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Full Length Research Paper

Towards a more sustainable surface raw water tariff structure in the Vaal basin: A situational analysis

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With an increasingly urbanised population, further study was necessary to determine if water could be used more efficiently by applying efficient tariff structures in combination with decision support tools in the form of models. This paper highlighted challenges towards establishing a sustainable surface raw water tariff structure. Limitations of using the pollute-pays principle for setting a surface raw water tariff structure within a highly urbanised environment were noted. A tariff structure in the Upper and Middle Vaal Water management Areas which are part of the Vaal basin in South Africa was shown to promote inequity such that a downstream user paid more for using more polluted water. Recommendations specific to the Vaal basin included adopting a user-pays principle and also use of a model that incorporated variability in surface raw water quality for tariff setting and also for purposes of predicting potable water treatment costs.

Key words: Polluter-pays principle, sustainable tariff structure, urbanised population, user-pays principle, Vaal basin.

INTRODUCTION

Countries are now broadly aware of the need to take into account environmental issues in their decision making processes for proper management of the nation's water resources and also for the purposes of establishing efficient, sustainable and economic water pricing methods.

Many have evolved complex and sophisticated procedures to accomplish this. At the same time, it is clear that across different environmental dimensions, degradation is still accelerating, with uncertain but potentially very serious implications (Ekins et al., 2003). Moreover, notwithstanding the opportunities that undoubtedly exist for activities, developments and policy initiatives that could yield economic and social, as well as environmental benefits, trade-offs are still considered the dominant experience. Economic benefits are being achieved at the expense of environmental degradation.

Such a situation suggests that more weight still needs to be given to environmental considerations across the whole spectrum of policy making, in both industrialised and less industrialised countries. But this then begs the question of, what criteria should be used, and how should environmental issues be framed with respect to other economic and social objectives, in order to increase the probability of environmentally favourable decisions being taken? Conceptualising the environment and its resources as natural capital is one such approach to

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Abbreviations: BWDC, Bulk Water Distribution Cost; **DWA,** Department of Water Affairs; **DWAF,** Department of Water and Environmental Affairs; **RWAT,** Raw Water Abstraction Tariff; **TCTAC,** Trans-Caledon-Tunnel Authority charge; **WB;** Water Board; **WBs**, Water Boards; **WRCL,** Water Research Commission Levy.

addressing this question (Ekins et al., 2003).

Shortcomings of the polluter-pays principle

Historically, rivers have been used as sinks of wastewater generated as a result of growing industrialisation and from an ever increasing volume of sewage as this responded to population growth. The polluter-pays principle argues that polluters will be less inclined to over-use the assimilative capacity of water courses in an unsustain-able way. The underlying aim then, is to rationalise water use among stakeholders in order to drive towards sustainable and efficient resource use. Unfortunately, the major challenge encountered is how to designate the real originator of pollution costs (Correljé et al., 2007), hence the lack of clarification of the economic concept of value, viewed as often at odds with how industries perceive the significance of their own use.

The user-pays principle

From the aforementioned challenges, it is then recommended to consider the user-pays principle as an important indicator component of societal costs of water pollution, calculating the cost of water treatment due to diminished water quality. In addition, while efficient management of water supplies must balance the costs of cleaning, using, or avoiding use of polluted water, the marginal cost of improving the raw water quality generally should still not exceed the marginal benefit of such an improvement, for practical purposes.

Further, this could, for example, be acknowledged for most economic activities that affect the environment, either through the use of natural resources as input or by using the `clean' environment as a sink for pollution. The costs of using the environment in this way are called externalities, because they are side effects of the economic activity. They are external to markets, thus their costs are not part of the prices paid by producers or consumers. Pretty et al. (2001) cautions that if such externalities are not included in prices, they distort the market by encouraging activities that are costly to the society even if the private benefits are substantial.

Such is the case when polluted water is treated to potable water quality standards. The tradition is to internalise the cost of treatment due to the pollution by setting the tariff structures to offset the cost of production. This costing model is structured without any regard to other factors like the cost of depleting the water resource itself by altering its natural ecological functionality, a cost which should ideally be borne by the user of the natural resource. This skewed scenario is as a result of the basic thinking that money is paid only for human services, with nature never getting paid. The “willingness-to-pay” based approach which has been practiced by the neoclassical-oriented environmental economists to shadow-price the value of natural environment, has also been criticized by ecologists as a subjective approach which lacks the biophysical value basis (Huang and Odum, 1991).

A situational analysis

In South Africa, a pricing strategy for raw water charges allows the Department of Water Affairs (DWA) which is the custodian of national water resources, to sell raw water to bulk potable water treatment plants (water boards) generally at a fixed price, determined annually. The cost of this water does not generally take into account, the quality of water that the water boards (WBs) receive. WBs are then expected to treat this water to specified potable water standard for distribution to local authorities which then supply to consumers.

Consumers are charged based on the volume they consume, presumably a charge that would recover the cost of treatment and other associated overheads, which are agreed upon in advance. The charge, in essence, also incorporates an internalised cost of potable water treatment due to diminished water quality, and this represents an important component of societal costs of water pollution (Dearmont et al., 1998). Setting the tariff structures to offset the cost of production is a traditional practice, especially when polluted water is treated to potable water quality standard.

The result of this could be one of two things, namely that upstream and downstream consumers within the same basin pay different rates or that the WBs might be operating at a loss. Based on recent and ongoing re-search in the Upper and Middle Vaal Water Management Areas (U&MVWMAs) of the Vaal basin, this paper discusses the implications of this on the final cost of treatment, especially as water along the Vaal River is highly saline and generally of poor quality.

Water quality versus surface raw water tariff

Figure 1 shows South Africa’s WMAs as defined in DWAF (2004). The interest WMAs are the Upper and Middle Vaal within the Vaal basin. VR and its tributaries are exerted to various stresses as the main channel stretches from eastern part of the country towards the west. This paper focuses on the VR section between Vaal and Bloemhof dams. Major tributaries in the Upper Vaal WMA drain the greater East Rand to provide poor quality raw water downstream of the Vaal dam and into the Middle Vaal WMA. DWAF (2007) used salinity (Figure 2) to map the quality trending in the interest study area. Figure 2 shows that tributaries in the Upper Vaal WMA caused VR water quality to deteriorate downstream of the Vaal dam.

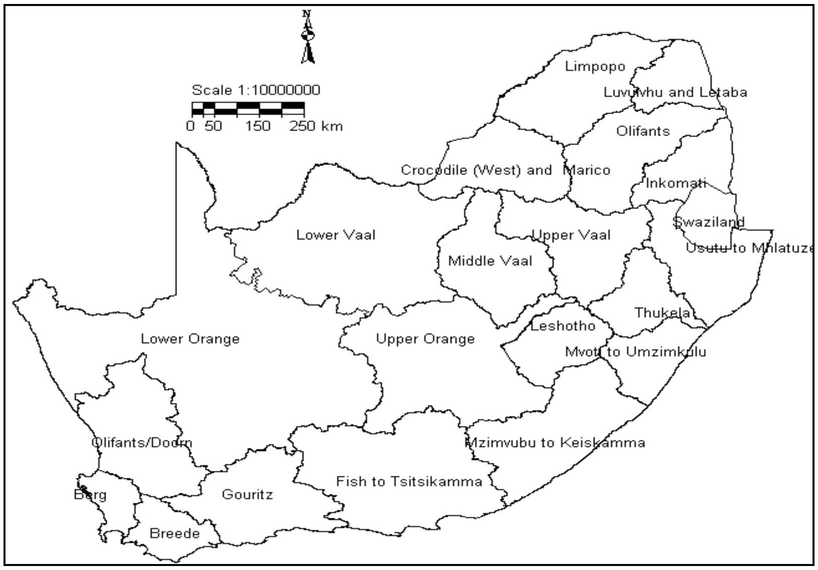

Figure 1. South Africa's Water Management Areas.

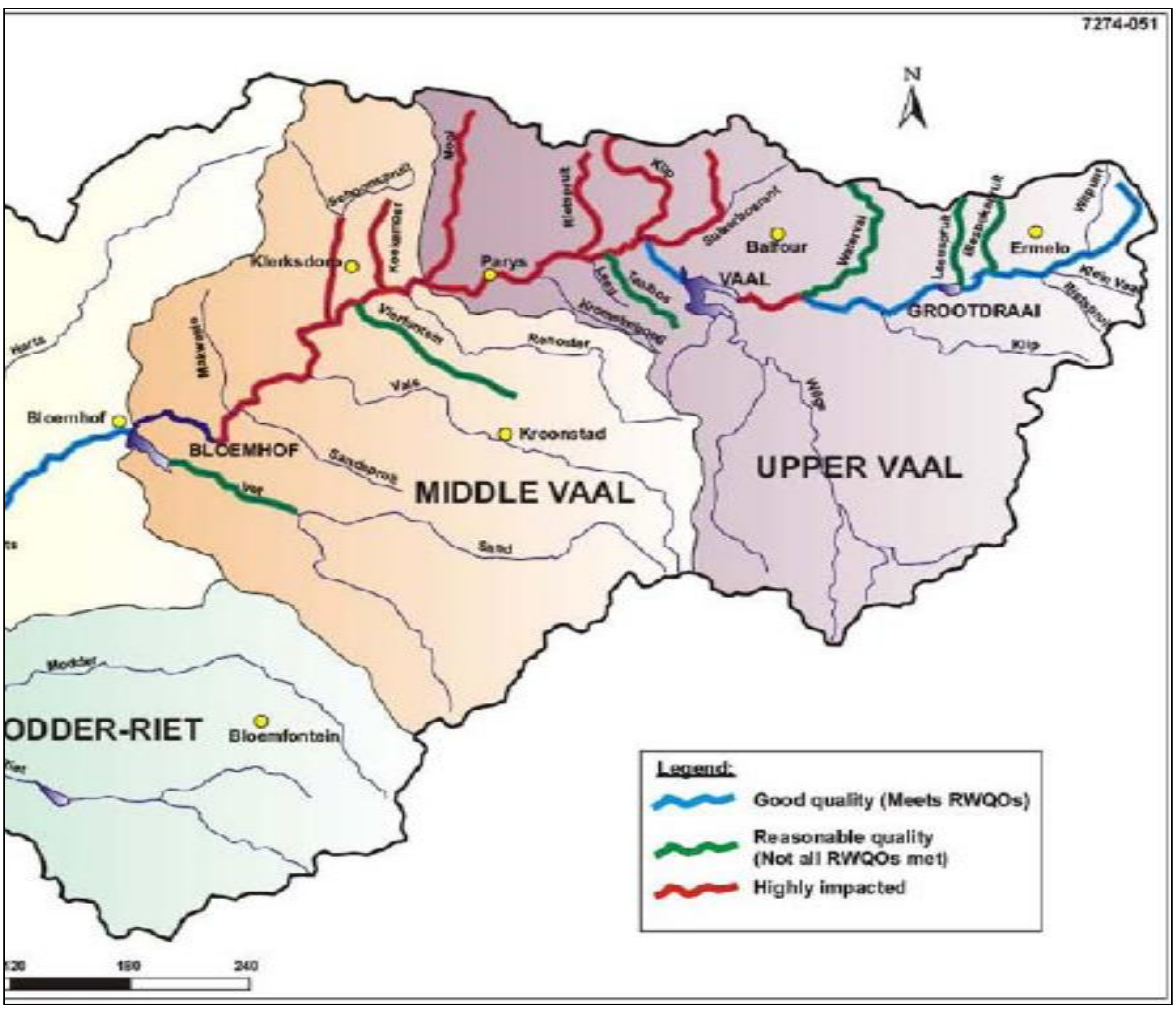

Figure 2. Water quality variability along the VR (Source: DWAF, 2007).

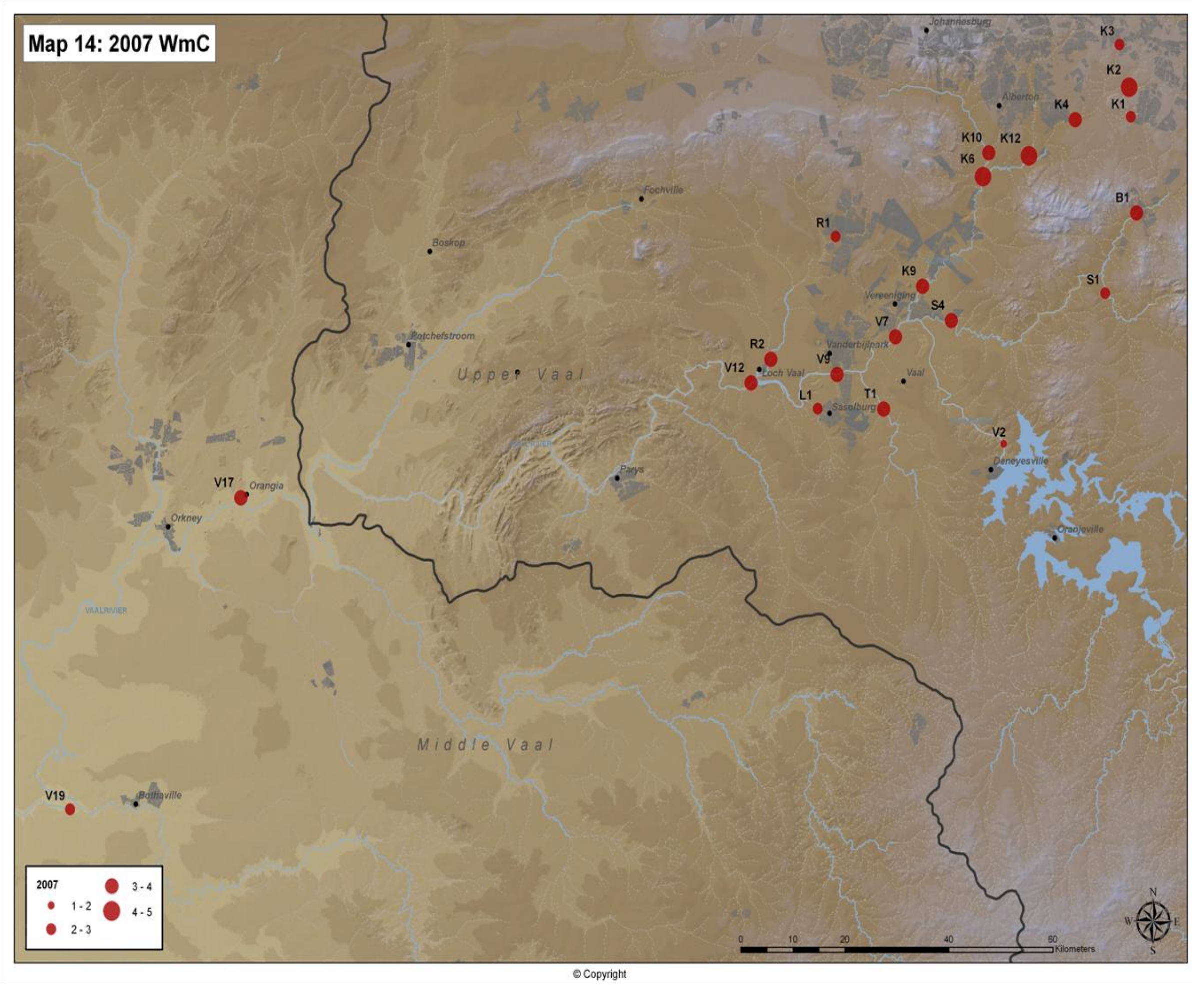

Figure 3. WQI (WmC) for Upper and Middle Vaal WMAs for 2007 (Source: Dzwairo, 2011b).

Table 1. VR main channel sampling points.

Code	Strategic position
V2	Upstream of confluence Suikerbosrant/Vaal Rivers and just downstream of the Vaal dam wall
V7	Vaal barrage at 37 km from the Barrage wall
V9	Vaal barrage at 24 km from the Barrage wall
V12	Barrage wall and just downstream of confluence Rietspruit at Loch Vaal (RvR)/ Vaal Rivers
V17	Midvaal Water Board raw water intake works
V19	Sedibeng Water Board raw water intake works

Dzwairo (2011a) and (2011b) confirmed the water quality trending but employed different quality indicators. Dzwairo (2011a) used electrical conductivity and mapped an ecological functionality while Dzwairo (2011b) modelled a water quality index (WQI) as indicated in Figure 3 and for the same year 2007, specific to the study area. Sampling points labelled V2 to V19 are on the main VR channel while all others are on tributaries that flow into the Vaal River, downstream of the Vaal dam (Figure 3). Table 1 provides the full description of the sampling points in Figure 3. Both papers concluded that tributaries in the Upper Vaal WMAs negatively affected VR water quality. Tributary sampling point descriptions are provided in Table 2.

Table 2. Sampling points on tributaries of the Vaal River.

Code	Strategic position
B1	On Blesbokspruit River, which is a tributary of Suikerbosrant River (SR). It flows into SR between S1 and S4
K1	On Waterval River, which is a tributary of RwR (Rietspruit at Waterval). It flows into RwR between K2 and K4
K2	Most upstream point considered on RwR.
K3	On CT, a tributary of RwR. It flows into RwR between K2 and K4
K4	Most downstream point on RwR before confluence Klip River (KR)/RwR
K6	On KR and downstream of confluence KR/RwR
K9	Most downstream point on KR before confluence KR/VR
K10	Most upstream point considered for KR
K12	On Natalspruit River (NR), a tributary of RwR. It flows into RwR between K4 and confluence RwR/KR
S1	Most upstream point considered on SR
T1	Most downstream point on Taaibospruit River (TR) before confluence TR/VR
L1	Most downstream point on Leeuspruit River (LR) before confluence LR/VR
R1	Most upstream point considered on RvR
R2	Most downstream point on RvR before confluence RvR/VR

The strategic confluences monitored tributary water quality and by monitoring each confluence's immediate upstream and downstream sapling points, the impact of each tributary's quality contribution could be monitored and mapped.

The Upper Vaal Water Management Area

The VR is a very important and strategic entity in South Africa. The system supports sprawling urban and industrial areas (DWAF, 2003) which account for about 60% of the economic activities of South Africa. The Upper Vaal WMA is the economic hub of South Africa (DWAF, 2004a, 2004b; Grobler et al., 1987; Stevn and Toerien, 1976; van Steenderen et al., 1987). The WMA is highly developed and is characterised by large urban centres, industrial areas, power generation, mining and agriculture.

The VR section that falls within this WMA is characterised by poor quality water because of return flows from industrial, sewage treatment works and gold mine discharges and seepages from tailings dams, as well as urban runoff and discharge from many sewage treatment plants located in the study area.

Figures 2 and 3 (using the sampling point V2) indicate that good quality water flows out of the Vaal dam up to the confluence with Suikerbosrant River. Figure 2 indicates that Suikerbosrant River is highly impacted and does not meet even the raw water quality objectives (RWQOs). The VR drains Greater Johannesburg to the Vaal Barrage and the Atlantic Ocean via the Klip River, thus the Klip (Figure 2) also feeds highly impacted water into the Vaal River, as do all the other tributaries within the 478 km stretch of the VR between Vaal dam and Bloemhof dam. Pollution attenuation into the Middle Vaal WMA is insignificant up to Bloemhof dam DWAF, 2007; Dzwairo, 2011b). The flow in the main stem of the Vaal River, downstream of Vaal Dam and upstream of Bloemhof Dam, is largely influenced by the 600 mg/ℓ blending and/or dilution options put in place due to the high salinity content of the mine dewatering as well as the diffuse sources originating from the highly urbanised areas, all discharging into the catchment of the Vaal Barrage (DWAF, 2004c).

The Middle Vaal Water Management Area

Urbanisation and agricultural activities affect water quality in the Middle Vaal WMA. Although less urbanised than the Upper Vaal WMA and more rural in character, the WMA's gold and diamond mines as well as other point sources of pollution including sewage treatment plants, affect Vaal River's water quality. This exerts pressure on already poor quality water from upstream (Upper Vaal WMA).

The principle of a tariff

The principle of a raw water tariff is based on the assumption that information used for costing purposes, provided by companies responsible for treating that water to potable standard, is reliable. The principle has implicit faith in the operators that they will provide correct data against which major decisions would be taken. It also suggests that while arriving at the costs of distribution,

Table 3. Surface raw water tariff components for the Vaal System.

Starts in April	WRMC (c/m³) Domestic & Industrial		RWAT (c/m³)		TCTA for Vaal system only (c/m³)		Total charge (c/m³)	
Year	UVWMA	MVWMA	UVWMA	MVWMA	UVWMA	MVWMA	UVWMA	MVWMA
2003	0.75	1.07	0.00	0.00	0.00	0.00	0.75	1.07
2004	0.96	1.07	26.00	26.00	116.10	116.10	143.06	143.17
2005	1.30	0.98	28.30	28.30	122.40	122.40	152.00	151.68
2006	1.42	1.48	26.82	28.30	131.58	131.58	159.82	161.36
2007	1.32	1.55	26.82	26.63	140.83	140.83	168.97	169.01
2008	1.37	1.61	27.81	27.81	147.59	147.59	176.77	177.01

the information provided by the distributing authorities would be acceptable and returns/incentives/disincentives would be calculated on the basis of this information. Be that may, tariffs must be capable of providing revenues that cover operation and maintenance costs including fuel, and provide a return of and an adequate return on the operator's investment (Rosenzweig et al., 2004).

However where an operator cannot break even, it almost always means higher tariffs for consumers since government generally does not have the resources to fund subsidies sufficient to avoid charging customers more. Ruijs et al. (2008) report of a combined regressive–progressive block model which makes potable water expensive for the poorest of the population. In this instance changing the model in such a way that the income distribution improves and the financial situation of the operator does not deteriorate, is a challenge. Zérah (2008), however, argues that efficiency gains are still possible and consumers should not bear the costs of operators' inefficiencies. The tariff structure of the Upper and Middle Vaal WMAs was investigated in this paper as a situational analysis.

MATERIALS AND METHODS

Historic surface raw water tariffs at tier1 of the cost chain for water services (tariffs charged to WBs by the DWA) for years 2003 to 2008 and supporting documentation were analysed. Data sources were DWA and annual reports from the Trans-Caledon-Tunnel-Authority (TCTA), the Water Research Commission (WRC) and Rand Water board. The tariffs were clustered and discussed in relation to surface raw water quality trends for the Upper and Middle Vaal WMAs obtained from DWAF (2007) and Dzwairo (2011a; 2011b).

RESULTS AND DISCUSSION

Generally at tier1, the following charges applied: in all WMAs:

1. Water Resources Management charge (WRMC) for both domestic and industrial use
2. Water Research Commission levy (WRCL), a charge collected by the water boards
3. Raw water abstraction tariff (RWAT)
4. Trans-Caledon-Tunnel Authority charge (TCTAC) for specific catchments
5. Bulk water distribution cost (BWDC).

Specifically to the Upper and Middle Vaal WMAs, upstream and downstream WBs that abstracted directly from the VR paid: WRMC, TCTAC and RWAT. The WBs paid the same TCTA charge as well as a very similar RWAT. For the WRMC, a WB in the MVWMA (downstream), however, generally paid more than a WB in the UVWMA (upstream). The tariff structure results are indicated in Table 3, for years 2003 to 2008.

Figure 4 was obtained after clustering the WRMC for both WMAs. It indicated a dominance of the UVWMA for the two lower clusters 0.50-1.00 (c/m³) and 1.00-1.50 (c/m³) while the MVWMA predominantly covered the higher 1.50-2.00 (c/m³) cluster.

CONCLUSION

From the salinity (Figure 2) and WQI (Figure 3) maps, it can be concluded that the tributaries Suikerbosrant, Klip and Blesbokspruit impacted VR's water quality negatively. VR did not recover towards downstream and into Middle Vaal WMA. This resulted in WBs located in that downstream WMA to abstract poorer quality water for treatment to potable standard, as compared to WBs that abstracted raw water from VR just downstream of the Vaal dam wall at V2, for example.

Clustering the WRMC for the study area indicated that in the Upper and Middle Vaal WMAs, a downstream WB paid higher WRMC for more polluted surface raw water than an upstream WB. This presented an inequitable situation, because of the added pressure where the cost of the surface raw water which was treated for potable water use accounted for about 50% of the WB's total treatment cost.

This study recommends that WQI be incorporated into the tariff structure at tier1 of the cost chain for water services to ensure fairness of service delivery and spread

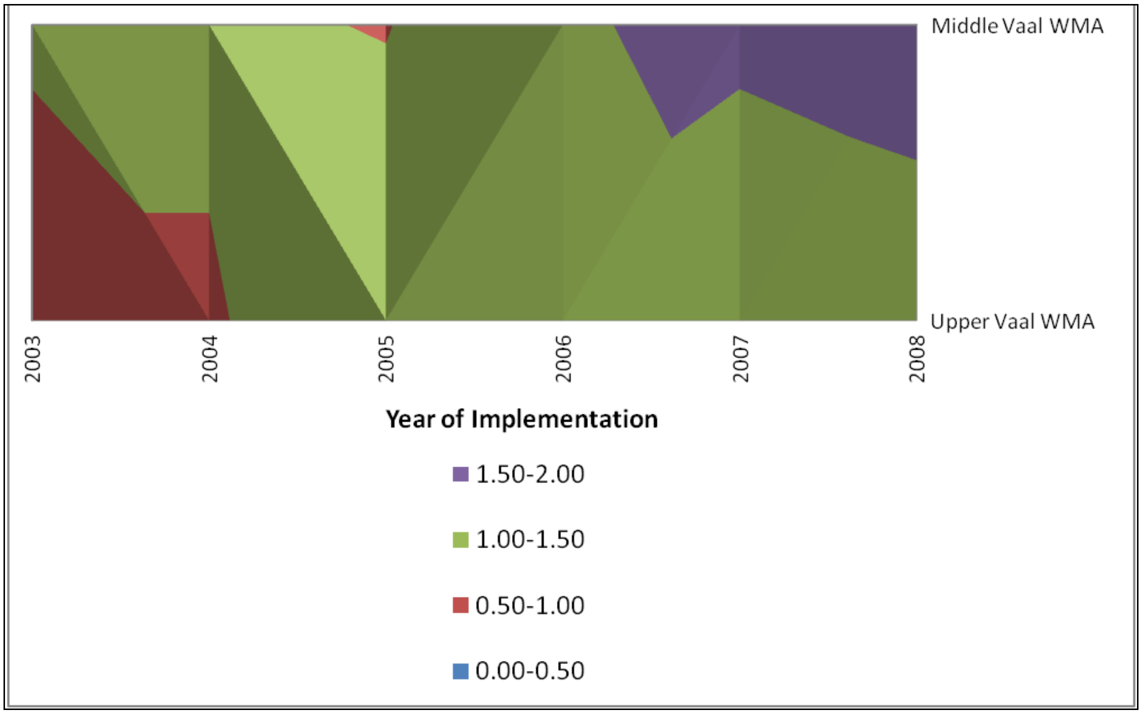

Figure 4. Clustering of the Water Resources Management charge (2003-2008)

of burden to consumers based on quality requirements. This would provide a pricing system based on sustainable water resource management as it addressed upstream-downstream equity issues. Use of a water quality variability model would also ensure that a WB which abstracted poor quality water purchased that water at a lower price than another WB which abstracted better quality water. This equity factor, according to the principle of tariff, could then benefit the consumer at the end of the cost chain for water services.

The overall approach in essence embraced the user-pays principle, recognising that water is a capital resource that needs to be costed properly where its quality varies spatially and temporally. Incorporation of variability of quality into a tariff model would also enable the prediction of potable water treatment costs.

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