater drains.

The overall attitude of the community with regard to health and hygiene, as well as water, is positive. Its most urgent demand is for improved facilities in terms of water and solid waste. This is matched by the need for education. People are generally willing to pay for the services they use. The exception is among the people of extreme poverty. People feel that poverty is responsible for all their woes and experience the real cause of poverty as lack of education and of industrial or administrative skill.

The survey indicated that a polluted water environment might cause poor community health, and thus contribute to poverty. It further indicated that poverty could lead to low payment for services, so that services would remain inadequate or poorly maintained. This could result in inappropriate use of services and in polluted water resources. A pollution cycle is formed, which exacerbates the problem over time. The results of the survey suggest that the key to a sustainable management programme for protecting water resources lies in breaking the pollution cycle by addressing the socio-economic issues that influence water quality. From this it follows that a community's attitudes and values are essential aspects of pollution prevention. This remains a problem in the study area.

A major obstacle to addressing these socio-economic causes for pollution of the water resources in and around developing communities is the belief that the government is responsible for dealing with such issues. However, from informal discussions conducted during the survey it was evident that the community feels a growing need to participate in, and contribute to decision-making processes with regard to their water resources. Given the rapid urbanisation of South African communities, and the fact that limited local government funding has to cover a wide range of services, most local authorities are struggling to manage their water resources (DWAF 1998). It is therefore crucial that the community be involved in both planning and management, take responsibility, and become accountable for the development, management and protection of its water resources. This concurs with Hill *et al* (2001) that community empowerment by information sharing and education is as important as solving the problem at hand, and that in order to succeed an inter-sectoral approach for engaging people in the process of developing their own community must be adopted. Ultimately, water resources development and management processess need to become more people-orientated, rather than dominated by technical considerations as in the past (DWAF 1996).

6. Conclusion

The study was concluded with the formulation of a Water Quality Management Plan (WQMP). This is an integrated plan attempting to address the management of water quality in developing communities. The key objective of the WQMP is the integration of the environmental, physical, social and economical issues relevant to the effective management of water quality, in consultation with internal and external stakeholders, in order to achieve sustainability in the aquatic environment. In other words, the WQMP integrates the results of environmental and socio-economic assessments into management interventions and strategies, and prioritises actions that:

- assist in the long-term management and rehabilitation of the water courses and lead to cost-effective and practical solutions;
- ensure the provision of adequate source control and regional management measures in a balanced way in order to manage the quality and quantity of water in the catchment;

- provide opportunities for the active participation of the community and relevant stakeholders in order to protect water course values;
- promote environmentally sustainable development in the catchment by means of water-sensitive urban design practices, and
- minimise the impact of future development by identifying the infrastructural requirements of infill areas earmarked for development.

The Water Quality Management Plan will be published in a follow-up paper.

Bibliography

AGRAWAL G D

2001. Bridging the gap in diffuse pollution — abatement between developed and developing countries. Marino & Simonovic (eds) *Proceedings of the 5th International Conference on Diffuse Pollution and Watershed Management*. Milwaukee, Wisconsin. Wallingford, Oxfordshire: IAHS: 291-8.

BINNS T

1996. This changing world: people, environment and development in West Africa. *Geography* 81(4): 361-407.

CHAPMAN D

1992. *Water quality assessments*. London: Chapman & Hall.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF)

1996. The philosophy and practice of integrated catchment management: implications for water resource management in South Africa. Report No TT81/96. Pretoria: Water Research Commission.

1997. A Draft White Paper on Integrated Pollution and Waste Management for South Africa. Pretoria: Dept of Water Affairs and Forestry.

1998. Managing the water quality effects of settlements: the national strategy. Policy document U 1.1. Pretoria: Dept of Water Affairs and Forestry.

HARDOY J E & D SATTERTHWAITE

1992. *Environmental problems of third world cities: a global issue ignored*. London: Earthscan.

HILL T R, N MOTTEUX, E L NEL & G PAPALOIZOU

2001. Integrating rural community and expert knowledge through applied participatory rural appraisal in the Kat River Valley, South Africa. *The South African Geographical Journal* 83(1): 1-7.

HORNE A J & C R GOLDMAN

1992. *Limnology*. 2nd ed. New York: McGraw-Hill.

KRIGE D S

1991. *Homes apart: South Africa's segregated cities*. London: David Phillip Publishers.

1997. Post-apartheid development challenges in small towns of the Free State. *The South African Geographical Journal* 79(3): 175-8.

1998. The challenge of dismantling spatial patterns constructed by apartheid in the Bloemfontein-Botshabelo-Thaba Nchu region. *Acta Academica Supplementum* 1998(1): 174-218.

MORRIS M, Z PATEL & M BYERLEY

1996. Violence and sustainable development in the Durban metropolitan area. *Urban Forum* 7(2): 183-202.

PRETORIUS E
2002. The impact of socio-economic and human behavioural factors on the water of the Fontein Spruit catchment — a water management model study in a developing community. Unpubl PhD thesis. Bloemfontein: University of the Free State.

PRETORIUS E & G DU T DE VILLIERS
2002. The impact of informal living conditions on water quality in the Bloemfontein municipality. *The South African Geographical Journal* 84(2): 199-207.

ROOS J C & A J H PIETERSE
1994. Light, temperature and flow regimes of the Vaal River at Balkfontein, South Africa. *Hydrobiologia* 277:1-15.

SCHMIDT B
1998. Impact of culture on development: making sustainable development 'human'. *South African Journal of Ethnology* 21(1): 41-53.

WENTZEL R G
1983. *Limnology*. Philadelphia, New York: Saunders College Publishers.