EXECUTIVE SUMMARY

Various studies have suggested that in order to ensure access to adequate sanitation facilities for all in the country within the constraints of the country's financial resources, it will be necessary to use a mix of levels of service[1], an option which (ignoring costs of pollution[2]) is significantly cheaper than high levels of service throughout: At the Water and Sanitation 2000 workshop in 1991 a scenario was proposed in which some 50% of sanitation systems in the urban areas of the country by the year 2000 would be ventilated improved pit (VIP) latrines (Jackson, 1991). Subsequently, the Municipal Infrastructure Investment Framework (MIIF) study (Ministry in the Office of the President and the Department of National Housing, 1995) proposed a programme of infrastructure provision that would eliminate much (but not all) of the backlog within 5 to 7 years and would match service levels with predicted household income levels in 10 years (i.e. by the year 2005). This programme would result in a 55:25:20 distribution nationally between full, intermediate and basic levels of service.

Both studies therefore have envisaged a significant amount of on-site sanitation in use in the urban areas of South Africa for the foreseeable future. However, a concern that is often raised in relation to the use of on-site sanitation is the potential pollution of water resources that is associated with these systems. This concern about environmental impact of on-site sanitation systems appears to be serious enough to persuade some decision-makers in the urban areas of the country to opt for the provision of full water-borne sanitation where, but for this concern about environmental impact, on-site sanitation might have been used, thereby foregoing the significant potential cost saving in the construction, operation and maintenance of the service.

There is therefore a need to translate the environmental impact of sanitation systems (and on-site sanitation in particular) into financial terms so as to enable a comparison of these systems to be made, which includes not only the cost of the construction, operation and maintenance of the systems, but also the cost of their respective environmental impacts.

This study:

- provides a methodology for assigning a financial cost to the environmental impact of different sanitation systems;
- provides a first estimate of the comparative costs of pollution from different sanitation scenarios in Gauteng, as well as a very rough first estimate of the comparative costs of pollution from different sanitation systems in general.

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1 A *basic* level of service for sanitation would comprise on-site sanitation (e.g. a VIP latrine), while an *intermediate* level of service would comprise simple water-borne sanitation. Simple water-borne sanitation may include on-site systems such as the LOFLOS (low flush on-site sanitation system, also referred to by some as an aquaprivy). A *full* level of service would comprise full water-borne sanitation. A *basic* level of service is sometimes referred to as a *low* level of service, while a *full* level of service is referred to as a *high* level of service. Lower levels of sanitation service therefore tend to be on-site services, whereas higher levels of service tend to be off-site services.

2 The term 'pollution' or 'pollutant' is used where the concentrations exceed acceptable levels. Otherwise the term 'contamination' or 'contaminant' is used.

is the fact that the concentration of PO_4-P entering Hartbeespoort Dam at weir A2H012 was virtually the same as the concentration of effluent leaving the Northern works (WWTW) some 30km away.

3 The *effect of the wetlands on the Klip River* was not investigated in depth in this study. The effect of wetlands on the nutrient loading on the Vaal Barrage - certainly compared with Hartbeespoort Dam - may be very significant.

4 The *existing* (REM) models for both nutrient budget and nutrient-algae poorly described lake response in Hartbeespoort Dam over the past 10 years.

5 Accounting only for phosphorus, a (modified) nutrient-algae model adequately (for the purposes of this study) described the lake response. This implies that even if the lake is nitrogen-limited at certain select times, the effect of phosphorus is overriding.

6 By comparison with water-borne sanitation discharges - even from well-functioning WWTW meeting the special standard of 1mg/l PO_4-P - pollution from on-site sanitation is negligible. The 'wild card' is grey water; although the effect is not completely random in that if the contaminants remain in the subsurface, it isn't a problem. It needs some serious attention. A controlled experiment may be the best approach to further investigation. Pillay by her assumptions suggested that it was negligible. Ashton and Grobler in their Botshabelo study identified it as a critical question, and presented a range of scenarios.

7 Nitrate contamination of groundwater *will* occur. In Gauteng, contamination of groundwater has *already* occurred (e.g. in Soshanguve). Groundwater is certainly a strategic resource. Dolomitic areas need special consideration. However, fractured rock aquifers are small.

8 It has been assumed in this study that one is only concerned with human wastes i.e. that one is able to address the problem of inorganic salts, refractory organics, heavy metals etc by other means - and at source.

9 Because WWTW effluent standards are concentration-related (e.g. 1mg/l PO_4-P), one needs to keep an eye on growth of household water consumption (and hence sewage flow) for the full water-borne (WB) LOS. The reason is that if the flow volume doubles (for the same concentration of contaminants), then the *mass load* doubles (while still meeting the effluent standard). That can have a serious effect on the receiving impoundments. *Mass load* may well be a more appropriate measure for monitoring contaminant levels than *concentration*.

10 In terms of environmental impact, there is little difference between basic (e.g. the VIP) and intermediate on-site sanitation systems (e.g. the LOFLOS).

Costing

1 For all water treatment - both surface water and groundwater - the cost is a *step-wise function* as one moves to new processes in the treatment train, with deteriorating raw water quality.

2 *Costs of surface water treatment:* For the smaller sized - i.e. 50Ml/d - plant capacity (2000 costs) the cost sequence for different process combinations is estimated as follows:

- conventional (settling and filtration) 30c/kl
- conventional + flotation 37c/kl
- conventional + PAC 36c/kl
- conventional + GAC 50c/kl
- conventional + flotation + GAC + ozone 65c/kl

For a large capacity works (i.e. 200Ml/d) water treatment costs are about 20-25% lower than the above figures.

3 *Maximum* additional cost of surface water treatment to deal with poor quality raw water roughly *doubles* the costs of conventional treatment. For a relatively small works (50Ml/d) the magnitude of the increase (from 30c/kl to 65c/kl) amounts to about 35c/kl. For a larger works (200Ml/d), the proportional increase would remain about the same, but the magnitude of the increase would be somewhat less - about 30c/kl.

4 *Costs of groundwater treatment:* Treatment of groundwater resources is considerably more expensive than the treatment of surface water resources - with groundwater treatment ranging between R1.60/kl and R3.15/kl depending on plant capacity and process.

5 Because groundwater is generally not treated before use (in certain cases, it may be disinfected), the *additional* cost of treatment due to poor raw water quality for groundwater is suggested to be the *full* cost of treatment. This may not be entirely reasonable, but is suggested as a *very worst case* scenario for the purposes of this study.

6 Assuming this to be the case, the *additional* cost of groundwater treatment is somewhere between 4 and 9 times the *additional* cost of surface water treatment (30-35c/kl).

7 *Costs of provision (i.e. construction, operation and maintenance) of the different levels of service of water supply and sanitation* in Gauteng (2000 costs) are:

- Stand-pipe and VIP (basic) R130/cap.a
- Yard tap and aqua-privy (intermediate) R160/cap.a
- House connection and water-borne sanitation (full; *essential* use) R260/cap.a
- House connection and water-borne sanitation (full; *convenience* use) R530/cap.a

8 Assuming a maximum yield (assumed to be natural MAR) for the Gauteng portion of the catchment of the Vaal Barrage downstream of Vaal Dam - essentially consisting of the catchments of the Suikerbosrant River (C21) and the Rietspruit/Klip River (C22) - of 275Mm^3/a at an additional unit cost of treatment of 30c/m^3, the total *additional* cost of treatment will amount to R82.5, say R83million/a. For a population of 4.5 to 5million people in the catchment (in 2000), this translates to only R18, say R20/cap.a. At the lower concentrations of contaminants, it will increase the use of PAC (say 7c/kl), which amounts to less than R4/cap.a.

9 A key requirement is that the (clean) water imported from Lesotho Highlands should not be mixed with (contaminated) water from the Vaal Barrage (requiring more sophisticated treatment processes).

10 Similar calculations to those for surface water can be made for the use of groundwater resources. Assuming a maximum yield (assumed to be the Groundwater portion of the Groundwater Harvest Potential) for the Gauteng portion of the catchment of the Vaal Barrage downstream of Vaal Dam - essentially consisting of the catchments of the Suikerbosrant River (C21) and the Rietspruit/Klip River (C22) - of 125Mm^3/a at an additional unit cost of treatment of R1.90/m^3, the total *additional* cost of treatment will amount to R237.5, say R238million/a. For a population of 4.5 to 5million people in the catchment (in 2000), this translates to only R53, say R50/cap.a.

11 For the Gauteng portion of the catchment of the Vaal Barrage downstream of Vaal Dam, the sustainable yield of groundwater is about *half* that of the surface water. The additional cost of treatment of groundwater due to deteriorated raw water quality is about *five* times

the equivalent additional cost of treatment for surface water. Translated to a cost per person per year, the additional cost of treatment of groundwater is therefore about 2.5 times the equivalent cost for surface water treatment. However, with current utilisation of groundwater of this catchment only about 6% (7.5Mm^3/a) of the maximum yield, this cost is still far from being realised.

12 By comparison with the costs of a higher level of service of water supply and sanitation, the maximum additional costs of treatment are small. For surface water, the additional cost of treatment (R20/cap.a) is only about 15% of the difference in cost between a basic and a full level of service (*essential* use) (R130/cap.a). If water usage for the full level of service increases towards *convenience* use, then the relative cost of treatment will drop even more. For groundwater, the additional cost of treatment (R50/cap.a) is about 40% of the level of service cost difference.

13 In summary, even *conservative* (i.e. high) estimates of additional treatment costs (either surface water or groundwater), *fully* (i.e. very conservatively) assigned to pollution from sanitation systems, are still *well less than half* the cost difference between basic and full (essential use) levels of service of water supply and sanitation (based on the particular catchments used in the analysis).

Application of model to Hartbeespoort Dam

1 From 1990 sanitation figures, there are not that many people with inadequate sanitation in Gauteng. Most are in the 'fringe' areas. These will start to be included in the cross-boundary municipalities; but if one is looking at Gauteng only, there isn't a massive problem. 90% have full water-borne sanitation.

2 Based on estimated population figures and effluent flows from WWTW, water usage for sanitation in the Hartbeespoort Dam catchment appears to be considerably higher than (about double) the figures originally estimated for that level of service. The variation in flow is large enough to warrant more than one level of service for water-borne sanitation (e.g. low level use and high level use); although it is likely that there will be less variation in per capita contaminant loads than in per capita flows. It is unclear whether these changes in water usage occur evenly, in which case more than two (say three i.e. low, medium and high) levels of service for water-borne sanitation may be necessary, or whether there is a step-wise change, in which case the two levels of service may suffice.

3 A not unreasonable flow/TP relationship, which *aggregated* both point and non-point sources, could be identified at weir A2H012. Such a flow/load relationship could *not* be established for Northern works alone; nor could it be established for weir A2H012 minus Northern works. This is anomalous. A possible explanation is that there is in-stream sedimentation of P, and transport of this P into Hartbeespoort Dam is more dependent on general stream flow than on discharge from the WWTW. This is also supported by the fact that spikes of PO_4-P discharged from WWTW are not evident in the flows entering Hartbeespoort Dam; neither is any clear lag evident between discharge from WWTW and entry into Hartbeespoort Dam (in contrast to what Pillay found for Inanda Dam). To draw any further conclusions would require more detailed analysis.

4 The response of the lake to contaminant loads is not static. In particular, it appears that either an algal species shift or a change in the response of the algae to nutrient load can be triggered by events such as floods or droughts. These changes in lake response overshadow any changes in nutrient loading. The increased incidence of algal blooms in Hartbeespoort Dam since February 1996 has not been as a result of increased

contaminant loading, but rather as a result of changed lake response, which appears to have been triggered by the high flows and contaminant loads of February 1996. Once the shift had occurred, the lake did not revert to its earlier response characteristics.

5 In terms of allocation of the cost of pollution, approximately *half* of the increased cost of surface water treatment as a result of deteriorated water quality could be attributed to sanitation systems, and most of this to full water-borne sanitation.

General comments + conclusions

1 While in themselves, most of these findings are not entirely new (virtually all of them are based on *existing* data), it is the *implication* or *significance* of a finding in one area (e.g. planning) for another area (e.g. water quality) that is particularly noteworthy.

2 Water-borne sanitation (WB) discharges directly to the surface watercourses. It is currently the major contributor to pollution (primarily phosphorus) from sanitation systems in Gauteng.

3 Even effluents meeting the effluent quality standards have a major impact on water bodies; and, added to that is the fact that a number of the sewage treatment works do not meet the standards at all times.

4 The situation in Gauteng with respect to sanitation provision and consequent pollution over the next 10 years appears to be slow to change: It appears that it is water-borne sanitation that is - and will continue - to have the major effect on lakes in Gauteng (with a bit of a 'wild card' being diffuse load washed off the *surface*). Although one can get significant changes in demographics, settlement patterns and LOS at a local (i.e. municipal) level in a relatively short space of time (say, of the order of two or three years), it takes a fairly extended period of time (say, of the order of a decade or two) to change the overall patterns of a large area such as Gauteng.

5 Unless the 'polluter pays' principle is established, there is little incentive to use a cheaper system than full water-borne systems.

6 With return flows from WWTW making up such a large proportion of the flow into impoundments such as Hartbeespoort Dam, it is becoming difficult to separate out issues of quality from issues of quantity. More specifically, some service providers may prefer to use (and treat) return flows of poor quality rather than import expensive but excellent quality water through inter-basin transfer schemes.

7 Environmental impact is one of several factors to be considered in the choice of level of service of sanitation. It is important not to confuse these different factors. Environmental impact should *not* be given as the reason for not using a particular system, when in fact the reason is motivated by other considerations, such as promotion of equity among users.

In the light of the above conclusions, the following recommendations are made:

1 That the method of pollution costing proposed in this study be *adopted* as an input to deciding whether or not to use on-site sanitation;

2 That policy regarding sanitation use be set at *provincial level - or higher* i.e. at national level - and that DWAF (as custodian of the country's water resources) issue permits for the use of on-site sanitation;

3 That a *workshop* be held to publicise the results of this work, and to identify priority areas for implementation and further development of the principles proposed in this study.

Critical issues that require further investigation include the following:

1. The environmental impact of grey water discharged to the ground surface;
2. The mechanisms surrounding changes in the response of algae to nutrient loads - and possible interventions to control this;
3. The stages at which new water treatment processes need to be introduced to deal with deteriorating raw water quality;
4. Quantitative estimates of the costs of loss of recreation and property value as a result of deteriorated impoundment water quality;
5. Clearer identification of the characteristics of natural resources (including both quantity and quality) and the 'ownership' of these.