# UNDERSTANDING THE USE AND DISPOSAL OF GREYWATER IN THE NON-SEWERED AREAS IN SOUTH AFRICA

Report to the
Water Research Commission

by

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on behalf of

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# Executive Summary

## Introduction

There is currently a strong drive from the South African government to attain adequate water and sanitation coverage throughout the country and the basic level of service to meet this requirement being applied to the majority of authorities in urban and rural areas relates in most cases to on-site dry latrines (VIPs or similar) and 25 litres of potable water per capita per day (*l*/c.d) within 200m cartage distance. The targets for the provision of basic water services to all people in South Africa (SA) are set out in the "Strategic framework for water services" (DWAF, 2003), which outlines Government's commitment to eliminating the backlogs and to progressively improve these levels of service over time. In order to meet these targets (access to basic water supply by 2008, and to basic sanitation by 2010), the connection of low-income settlements to municipal water sources has subsequently occurred on a massive scale, frequently without giving adequate attention to greywater management in those areas that are non-sewered. Recent estimates show that there are approximately 20 million people in SA without access to on-site waterborne sanitation (Statistics South Africa, 2005). In the absence of suitable conveyance systems, greywater is generally disposed of onto the ground outside the dwellings and the resulting total pollution load, particularly from densely populated settlements, has the potential to create a host of environmental and health impacts. It is likely that the problems related to the disposal and management of greywater will increase as basic water and sanitation services are attained and improved, and solutions are therefore required to manage these impacts.

In response to this, a two-year investigation was initiated into the use and disposal of greywater in the non-sewered areas of SA, and in particular to attempt to assess the health and environmental impacts of greywater in these communities. The potentially negative impacts from greywater disposal are felt most strongly in those areas where water supply services and on-site sanitation have been implemented but little or no consideration has been given to the planning for and management of greywater. The association between poor sanitation and ill health is well-known, as demonstrated by World Health Organisation (WHO, 1996) estimates that diarrhoeal diseases are responsible for over a quarter of the deaths of children in the world, and the fact that 80% of these deaths are reported as resulting from a lack of sanitation and water (Esrey, 1998). In South Africa, recent research has shown that 43 000 people, mainly children under the age of 5 years, die from diarrhoeal diseases each year (Mara, 2001) and it is in this context that it has become essential to establish the link between greywater disposal and environmental health issues.

The main aim of the research was to quantify the greywater problem and develop options for the management thereof, both in terms of reducing health and environmental risks by eliminating inappropriate disposal of greywater, as well as providing benefits to some communities through controlled reuse.

Two main outputs were envisaged for the project, one at strategic level and the other at implementation level. Government policy makers require guidance in the development of strategies for the management of greywater, particularly with respect to typical greywater generation rates and the likely impact of changes in the service levels associated with water and sanitation services. Communities and municipal planners need support in determining greywater management options and determining the solutions required to reduce any negative impacts.

For the purposes of the investigation, greywater was defined as the wastewater that is produced from household processes (e.g. washing dishes, laundry and bathing) without input from toilets. Non-sewered areas are defined as those areas **without on-site waterborne sanitation**. In this context waterborne sanitation has been taken to include all methods of sewage treatment from flush toilets, including septic tanks. Communities with dysfunctional or inadequate sewerage systems (particularly communal toilet facilities) were also included in the definition of non-sewered areas.

## Methodology

Following the literature review, on-site surveys of selected communities in six of the nine provinces of SA (39 sites in total) were conducted over a period of approximately one year through the use of standardised questionnaires. Greywater management is affected by sociological, environmental and institutional factors, which necessitates the collection of large quantities of data and the use of specialist knowledge. In each community, therefore, surveys were carried out of current greywater management and recycling activities. Cultural practices pertinent to water use and management were documented to determine whether they hindered or promoted the adoption of greywater recycling and how they impacted on greywater management as a whole. The volumes of greywater generated were calculated from the amount of water consumed per household. In the absence of any formal metering, the figures for water consumption were based on estimates given by the occupants themselves (usually determined by the number of buckets of water collected during each day). General observations were also made of the physical surroundings, climate, topography etc. as well as any environmental considerations related to the settlement. Limited water quality sampling of typical greywater and source water was undertaken, mainly through the use of field test kits, to try and get a general understanding of the overall quality of the greywater emanating from non-sewered areas, particularly in respect of its nutrient loading and oxygen demand.

## Findings from study

The main environmental and sociological findings from the site surveys were:

- High-density, non-sewered settlements in close proximity to water bodies have significant impacts on the biophysical environment. These sites must be clearly identified and some form of technological and strategic intervention must be implemented as a matter of urgency.

- The environmental impacts resulting from settlements with low population densities in rural areas that are situated some distance from water bodies appear to be minimal. It can be concluded that rural settlements situated on relatively flat, well-drained soils do not have an obvious greywater drainage problem, although the long-term potential for a significant deterioration in groundwater quality should be monitored. Low density rural settlements situated on hilly topography, and in close proximity to water bodies, pose a greater risk to the pollution of water resources. The quality of water downstream of such settlements can be compromised further by the behaviour of upstream users.
- In different parts of the country the researchers found that changing socio-economic circumstances influence the amount of water used per household as well as the types of detergents, how often laundry washing activities are undertaken, and the amount of greywater generated.
- Most people consider alternative water provision and wastewater management techniques as temporary measures only and expect to have waterborne sanitation and a continuous supply of potable water in their homes in the near future.
- In both rural and urban settlements the most common method for households to manage wastewater is to dispose of it onto the ground. Many interviewees were conscious of potable water scarcity and indicated a willingness to conserve water if the authorities showed them how this could be done. Most of the people interviewed, however, believed that greywater was dirty, even toxic, and could not be used.
- In densely-settled areas as well as those where drainage was particularly poor, a number of health problems were identified by residents, including mosquito infestation from smelly, stagnant water and children falling ill after playing in the water. There was little space for gardening in these areas and greywater was perceived to be a problem rather than a potential resource for recycling.

The total volume of greywater currently being generated in the non-sewered areas of South Africa has been estimated by applying a greywater return factor (ranging between 65% and 85%, average 75%) to the amount of water consumed per household and multiplying this with the number of non-sewered households in each province (using modified Census 2001 figures). Table 4.3.3 shows the estimated quantity of greywater being generated in the non-sewered areas of each of the provinces of South Africa.

These figures are only an estimate however and may not include areas that have been nominally provided with services (and are therefore considered to be sewered in the Census data) but where the services are dysfunctional. The figures are also based on the average household water consumption figures from non-sewered areas with mainly **off-site** water supply. It has been assumed that 25% of the non-sewered households in SA have access to **on-site** water supply and that they consume approximately twice the average amount of water than those that use off-site water (i.e. 200 *l*/du.d). The total volume of greywater that is generated on a daily basis in the non-sewered areas of SA (based on an average 75% return factor) can therefore be estimated at just over 500 000 $m^3$ per day. This amounts to approximately 185 million $m^3$ per year – equivalent in volume to a medium sized dam such as Voëlvlei near Cape

Town, or approximately 50% of the current water demand of that city. The estimated return figure of 75% has little bearing on this outcome. The corresponding figures for total greywater volumes in non-sewered areas using the upper (85%) and lower (65%) limits for the return factor, as per the literature, would be approximately 575 000 $m^3$ and 440 000 $m^3$ per day respectively, which are not significantly different from the initial estimate. This illustrates the relatively limited potential for the use of greywater as an alternative water resource at a country-wide scale, and suggests that potential benefits from greywater use would only be from irrigation at the household level to supplement nutrition requirements. On the other hand, these figures highlight the fact that greywater disposal in dense non-sewered areas is likely to result in significant health and environmental impacts, particularly in dense urban environments where large volumes of greywater are generated.

**Table 4.3.3: Total quantities of greywater in the non-sewered areas of South Africa**

| Province | Total no. hholds Census 2001 | Non-sewered hholds Census 2001 | Non-sewered hholds GHS 2004 | % diff | Ave water cons. (l/du.day) | Greywater volumes ($m^3$/day) |
|---|---|---|---|---|---|---|
| W. Cape | 1 173 303 | 162 473 | 85 000 | -48% | 75 | 4 781 |
| E. Cape | 1 512 664 | 1 016 668 | 1 151 000 | +13% | 90 | 77 693 |
| N. Cape | 206 844 | 69 819 | 64 000 | -8% | 105 | 5 040 |
| Free State | 733 302 | 393 850 | 324 000 | -18% | 105 | 25 515 |
| KwaZulu-Natal | 2 086 251 | 1 219 474 | 1 303 000 | +7% | 95 | 92 839 |
| North West | 929 000 | 603 438 | 545 000 | -10% | 105 | 42 919 |
| Gauteng | 2 651 247 | 484 533 | 298 000 | -38% | 100 | 22 350 |
| Mpumalanga | 733 135 | 452 866 | 418 000 | -8% | 120 | 37 620 |
| Limpopo | 1 179 965 | 989 569 | 1 049 000 | +6% | 145 | 114 079 |
| **Total for off-site water supply, 75%** | **8 404 284** | **4 044 517** | **3 927 750** | **-3.0%** | **105[1]** | **309 310** |
| **Total for on-site water supply, 25%** | **2 801 427** | **1 348 173** | **1 309 250** | **-3.0%** | **200[2]** | **196 387** |
| **Grand total** | **11 205 711** | **5 392 690** | **5 237 000** | **-3.0%** | **-** | **505 697** |

Notes: 1. Average provincial household water consumption for households with off-site supply, from site surveys
2. Estimated water consumption for households with on-site supply

## Greywater management options

Greywater management options were developed to assist communities and municipal authorities in determining how greywater can safely be disposed of in their areas. The main assumption in the development of these options is that non-sewered areas do not have waste removal mechanisms for greywater and that disposal options are limited to beneficial use (either on- or off-site, e.g. irrigation), disposal on-site or disposal off-site. In order to prevent major health and environmental impacts resulting from greywater disposal in these areas, the most important issues are to ensure that:

- there is no ponding of the greywater,
- the greywater does not get into surface water systems, and
- greywater is not allowed to build up in the soil to such an extent that it becomes a hazard.

Beneficial use of greywater is considered to be the most sustainable disposal option, but in reality is rarely achieved as there are two critical issues regarding greywater quality that must be resolved before any reuse initiative can take place:

1. **Health aspects** – adequate controls must be in place to ensure that the risk of infection from any pathogenic organisms present in the greywater is negligible.
2. **Soil conditions** – conditions should be suitable, or measures in place, to prevent damage to the soil resulting from the long-term application of greywater with high levels of salinity.

The above issues imply that there is a need for strong institutional support and monitoring if the beneficial use of greywater is to be considered. On-site disposal of greywater is widely practiced throughout the non-sewered areas of South Africa and is an acceptable option in areas with low to medium settlement densities and well-drained soils. Off-site disposal of greywater is the remaining option for those areas where the settlement characteristics, e.g. high densities, clay soils, high water tables etc., are such that on-site greywater disposal would create significant environmental and health impacts.

Various factors were identified as being important when considering greywater management options in non-sewered areas, the three most critical being:

1. **Water consumption** [measured in litres per household (or dwelling unit, du) per day] – the issue of greywater is inseparable from that of water supply as all water that is supplied to a settlement which is not consumed must be disposed of in some manner. The general premise is that if the volume of water supplied is low and the settlement density is not too high then greywater disposal to the ground in the vicinity of the dwelling may be possible.
2. **Settlement density** [measured in dwelling units (du) or numbers of households per hectare (ha)] – this has been determined as being a key driver with respect to greywater management owing to the fact that large numbers of people living in densely-populated settlements generate increased volumes of waste, which cannot adequately be disposed of in the limited available space.
3. **Soil / surface properties** – these relate to the drainage conditions of a particular area and are not necessarily directly related to the soil properties themselves. They are affected by settlement densities and previous practices with respect to greywater disposal (e.g. build-up of grease and "scum" on soil surfaces, as well as the impact of high pedestrian traffic in built-up areas that causes hardening and reduce the soil's ability to drain efficiently). There are ongoing concerns about greywater disposal leading to groundwater

contamination, particularly in dolomitic areas where poor drainage conditions could lead to the formation of sinkholes and where porous and fractured rock conditions accelerate surface to groundwater flow, but it was not possible to investigate individual aquifers during the course of this project – the identification of the impacts of greywater disposal on groundwater quality has been included as a recommendation for future research.

The results of the site surveys showed that settlement density together with the consumption of water per dwelling unit appear to be the most critical factors in determining whether greywater can safely be disposed on- or off-site. It was therefore decided that the quantitative measure used would be the quantity of greywater per hectare ($G_G$) that needs to be managed, as shown in Equation 4.1:

$$G_G = QD \qquad [4\text{-}1]$$

where, $G_G$ is the greywater generation rate, *l*/ha.day
Q is the greywater produced per household (water consumption x 75%), *l*/du.day,
D is the density of households per hectare, du/ha,

Greywater generation rates for non-sewered settlements in SA and the likely impact of changes in service levels with respect to water supply (e.g. higher water consumption leading to increased generation of greywater) were calculated by using Equation 4.1, with figures for settlement densities acquired from local authorities, and average water consumptions from the on-site surveys as applied to particular types of settlements. Tables 4.4.1 and 4.5.2 have been combined to show the calculated greywater generation rates for the settlements that were surveyed as well as some of the average greywater quality data obtained during the sampling exercises.

The recommendations regarding management options for different settlement densities that were made in “Managing the water quality effects of settlements: Planning to avoid pollution problems” (DWAF, 2001g) were adapted for use in this project by linking the greywater generation rates to settlement densities. In this way, it was possible to determine ranges of greywater generation rates for this project, with associated recommended management practices:

- **Low density –** <500*l*/ha.day (generally equates to densities of <10 du/ha and plot sizes >800$m^2$). Soakaways installed at water collection points and standpipes should be sufficient to protect water resources and prevent health risks.
- **Low / Medium density** – 500-1500*l*/ha.day (equates to densities of 10-30du/ha and plot sizes 800-300$m^2$). Soakaways must be installed at tapstands and in-home or yard connections should be connected to an on-site disposal system.
- **Medium / High density** – 1500-2500*l*/ha.day (equates to densities of 30-50du/ha and plot sizes 300-150$m^2$). If yard connections are supplied as recommended by DWAF, on-site disposal systems should be installed; otherwise formal washing areas with disposal options are required.
- **High density** – >2500*l*/ha.day (equates to densities of >50du/ha and plot sizes <150$m^2$). There should be off-site disposal of all effluent.

It is important to note that greywater impacts increase exponentially in very dense settlements due to the fact that the amount of open space decreases markedly with density in these areas; off-site disposal of greywater is thus recommended for areas where the settlement densities are >50 du/ha.

**Table 4.4.1 and Table 4.5.2: Greywater quantity and quality for survey sites**

| Name of settlement | Prov | Density du/ha | Average water use l/du.day | Grey-water gen. rate l/ha.day | Average values for wash water samples | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | COD mg/l | $NH_3$ mg/l | TKN mg/l | Tot P mg/l | Oil & Grease mg/l | Cond mS/m |
| Clanwilliam | WC | 12 | 65 | 585 | - | - | - | - | - | - |
| Redhill | WC | 11 | 80 | 660 | 1470 | - | 20 | 27 | 176 | 155 |
| Lingelethu | WC | 29 | 55 | 1196 | 6190 | - | - | - | - | - |
| Fairyland | WC | 34 | 75 | 1913 | 2320 | - | 60 | 88 | 30 | - |
| Kleinmond | WC | 25 | 105 | 1969 | 3510 | - | 110 | 146 | 29 | - |
| Masiphume- | WC | 29 | 100 | 2175 | 7850 | - | 130 | 98 | 242 | - |
| Khayelitsha | WC | 67 | 55 | 2764 | 3580 | - | - | - | - | - |
| Sweet Home | WC | 60 | 70 | 3150 | 8490 | - | 172 | 144 | 307 | - |
| Masakhane* | MP | 6 | 115 | 518 | - | 3+ | - | 5+ | - | 1040 |
| Doornkop* | MP | 15 | 120 | 1350 | - | 3+ | - | 5+ | - | 126 |
| Mashati* | LIM | 3 | 140 | 315 | - | 3+ | - | 5+ | - | 289 |
| Manapyane* | LIM | 3 | 150 | 338 | - | 3 | - | 5 | - | 112 |
| Tlhalampye* | LIM | 4 | 125 | 375 | - | 3+ | - | 5+ | | 461 |
| Leeufontein* | LIM | 5 | 150 | 563 | - | - | - | - | - | 770 |
| Jane Furse* | LIM | 5 | 180 | 675 | - | 2.9 | - | 1.6 | - | 389 |
| Winnie Park* | LIM | 8 | 130 | 780 | - | 3+ | - | 5+ | - | 234 |
| Seshego Z5* | LIM | 10 | 115 | 863 | - | 3+ | - | 5+ | - | 140 |
| Mahweler- | LIM | 10 | 145 | 1088 | - | 0.5 | - | 5+ | - | 90 |
| Doornkraal* | LIM | 15 | 135 | 1519 | - | 3+ | - | 5+ | - | 489 |
| Pietersburg* | LIM | 18 | 130 | 1755 | - | 3+ | - | 5+ | - | 1530 |
| Moth- | LIM | 25 | 140 | 2625 | - | 3+ | - | 5+ | - | 196 |
| Emahobeni* | EC | 10 | 45 | 338 | - | 3+ | - | 2.9 | - | 381 |
| Mputhi* | EC | 8 | 75 | 450 | - | 2 | - | 1.3 | - | 783 |
| Phakamisa* | EC | 8 | 80 | 480 | - | 3+ | - | 1.9 | - | 514 |
| Bongweni* | EC | 5 | 160 | 600 | - | 3 | - | 3.5 | - | 916 |
| New Payne* | EC | 10 | 80 | 600 | - | 2.6 | - | 4.5 | - | 113 |
| Silvertown* | EC | 20 | 70 | 1050 | - | 3+ | - | 5+ | - | 189 |
| Orange | EC | 30 | 60 | 1350 | - | 2.2 | - | 5+ | - | 764 |
| KwaShange | KZN | 3 | 100 | 225 | - | 12.5 | 56 | 57.4 | 730 | 59 |
| Emambedwini | KZN | 4 | 80 | 240 | - | 8.5 | 39 | 112.4 | 1365 | 567 |
| Emaqedini | KZN | 5 | 100 | 375 | - | 5.7 | 7 | 15.6 | 397 | 70 |
| Boboyi | KZN | 5 | 110 | 413 | - | 3.0 | 20 | 34.4 | 1948 | 128 |
| Zolani | KZN | 20 | 85 | 1275 | - | 3+ | 45 | 37.6 | 1947 | 199 |
| Cato Manor | KZM | 25 | 95 | 1781 | - | 7.6 | 164 | 7.5 | 108 | 54 |
| Barcelona | GP | 25 | 95 | 1781 | - | - | - | - | - | - |
| Mayfield Ext | GP | 32 | 95 | 2280 | - | 21.8 | 43 | 240.0 | 1484 | 653 |
| Freedom Sq | GP | 162 | 110 | 13365 | - | - | - | - | - | - |
| **Average** | | **20** | **104** | **1385** | **4770** | **-** | **72** | **-** | **730** | **366** |

Notes: 1. * indicates sites where analyses were conducted with field test kits only
2. + indicates extent of measurement range for field instrument
3. WC – Western Cape, MP – Mpumalanga, LIM – Limpopo, EC – Eastern Cape, KZN – KwaZulu-Natal, GP - Gauteng

There are other criteria which could also affect the decision to dispose of greywater off-site and further recommendations in this regard are indicated in Table 4.5.1. Management options can be determined through the use of rule-based flow diagrams (decision trees) which ask relevant questions for each criteria in order to evaluate their individual or combined impacts on greywater management. An example of a decision tree for greywater generation rate is shown in Figure 4.5.2.

**Table 4.5.1: Recommendations regarding off-site disposal of greywater**

| Criteria | Off-site disposal of greywater recommended |
|---|---|
| Settlement density (du/ha) | When density >50 du/ha |
| Greywater generation (*l*/ha.day) | When $G_G$ >2500*l*/ha.d |
| Soil/surface properties | Surfaces hard-packed / impervious (heavy clay / rock) |
| Topography | When slopes >30% |
| Depth to water table | If depth to water table <1m |
| Proximity to sensitive environments | Within floodplains (e.g.1:50year) |

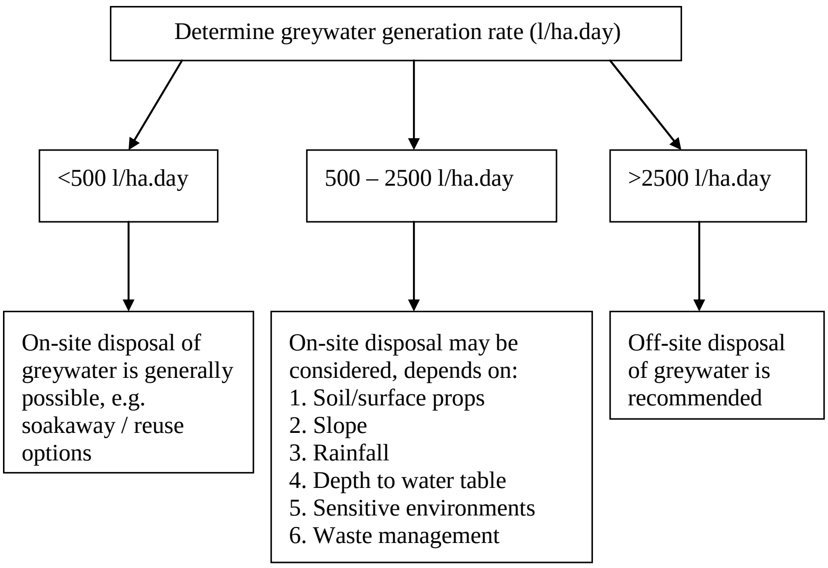


**Figure 4.5.2: Decision tree for determining appropriate greywater management options**

The results from the on-site surveys indicate that:

- The water quality results suggest that greywater is generally unfit for use except under controlled conditions; this was confirmed during discussions with residents who reported that greywater use initiatives are generally not well-supported.
- In low-income, high-density areas where greywater use initiatives are generally not feasible (or affordable), the emphasis for interventions should rather be placed on

treatment / disposal systems which ensure that the management of greywater does not have negative health and environmental impacts. The provision of emergency water supplies to informal settlements in particular generates significant volumes of greywater that either gets disposed of into the stormwater system leading to pollution of downstream waterbodies, or gets discharged onto the ground in the settlement resulting in nuisance and / or health impacts.

- Greywater management has been neglected in the service delivery planning process for non-sewered settlements in South Africa and the consequences of this non-functioning service delivery model are evident in the greywater disposal issues that have been highlighted. Based on the results of the site surveys, there is significant risk involved with the disposal of greywater, particularly in the high-density urban settlements. It is important that there is strategic planning with respect to service delivery, technology choice, budgets, implementation / education etc. at central as well as local government level.
- Most people believe that the solution to their water supply and wastewater management problems rests with municipal authorities alone. This appears to be based on a sense of entitlement resulting from the Government's stated policy regarding the delivery of waterborne sanitation in fully-serviced homes to as many citizens as possible. Most people therefore consider alternative water provision and wastewater management techniques as temporary measures only. Another issue revolves around the concept of water recycling and Government policies in this regard – people are suspicious that they will be getting an "inferior" product if recycling is introduced.
- Not enough is known at present about the health challenges that may be presented by the use of greywater for irrigation of food crops, and the management of any recycling practice is therefore crucial. The over-riding principle is that the use of greywater for the irrigation of edible food should not be allowed in non-sewered areas without being able to quantify the risks involved. Unrestricted use of greywater (without education on the risks involved and supervision of the practice to ensure adherence to safety precautions) is likely to increase the disease burden on those who can least afford it.
- In non-sewered areas the main control in terms of greywater management seems to be the household water supply (these are mainly informal settlements, and services are generally temporary with water supply often very limited), but the potential impacts of improving and / or increasing the levels of water supply to these areas must be taken into account when considering strategies to mitigate impacts. Although there will undoubtedly be some benefits to communities in terms of improved hygiene control, increasing the water supply to settlements will also have the effect of increasing the amount of greywater that is generated, which then needs to be disposed of.
- Greywater management initiatives are unlikely to be successful unless the recipient communities are involved in the decision-making process, as well as in the implementation and operation of the systems. However, the issue of ownership is difficult in changing populations as with informal settlements where there is often no

identifiable community structure and therefore no community-based system for taking responsibility for greywater management initiatives.

## Strategies and guidelines for greywater management

There are two central issues regarding the strategic management of greywater which allow for health improvement, water conservation, use (where possible) and environmental protection:

1. Challenge of turning greywater into a beneficial resource if it does not constitute a hazard.
2. Response to crisis situations where greywater becomes a health hazard, e.g. in densely populated settlements.

The variety of challenges (e.g. the impact of detergents, the general health of residents and the influence of HIV/AIDS etc. ) with respect to greywater management in non-sewered areas is much greater than has been investigated in this project. It has been possible, however, to develop some initial strategies with these two issues in mind:

- Settlement planning is key. The management of greywater should be included at the planning stage for the provision of water services to non-sewered settlements, in collaboration with the affected communities.
- The decision to promote either the disposal of greywater in such a manner so as to avoid negative impacts, or encourage the safe use of greywater in settlements, should be taken based on the density of the settlement and the quality of the greywater. Greywater produced in high-density informal settlements should NOT be used for the production of edible crops or distributed over surfaces that humans come into contact with.
- Based on the quality of greywater generated in low-income, densely-settled urban areas, it should be managed as sanitation rather than drainage in these settlements. Local authorities should provide greywater disposal systems in densely-settled areas that either treat the greywater on-site so that it meets acceptable limits for discharge, or convey the greywater to a sewerage system. It is vital that the local authorities are committed to the proper operation and maintenance of these systems.
- Education and training of communities in greywater management is vital, together with the provision of “material possibilities” in the form of money, infrastructure, service availability etc. which can encourage people to get involved in working towards the creation of healthy environments. It is essential therefore that the relevant services be installed within the capacity of the government to deliver, even if these only comprise “emergency services” as in the case of informal settlements.
- Simple technological solutions should be explored further.

As previously noted, it is essential to address the potential for greywater generation when planning and developing settlements, and the integration of suitable long-term service provision is necessary in order to alleviate the problems of greywater management (Wood et al., 2001). This is particularly relevant in densely-settled areas where the options for greywater use are limited and the focus is on safe disposal only. Various guidelines have been suggested when planning for greywater disposal in high-density settlements:

1. Settlement planning
   - Avoid establishing settlements on steep slopes in order to prevent erosion and runoff of greywater and stormwater (Wood et al., 2001).
   - No development should occur in the 1:50 year floodline (Wood et al., 2001).
   - Open spaces should be maintained within the settlements in order to, *inter alia*, assist in pollution control, absorb rainfall and reduce flooding (Wood et al., 2001).
2. Service provision
   - Water standpipes should be provided within 100 m of each household (Wood et al., 2001).
   - Reduce water wastage (and concomitant increased volumes of greywater) at standpipes through the use of fittings such as automatic shut-off taps.
   - Provision must be made for the collection of greywater and leakage from water standpipes; preferably infiltration beds and soakaways should be provided at the standpipes (or drainage to gravitate the greywater to sewer or an appropriate site for handling and disposal) so that ponding of contaminated water is minimised (Wood et al., 2001).
   - In addition to providing a greywater disposal facility at each water supply point, additional disposal points should be installed so as to reduce the walking distance from dwellings to disposal point to a maximum distance of 25 m (City of Cape Town, 2005).
   - For new standpipes, greywater disposal points with galvanised gratings should be provided (City of Cape Town, 2005).
   - Where communal washing facilities are provided, sediment and fat traps are required before disposal of greywater (City of Cape Town, 2005).
   - Communal sanitation facilities should be conveniently located (Wood et al., 2001) and must include washing facilities with provision for the disposal of greywater.
3. Greywater disposal
   - The preferred option for greywater disposal is by gravity to sewer – the collection and treatment of greywater in ponds or wetlands is not a viable option for many high-density settlements owing to the lack of large open spaces, the health risks and safety considerations (Wood et al., 2001). Alternatives to disposal to sewer can include modified septic tanks (with enzymes) and centralised collection of greywater, e.g. tankers.

- Purpose-built greywater disposal soakaways should be provided for plots that are <350 $m^2$ (eThekwini, 2003), but can only be provided in areas where the soil is permeable and the water table is low (City of Cape Town, 2005).
- Should discharge into the stormwater system be considered, further treatment of the greywater is required (City of Cape Town, 2005).

4. Operation and maintenance

- Communities provided with greywater disposal systems should be educated in terms of their purpose and correct use, i.e. greywater systems may not be used for the disposal of blackwater or night soil (City of Cape Town, 2005, eThekwini, 2003).
- The maintenance of gratings and sediment and fat traps should be programmed to take place on a regular cycle, depending on capacity and usage of system (City of Cape Town, 2005).

There are also some basic handling rules with respect to health issues that should be followed when disposing or reusing greywater in rural areas, as well as some of the more formalized urban and peri-urban areas that have enough space for on-site disposal (i.e. low and medium density). These guidelines have been adapted from Murphy (2005) and include the following:

- Use natural cleaning products where possible, e.g. phosphate-free, low-sodium, and zero-content boron (Fane & Reardon, 2005; CSBE, 2003)
- Do not store greywater for more than 24 hours (and preferably no more than a few hours) before use or disposal (Fane & Reardon, 2005; State of Victoria, 2003)
- Do not dispose of greywater to surface or stormwater or into the groundwater system (State of Victoria, 2003)
- Ensure greywater does not contaminate drinking water sources (State of Victoria, 2003)
- Greywater should not be allowed to leave the boundaries of the property on which it is generated (CSBE, 2003; State of Victoria, 2003)
- Greywater should be withheld from areas where children play, such as lawns (CSBE, 2003; State of Victoria, 2003)
- Do not irrigate with greywater if the soil is already saturated and do not allow surface ponding of greywater (State of Victoria, 2003;, Fane & Reardon, 2005)
- Do not use kitchen wash water or water that has been used to wash nappies or other clothing soiled by faeces and/or urine, for irrigation purposes (State of Victoria, 2003; Little, 2004)
- Do not use greywater if anyone on the premises is suffering from an infectious health condition (Little, 2004)
- Always use subsurface irrigation and never hose, spray or mist with greywater (State of Victoria, 2003)

- Avoid watering fruits and vegetables with greywater if they will be eaten raw or under-cooked and always wash and cook food that has been irrigated with greywater (CSBE, 2003; State of Victoria, 2003)
- Wash hands after contact with greywater (State of Victoria, 2003)

## Conclusions

This study has provided a general overview of the large variety of conditions that occur in the non-sewered settlements in SA, and has highlighted the implications of certain settlement characteristics (specifically settlement density) on greywater management in these areas. In addressing the original objectives of this research the following conclusions have been made:

1. There is a noticeable gap between Government policy on water provision and the long-term sustainable water management challenges for the country – whilst the water supply interventions are aimed at improving the health of individuals, no attention has been given to the resultant longer-term impacts on environmental health in non-sewered areas.
2. Social dynamics and behavioural patterns have a significant impact on the way that communities deal with water supply and wastewater management issues, particularly with respect to greywater disposal. These behavioural patterns (and the drivers associated with them) must be taken into account when assessing specific greywater management options for individual settlements. This is particularly relevant when considering greywater use options in certain areas where potable water resources are limited.
3. An estimated total volume of between 440 000 $m^3$ and 575 000 $m^3$ (average 500 000 $m^3$) of greywater is generated on a daily basis in the non-sewered areas of South Africa.
4. The quality of greywater in non-sewered areas differs significantly to the greywater that is generated in higher-income, sewered areas in that there is a greater variation in the concentration of the various pollutants and at its most concentrated it should be considered hazardous. There is therefore significant risk involved with the on-site disposal of greywater in non-sewered areas.
5. Whilst the links between greywater use and the polluting effects of detergents have yet to be established properly, it has been observed that people living in non-sewered settlements are generally not prepared to use greywater for irrigation purposes as it is considered harmful to certain species of plants. The water quality data from the site surveys confirmed that greywater from non-sewered areas is generally unfit for use.
6. Methods of reducing levels of sodium and phosphorous in greywater need to be investigated and the use of high phosphate detergents discouraged if the concept of using certain types of greywater (e.g. first-wash or rinse water) for irrigation purposes is to be considered.
7. The determination of greywater generation rates for specific non-sewered settlements throughout South Africa can be used to determine recommended management practices, with off-site disposal of greywater recommended for settlements that have greywater generation rates > 2,500 *l*/ha.d.

8. The management of greywater should be included in the series of targets that have been set for the delivery of sanitation services in terms of the Department of Water Affairs and Forestry's Strategic Framework for Water Services.
9. Greywater management should be included at the planning stage for the provision of water services to low-income settlements, as it is closely linked to the levels of service in a settlement, particularly the availability of water supply.
10. There are currently no definitive health regulations, guidelines or by-laws in place for the use / disposal of greywater in the non-sewered areas of South Africa. Management options must be put in place to reduce the negative impacts from greywater disposal practices in non-sewered areas, and it is vital that the relevant local authorities take ownership of any greywater management schemes in place.

In summary, it can be stated that, for the typical high-density informal settlements that are mushrooming around the main cities in SA, the greywater is particularly hazardous from a pathogenic and salinity point of view ("dark" greywater) and should be managed as a sanitation issue rather than a drainage one. It is essential that there is systematic management of greywater in non-sewered settlements both in terms of reducing health risks by eliminating inappropriate disposal and surface ponding, and also to provide benefits in terms of greywater use initiatives. Whilst it is important that communities are educated and empowered with respect to greywater management, it is the responsibility of the local authority concerned to ensure that working systems are in place.

## Recommendations for future research

The following future research needs in the field of greywater management have been identified from the current study:

1. Detailed long-term surveys of greywater generation, use and disposal, investigating current practices and their consequences, at local community level. This would include accurate measurements of water consumption and greywater generation in specific settlements. This is the subject of a current WRC project (K5/1654).
2. Development of guidelines for the management and use of greywater, specifically where it is being used in small-scale agriculture, including careful consideration of risk management in the context of greywater use in informal settlements – this is the subject of a current WRC project (K5/1639).
3. Detailed assessment of the quality of the greywater produced by low-income urban communities in South Africa with respect to pathogen loading and microbiological quality, and the health risks posed by such water.
4. The identification of preferred methods of communicating greywater management information to authorities and communities (e.g. maps, booklets, flow charts etc. ) so that successful strategies may be implemented, particularly in terms of healthcare programmes.

5. The identification of the specific impacts of greywater disposal from non-sewered areas on groundwater quality based on the consideration of specific aquifers, including the collection of a long-term data set and analysis of these aquifers.
6. The identification of the specific impacts of greywater disposal on the quality of surface water (wetlands, and rivers) downstream of non-sewered settlements, using tracer studies.
7. The identification of the specific impacts of greywater use and disposal on soil conditions through the use of soil salinity surveys.
8. Investigation into the links between greywater disposal and the polluting effects of detergents, i.e. the costs associated with the long-term use of various detergents on the environment, and the identification of methods of reducing levels of sodium and phosphorous in these detergents.
9. Assignment of financial, socio-economic and environmental cost estimates to greywater problems, and financial cost estimates to the management of future impacts.
10. Development of an information system to disseminate the most appropriate technological options for greywater disposal relevant to South Africa.
11. Research into the presence and levels of xenobiotic organic compounds (XOCs) in greywater and their environmental impacts.
12. Research into the levels of Boron (B) in greywater and how it impacts on the use of greywater as an irrigation resource.

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# Glossary of terms and abbreviations

| | |
|---|---|
| AIDS | Acquired Immunodeficiency Syndrome |
| ARC | Agricultural Research Council |
| B | Boron |
| Blackwater | Wastewater from flush toilets |
| BOD | Biochemical Oxygen Demand |
| CBO | Community Based Organisation |
| Cl | Chloride |
| CMS | Catchment Management Strategy |
| CoCT | City of Cape Town |
| COD | Chemical Oxygen Demand |
| CSBE | Centre for the Study of the Built Environment |
| CSIR | Council for Scientific and Industrial Research |
| DANCED | Danish cooperation for environment and development |
| DEAT | Department of Environmental Affairs and Tourism |
| DFID-KaR | Department for International Development – Knowledge and Research Programme |
| DO | Dissolved Oxygen |
| Domestic sewage | Combination of greywater and blackwater that is discharged to sewer |
| DRA | Demand Responsive Approach |
| du/ha | Dwelling units per hectare |
| DWAF | Department of Water Affairs and Forestry |
| EC | Electrical Conductivity |
| Ecosan | Ecological sanitation |
| EPA | Environmental Protection Agency |
| EU | European Union |
| FAO | Food and Agricultural Organisation of the United Nations |
| FBW | Free Basic Water |
| GDP | Gross Domestic Product |
| GHS | General Household Survey |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| Greywater | Wastewater that is produced from household processes (e.g. washing dishes, laundry and bathing) without input from toilets |
| ha | Hectare |
| HEA | Household Economy Approach |
| HIV | Human Immunodeficiency Virus |
| IDRC | International Development Research Centre |
| IIED | International Institute for Environmental Development |
| IMF | International Monetary Fund |
| IT | Information Technology |

| | |
|---|---|
| K | Potassium |
| *l* | litre |
| LA | Local Authority |
| *l*/c.d | litres per capita per day |
| *l*/du.d | litres per dwelling unit (household) per day |
| *l*/ha.d | litres per hectare per day |
| LOS | Level of Service |
| MCDM | Multi criteria decision making |
| MDG | Millennium Development Goal |
| Mg | Magnesium |
| N | Nitrogen |
| Na | Sodium |
| NGO | Non Governmental Organisation |
| $NH_3$ | Ammonia |
| Non-sewered | Without on-site waterborne sanitation |
| NWA | National Water Act |
| NWRS | National Water Resource Strategy |
| P | Phosphorous |
| $PO_4$ | Phosphate |
| RDP | Reconstruction and Development Programme |
| RSA | Republic of South Africa |
| SABS | South African Bureau of Standards |
| SAR | Sodium Adsorption Ratio |
| SDI | Sustainable Development Indicator |
| SIWI | Stockholm Water Institute |
| SS | Suspended Solids |
| STPP | Sodium tripolyphosphate |
| TCSC | Test case steering committee |
| UCT | University of Cape Town |
| UKZN | University of KwaZulu-Natal |
| UWWTD | Urban Wastewater Treatment Directive |
| VIP | Ventilated Improved Pit |
| WHO | World Health Organisation |
| WRC | Water Research Council |
| WRM | Water Resource Management |
| XOC | Xenobiotic Organic Compound |

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# 1. Introduction

The South African government is currently focused on attaining adequate water and sanitation coverage throughout the country. The basic level of service to meet this requirement relates in most cases to on-site dry latrines (VIPs or similar) and 25 litres per capita per day (*l*/c.d) of drinking water, as prescribed in the Water Supply and Sanitation Policy White Paper of the Department of Water Affairs and Forestry (DWAF, 1994). The connection of low-income settlements to municipal water sources has thus occurred on a massive scale in South Africa (SA), frequently without giving adequate attention to greywater drainage and management in those areas that are provided with on-site dry sanitation. In the absence of a suitable conveyance system, greywater is generally tossed onto the ground outside the dwellings and the resulting total pollution load, particularly from densely populated settlements, has the potential to create a host of environmental and health impacts. It is likely that the potential for problems related to the disposal and management of greywater will increase as the water services are improved, and solutions are therefore required to manage these impacts.

In response to this a two-year investigation was initiated by the Water Research Commission (WRC) of South Africa into the use and disposal of greywater in the non-sewered areas of SA, and in particular to attempt to assess the health and environmental impacts of greywater in these communities. The potentially negative impacts from greywater disposal are felt most strongly in those areas where water supply services and on-site sanitation have been implemented but little or no consideration has been given to the planning for and management of greywater. The association between poor sanitation and ill health is well-known, as demonstrated by World Health Organisation (WHO, 1996) estimates that diarrhoeal diseases are responsible for over a quarter of the deaths of children in the world, and the fact that 80% of these deaths are reported as resulting from a lack of sanitation and water (Esrey, 1998). In South Africa, recent research has shown that 43 000 people, mainly children under the age of 5 years, die from diarrhoeal diseases each year (Mara, 2001) and it is in this context that it has become essential to establish the link between greywater disposal and environmental health issues.

For the purposes of this study, greywater has been defined as the wastewater that is produced from household processes (e.g. washing dishes, laundry and bathing) without input from toilets, and non-sewered areas are those areas without on-site waterborne sanitation. Waterborne sanitation has been taken to include all methods of sewage treatment from flush toilets, including septic tanks. Communities with dysfunctional or inadequate sewerage systems (particularly communal toilet facilities) have also been included in the definition of non-sewered areas.

The original objectives of the research were as follows:

1. Complete a scoping exercise to identify current and historic greywater management initiatives in urban and rural areas, and to identify problem areas / challenges.
2. Determine and assess existing management and disposal practices within South Africa.

3. Quantify the greywater generated by different types of settlement and level of service.
4. Quantify and highlight potential problems / challenges that pose a risk to human and environmental health.
5. Assign a financial, socio-economic and environmental cost to greywater problems, and financial costs to the management of future impacts.
6. Propose strategic options and technical, financial, and social interventions for best management practices to be promoted to meet the various challenges.
7. Investigate the possibility of using GIS and spatial information technology for the ongoing management of greywater resources in South Africa.

It became evident during the course of the investigation that the requirements of Objective 5 could not be met within the time-frame and available budget of the project and it was therefore recommended that it be considered as a project on its own. This was acknowledged by the Reference Group and the decision was taken not to attempt to address this objective in any detail in the final report. Recommendations in this regard have been made in the chapter on future research requirements (Chapter 7).

The various chapters in the report deal with the following aspects:

**Chapter 2** reviews greywater management from both a local and international perspective and includes comment on the typical quantities and quality of greywater produced. Current legal aspects and policies are noted, as well as the government strategies that are in place for sanitation provision as a whole. The relevant social attitudes to sanitation issues, and in particular wastewater use, are also discussed in some detail.

**Chapter 3** describes the research methodology that was adopted and pays particular attention to the challenges that were faced in the development of this methodology. The site selection process and the survey procedures that were followed have also been recorded. The section on information flow provides details on the use of databases and GIS in the project and discusses the difficulties in obtaining the necessary spatial information for the ongoing management of greywater disposal in the non-sewered areas of South Africa.

**Chapter 4** presents the summarized findings from the case studies on greywater use and disposal in South Africa, specifically with respect to trends, behaviour patterns, lessons learnt etc. , and gives estimates for the amount and quality of greywater currently being generated in the non-sewered areas in South Africa. Census 2001 data was used (after being adjusted with more recent information from 2005) to convert the average figures for greywater volumes obtained for the individual sites, into estimates for the nine provinces, and hence for the country as a whole. This is followed by a discussion on the greywater management options that have been identified for non-sewered areas in South Africa and various proposals are made regarding interventions for greywater management. A brief description of the greywater issues that were identified in the DWAF “Dense Settlements” project has been included in order to compare these findings with the results from the site surveys conducted as part of this study.

The general strategies that have been developed relating to greywater disposal and use are described in **Chapter 5**, as well as the proposed management guidelines for the disposal of greywater in the non-sewered areas in South Africa

**Chapters 6 and 7** comprise a discussion of the overall findings and conclusions arising from the research project as well as recommendations for future research in this regard.

A comprehensive list of references is included at the end of the main body of the report. **Appendix A** gives examples of the questionnaires that were used during the site surveys as well as in the discussions with relevant officials at the local authorities that were visited. A list of some of the commercially-available greywater treatment technologies is included as **Appendix B**. The specialist input regarding the health aspects of greywater use is presented in **Appendix C**, which also contains limited statistics on the incidence of sanitation-related disease at district level in South Africa. The results from the on-site surveys throughout the country have been written up as a series of case studies, which appear as **Appendix D.**

# 2. Literature Review

The main focus of the literature review was to identify current and historic greywater management initiatives in South Africa, but it also included the identification of research into planning, strategies and procedures for sanitation provision, as well as the management of water quality effects on settlements. The concept of greywater use in terms of sustainable sanitation was investigated and some of the social and economic aspects of greywater use were also considered.

## 2.1 Review of legal aspects, policies and strategies relating to greywater

South African water policy has been in a state of rapid transformation since 1994. The main aim of the current policy is normalising water distribution practices so as to redress previous social inequalities, and to discourage colonial traditions of wasteful water use habits and patterns and promote sustainable usage of water. These new approaches are defined in the "White Paper on a national water policy (DWAF, 1997a), which also spells out the minimum standards that South African citizens can expect from their water services.

The health, legal and economic considerations as well as the determination of the National strategy for managing pollution from settlements are described in the DWAF reports on "Managing the water quality effects of settlements". They include: "The National strategy" (DWAF, 2001b), "Legal considerations for managing pollution from settlements" (DWAF, 2001c) and "The national costs of pollution from settlements" (DWAF, 2001d). These reports include references to the Water Services Act No. 108 of 1997 (RSA, 1997), which has as its primary focus the regulatory framework pertaining to the provision of water services, including sanitation services, by local authorities. It is worth noting that the Water Services Act defines water services as "water supply services and sanitation services", and sanitation services as "the collection, removal, disposal, or purification of human excreta, domestic wastewater, sewage and effluent resulting from the use of water" – i.e. this implies that greywater management should be included as part of the Water Services Act.

The "White paper on water supply and sanitation policy" (DWAF, 1994) defines basic adequate services as a potable water supply of 25*l*/person per day within 200m cartage distance, and a ventilated pit latrine per household. Rapid urbanisation and the increasing density of residential development in both urban and rural environments pose significant threats to groundwater from unimproved pit latrines, soakaways, leaking sewers etc. DWAF seeks to "ensure that groundwater quality is managed in an integrated and sustainable manner that provides adequate protection to the resource and secures the supply of acceptable quality for all recognised users" (DWAF, 1997b). While it is well recognised that the environment can protect itself against human inputs, including the disposal of waste on soil surfaces, there are limitations, which if exceeded, could result in contamination and then pollution. For this reason, the recommendations made in the document on "Policy and strategy for groundwater quality management in SA" (DWAF, 2000) are an attempt to promote the development and implementation of cleaner sanitation and waste disposal practices in rapidly developing areas. The "White paper on basic household sanitation" (DWAF, 2001a) expands on this by highlighting the impacts of poor sanitation on health and the environment, articulating government policies, providing a framework for sanitation improvement strategies, and promoting co-ordination amongst role-players.

The "Strategic framework for water services" (DWAF, 2003) spells out Government's commitment towards eliminating the backlog in basic water services and improving levels of service over time (e.g. "intermediate" water supply will be increased from 25*l* to 50*l* per person per day from a yard tap). Current targets for water and sanitation service provision are as follows:

- All citizens to have access to basic water supply by 2008
- All citizens to have access to basic sanitation by 2010
- All bucket toilets to be eradicated by 2006
- Investment in water services infrastructure to be at least 0.75% GDP
- Free basic water policy to be implemented in all Water Service Authorities by 2005
- Free basic sanitation policy to be implemented in all Water Service Authorities by 2010

There is no specific reference to greywater in the National Water Act (NWA) No. 36 of 1998 (Republic of South Africa, 1998) although the sections concerning water resource management do apply. According to the "White paper on a national water policy for South Africa" (DWAF, 1997a), South Africa's water is defined as a "common resource" and its use should be balanced with the protection of the resource in such a way that the resources are not degraded beyond recovery, i.e. "environmentally sustainable use". The requirements for ensuring long-term utilisation in terms of the policy necessitate implementing resource and source-directed measures – the source-directed controls focus on impacts from both point and non-point sources. These measures (which include standards, management practices, guidelines, procedures etc. ) are directed at managing and controlling the generation of waste at source and are aimed at provincial governments and municipalities. It is envisaged that the establishment of catchment management agencies in terms of section 78(1) of the NWA will assist with building capacity, developing guidelines and creating awareness in local government and with the inhabitants of the settlements.

There appears to be no objection in principle to the use of household greywater for individual property irrigation in South Africa but this is subject to the different wastewater regulations and by-laws of the relevant local authorities (Murphy, 2005). None of these regulations relate directly to greywater disposal however, and most refer only to normal precautions with respect to nuisances resulting from irrigation with any wastewater (such as using sub-surface or drip irrigation only) – either in terms of common law, the Health Act, or the NWA. Nuisances are defined *inter alia* as fly / mosquito breeding, objectionable odours, surface ponding of water, and entry of polluted water onto neighbouring properties (Alcock, 2002).

## 2.2 Characteristics of greywater

There has been a large amount of research internationally on the chemical and microbiological composition of greywater owing to the fact that there is increasing interest in the use of this wastewater in both industrialised and developing countries. Clearly, the composition of greywater depends on the sources from where the water is drawn, as well as the use to which this water is put, but there are general characteristics that apply to greywater. The typical composition of greywater generated in developed countries has been discussed in detail in the literature review by Eriksson et al. (2002). The focus of this research was on the content of oxygen consuming compounds, Chemical Oxygen Demand (COD) and Biochemical Oxygen Demand (BOD), nutrients and some microorganisms. Most of the COD derives from household chemicals like dishwashing and laundry detergents, which are also the primary source of phosphates ($PO_4$) and sodium (Na) in the greywater. The total nitrogen (N) content of greywater is lower than in domestic sewage as urine is generally not present. In general greywater contains lower levels of organic matter and nutrients compared with ordinary domestic wastewater, but heavy metals appear to be in the same concentration range. Microorganisms can be introduced into greywater from laundry and kitchen wash waters and can include pathogenic viruses, bacteria, protozoa and helminthes in variable numbers. Ottoson (2003) suggests that the risk of introducing pathogens into the greywater may however often be much lower than the indicator bacterial counts signal due to the fact that coliform indicator growth may occur in the system, thereby overestimating the faecal load.

Lindstrom (2000) reported that the most significant difference between blackwater and greywater lies in the rate of decay of the pollutants in each, with greywater generally decomposing much faster than blackwater. This means that greywater discharged directly into surface water will have a more immediate effect on the recipient waterbody than blackwater. The impact of greywater on groundwater is less than with blackwater discharges owing to the rapid decomposition rate of greywater once it infiltrates into soil.

Other pollutants that could occur in greywater include heavy metals and xenobiotic organic compounds (XOCs). XOCs constitute a heterogeneous group of compounds that originate from the chemical products used in households, such as detergents, soaps, perfumes etc. Information about the presence and levels of XOC’s is scarce and it has been recommended that further research be conducted in this regard if greywater is to be used for irrigation or infiltration as they may potentially be toxic to plants and could pollute the groundwater (Eriksson et al., 2002).

In his research on greywater use for sustainable water management in the sewered areas of Jordan, Al-Jayyousi (2003) further noted that the greywater collected from clothes washers, bathtubs, showers and basins is relatively low in suspended solids (SS) and turbidity, indicating that most of the contaminants are dissolved. Greywater generally has high COD (up to 5 000 mg/l) with a high COD:BOD ratio (4:1) with a deficiency in macronutrients (COD:$NH_3$:P of 1,030:2.7:1 compared to typical domestic wastewater of 100:5:1). It can also contain up to $10^5$/100 ml pathogens and these numbers increase on storage, making the key to successful treatment the immediate handling of the greywater before it reaches an anaerobic state.

A study in Malaysia by Idris et al. (2005) reported that a significant portion of the water in urban streams in that country is contributed by untreated sullage from residential settlements, and that this is a major contributor of pollution with high concentrations of BOD, COD, Ammoniacal Nitrogen ($NH_3$), $PO_4$ and Total Kjeldhal Nitrogen (TKN), and low levels of Dissolved Oxygen (DO).

In the South African context there was an absence of local data on the chemical and microbiological composition of greywater until the study by Alcock (2002), which considered in some detail the typical inputs as well as the chemical composition of domestic greywater from a middle-class, sewered household in Stellenbosch. Household greywater was found to have high concentrations of chloride (Cl), Na and potassium (K) with variable levels of N and phosphorous (P). The greywater was generally alkaline and had a reasonably high sodium adsorption ratio (SAR). As with the international research, it was noted that storage of greywater can lead to changes in its chemical and microbiological composition, which may increase the pollutant load.

More relevant studies in terms of the characteristics of greywater from non-sewered, lower-income communities in SA have recently been conducted by Källerfelt & Nordberg (2004), the Pollution Research Group of the University of KwaZulu-Natal (UKZN, 2005) as well as Stephenson et al. (2006). Källerfelt & Nordberg evaluated the effectiveness of local greywater treatment in the Moshoeshoe Eco Village and Hull Street housing estates in Kimberley, Northern Cape. The chemical analysis of the greywater samples that were taken from the inlets to the treatment facilities (comprising septic tank, sand filter, and modified french drain) are shown in Table 2.2.1.

**Table 2.2.1 Samples from the inlets to the greywater treatment units in Moshoeshoe Eco Village (Källerfelt & Nordberg, 2004)**

| Variable | Range | Mean value | Standard deviation |
|---|---|---|---|
| pH | 6.09-7.03 | 6.69 | 0.33 |
| Conductivity (mS/m) | 83.0-132 | 101 | 17 |
| $PO_4$-P (mg/l) | 14.8-56.2 | 30.2 | 15.5 |
| COD (mg/l) | 530-3520 | 1490 | 945 |
| SS (mg/l) | 69.0-1420 | 495 | 432 |

UKZN have conducted plant trials with household greywater from the Cato Manor area in Durban, and Stephenson et al. monitored the greywater from seven different households in Kwamathukuza township in Newcastle, KwaZulu-Natal where greywater is disposed onto the ground in front of the houses. Tables 2.2.2 and 2.2.3 summarise the greywater quality results from these studies. These results are compared to those obtained for the samples taken during the site surveys which were conducted as part of this research project in Section 4.4.

It was found during the Hull Street study that the bacteriological quality of the greywater varied considerably and was very dependent on the specific water use just before sampling (e.g. preparation of food, hand washing etc. ). In some cases there was an increase in *Escherichia coli* (E.Coli) counts at the outlet from the treatment units owing to the high levels of organic material in the septic tanks which promoted bacterial growth. On the whole, relatively little information is available on the microbiological composition of greywater in South Africa and what there is has focused mainly on total bacterial counts. An important defining factor in the measurement of the type and concentration of microorganisms in greywater is the general health of the population and the ability of infectious agents to survive outside of their hosts. What has been documented is that bacterial counts are likely to be higher in kitchen wastewater compared with bathroom and laundry wastewater, but that this would depend on whether there are babies in the family (there are higher bacterial loads from washing nappies) and the levels of personal hygiene. Consideration should be given in this regard to the role of greywater disposal in the transmission of pathogens, particularly if the method of disposal is not managed properly.

**Table 2.2.2 Summary of composite greywater sample from Cato Manor (UKZN, 2005)**

| Variable | Range | Mean value |
|---|---|---|
| pH | 5.8-6.3 | - |
| Conductivity (mS/m) | 144-148 | - |
| $PO_4$-P (mg/l) | - | 11 |
| COD (mg/l) | - | 1135 |
| TKN (mg/l) | 24-30 | - |

**Table 2.2.3 Summary of greywater sampling from 7 households in Kwamathukuza (Stephenson et al., 2006)**

| Variable | Range | Mean value | Standard deviation |
|---|---|---|---|
| $PO_4$-P (mg/l) | 0.29-18.89 | 4.48 | 7.13 |
| COD (mg/l) | 999-1625 | 1379 | 216.8 |
| SS (mg/l) | 265.2-1260.8 | 597.6 | 346.2 |

Recognition of the relationship between increasing phosphorous inputs to surface waters and the subsequent increase in eutrophication of water bodies resulted in efforts being made by the USA, Japan and some EU member states to reduce these phosphorous loads by decreasing the amount of sodium tripolyphosphate (STPP) used in detergents, and switching to alternative non-phosphate based additives, such as Zeolite A (European Commission, 2002). Recommendations on "Phosphates and alternative detergent builders" included a general ban on all EU member states on the use of STTP as a builder for household detergents, and improving wastewater treatment through implementation of the Urban Wastewater Treatment Directive (UWWTD).

In SA it appears that STTPs are still used to some degree in household detergents – Alcock (2002) reported that the water from clothes hand washing solutions typically contains between 0.62 and 1.22 g/*l* of STTP. A study conducted by Pillay (2001) on the impact of detergent phosphorous on eutrophication reported that the South African detergent industry formulates with phosphorous builders and therefore uses the maximum amount of phosphorous. An investigation of the costs and benefits of eliminating detergent phosphorous altogether indicated that the costs outweighed the benefits, but Pillay concluded that the cost of other systems which use reduced amounts of phosphorous should be investigated as they may still provide some benefit to the environment whilst being affordable.

## 2.3 Typical greywater volumes

The generation of greywater is directly related to the consumption of water in a household and is dependent on a number of factors including the level of service provision, tolerance of residents to pollution and the communities' level of awareness of health and environmental risks. It could be assumed that greywater accounts for virtually all water usage in non-sewered areas except for that which is used for drinking purposes, that which is used consumptively in cooking, and the water that remains on the surfaces of washed articles. Wood et al. (2001) noted that there is a general absence of data on the quantification of greywater in dense informal settlements owing to the fact that generally there is no proper measurement of services in these areas, and assumptions based on population estimates are indicative at best. During the on-site surveys that were conducted as part of this research, residents of non-sewered settlements reported water consumption figures ranging from 4.7*l* to 28*l* per capita per day (*l*/c.d) although, in the general absence of metering, these figures do not accurately reflect the total water drawn from the system (i.e. leaks, under-reporting etc. are not accounted for).

Källerfelt & Nordberg (2004) studied two settlements in Kimberley that have on-site, metered water supply with dry (ecological) sanitation in the form of urine-diverting toilets and greywater treatment facilities. The average water consumption for the two areas during the period of study was found to be 37*l*/c.d and the mean greywater flow into the treatment facility was calculated as 25*l*/c.d (i.e. 68%). This figure does not however take into consideration the fraction of greywater from households that is tossed onto the ground, and not disposed into the treatment system.

Alcock (2002) reported that water consumption in households without waterborne sewerage will be markedly less than in Western-style households and is primarily dependent on the availability of a standpipe at the house. Similarly, multiple-tap households will use substantially more water than those with access to only one tap. Alcock examined several water consumption surveys with reference to South African urban, peri-urban and rural areas in order to determine trends, and estimated that water consumption for households with a standpipe in the yard is of the order of 30 – 80*l*/c.d. Where water has to be carried from an external source (250m – 3km to the source), a mean consumption of 9 – 50*l*/c.d can be expected. The study also refers to research conducted by van Schalkwyk (1996), who estimated that the water used for dish-washing, cleaning the house, clothes washing, and personal hygiene varies from approximately 12 to 50*l*/c/d. Under such circumstances van Schalkwyk concluded that a greywater volume of 150*l* per household per day is possible, assuming a mean household size of 6, and the fact that up to half of the water used for washing could be retained on surfaces.

The planning scenario in Alcock's research referred to low income households with on-site sanitation and 200*l* ground-level water tanks. It was estimated that the available greywater generated per person at these households could be of the order of 25 – 75*l* per day, averaged over a week.

Consumptive water use coefficients were determined for various urban water use categories by Stephenson & Barta (2005) so that return flows to receiving river ecosystems could be determined. The figures that were given for RDP and informal houses with water connections (in-house or communal) but without waterborne sanitation ranged from 0 to 20%, i.e. 0 to 20% of the total water use was used consumptively and not disposed in any manner. This does not necessarily give an indication of the amount of wastewater that is discharged onto the ground however.

The ranges of typical domestic water consumption and greywater generation figures for the different levels of service (LOS) as quoted in the "Red Book" – "Guidelines for human settlement planning and design" (CSIR, 2001) are shown in Table 2.3.1. As will be seen in Chapter 4, these figures are in close agreement with the figures obtained during the site surveys.

**Table 2.3.1: Typical domestic water consumption figures and greywater volumes ("Guidelines for human settlement planning and design", CSIR Red Book, 2001)**

| Type of water supply | Typical consumption (*l*/c.d) | Range (*l*/c.d) | Greywater generation (*l*/c.d) |
|---|---|---|---|
| **Communal water point** | | | |
| • Well or standpipe at > 1000m distance | 7 | 5-10 | - |
| • Well or standpipe at distance 250 – 1000m | 12 | 10-15 | - |
| • Well or standpipe nearby, <250m | 20 | 15-25 | - |
| **Domestic water consumption** | | | |
| • Standpipe within 200m | 25 | 10-50 | 20-30* |
| • Yard connection | 55 | 50-100 | 30-60* |
| • Yard connection with dry sanitation | 55 | 30-60 | - |
| • Yard connection with LOFLOS | 55 | 45-75 | - |
| • Yard connection with full-flush sanitation | 55 | 60-100 | - |

* Sanitation type – pit toilets

Similar figures have also been determined in non-sewered areas around the world, e.g. Idris et al. (2005) investigated the disposal of greywater (sullage) from an urban residential area in Selangor, Malaysia, where the sullage from all houses is discharged via a detention pond into the Kuyoh River, and sewage is conveyed by a separate sewer line to an oxidation pond. The study concluded that approximately 83% of the total water consumption in the study area was released as greywater.

For the purposes of this study it was decided that a figure of 75% of the water consumed would be used to calculate the volumes of greywater being generated in the non-sewered areas in South Africa – see Chapter 4 for further details in this regard.

## 2.4 Greywater management initiatives

Greywater management initiatives have fast been gaining momentum as the pressures of increasing populations and poor or inappropriate service provision have resulted in the generation of surface and groundwater pollution, particularly in high density urban settlements, presenting a threat to community health and the receiving environment. The links between health, sanitation and poverty have been demonstrated through initiatives such as the Khayelitsha Water and Sanitation Programme (Stern et al., 2004) which highlighted the high rates of worm infestation and diarrhoea amongst children in informal settlements as a result of inadequate toilet facilities. The poor environmental health situation in Khayelitsha is further aggravated by highly polluted urban stormwater runoff which is caused by *inter alia* greywater and solid waste disposal, and there is therefore an urgent need to address the sanitation crisis.

In the report by Ashton & Bhagwan (2001) it was noted that the rapid growth of urban areas in SA has been accompanied by increased quantities of contaminated runoff from settlements, which has accelerated the degradation of water resources. The impact that low-cost, high-density urban land use has on catchments warrants urgent attention. Monitoring studies have to date often overlooked site-specific causes of contaminated runoff. An emerging problem in this regard is that of greywater, the disposal of which requires attention as it has the potential to cause severe pollution of water resources as well as impacting local soils.

The causes of water quality problems resulting from greywater disposal are reported in "A strategy to manage the water quality effects of settlements: A guide to problem analysis" (DWAF, 2001f) as being:

- physical – e.g. when no services are provided or the services are inadequate,
- institutional – e.g. when services are not operated or maintained properly, or
- social – e.g. when people do not use or pay for services properly, or when vandalism occurs.

It is unlikely that any cause will exist in isolation from another cause and there are likely to be numerous connections between physical, institutional and social causes. These should be taken into account when choosing specific greywater management options.

Another relevant South African study in this regard is the research done by Wood et al. (2001) which attempted to provide information on the significance of poor waste management in dense informal settlements where greywater and stormwater management are generally not recognised as services. The researchers tried to quantify the significance of greywater in informal settlements and identify specific contributory factors as well as opportunities for developing low technology options for the cost-effective optimisation of waste management, so as to permit the gradual development of greywater management. Factors identified in greywater generation were physical (services), institutional (existing service supply policies were reviewed), educational, and socio-economic. Some of the current South African greywater management initiatives that were identified in the study included the following:

- Provision of controlled water supplies to limit wastage, as in the Durban Metro stepped supply scheme.

- Community participation in technology selection and appropriate location, construction and maintenance of sanitation services (e.g. Kleinskool, Port Elizabeth).
- Stormwater management by provision of collection trenches which gravitate excess stormwater away from individual shacks in Soweto-on-Sea settlement, Port Elizabeth.
- The provision of catchpits in an informal settlement in Paarl to collect greywater from standpipes for drainage to the municipal sewerage system.

The study considered the community perspective as well as the local authorities' perceptions of service provision by consulting with a wide range of stakeholders, and provided the basis for the communities and service providers to select technologies and management opportunities to best suit their needs. It became clear during the research that water supply is the primary concern amongst residents of settlements, followed by sanitation, stormwater control, solid waste management, and lastly greywater pollution control. The communities tended to be relatively naïve on the importance of greywater management and did not have a good understanding of the role of Local Authorities in service provision. It was concluded that, as sanitation, solid waste and stormwater services are implemented in phases, opportunities for greywater management should be considered as part of the integrated services. The phased implementation of services should however not be allowed to create health problems in the short to medium term and the promotion of greywater management and control should form part of community healthcare programmes.

Drought-prone areas in SA have also started considering the use of greywater as an alternative water resource, and research has been conducted on the different use and treatment options that could be used to render the water fit for use. Van der Linde (1997) reported that the town of Hermanus has had to opt for a comprehensive water conservation programme due to the fact that the demand for water consistently outstrips the supply in the town. Included in their 12-point conservation plan are *inter alia* innovative tariff structures and the potential use of greywater for food gardening. Other management initiatives include using the greywater for dust control, car washing and in pour flush toilets. Pretorius & de Villiers (2003) observed people disposing of greywater via communal (sewered) toilets but this becomes problematic when the facilities are blocked and the additional volumes of wastewater could then cause the units to overflow, thereby exposing the users to pathogens. These potential hazards thus need to be taken into account when developing waste management plans for settlements.

## 2.5 Survey of greywater treatment and options for use

In order to fully understand the various greywater management initiatives that are taking place throughout the world it is necessary to carefully consider the characteristics of greywater, how it is generated and the possibilities for its treatment and use. According to Al-Jayyousi (2003) Japan, the US and Australia maintain the highest profile in greywater use worldwide, although Jordan, Israel, Canada, the UK, Germany and Sweden are also involved in active research and applications. Australia and the US are also considered by Al-Jayyousi to be the most advanced from a regulatory point of view, although there are regulations and guidelines in place in various countries to control the practice of greywater use and reduce health and environmental risks (e.g. State of Victoria, 2003).

A wide variety of technologies have been used or are being developed for greywater treatment and use, with the selection of technology depending on many factors such as the scale of operation, end use of the water and socio-economic factors including regional customs and practices (Jefferson et al., 2004). These systems include:

- Natural treatment systems
- Basic filtration
- Chemical processes
- Physical and physicochemical processes
- Biological processes

Greywater use initiatives in most countries are driven generally by limits on the water supply, either by high population densities or drought conditions. Greywater is typically used for restricted irrigation or toilet flushing, usually with some form of pretreatment on-site. Examples of this include the low cost greywater treatment units that were developed to help the rural poor in a case study in Jordan (Bino, 2004) where the quality of treated (generally anaerobic treatment) greywater was found to be suitable for restricted irrigation, i.e. crops not directly consumed by humans. In this study special environmentally-friendly detergents were also formulated with potassium and magnesium (Mg) ions (instead of sodium) in an attempt to control the long-term negative impacts associated with detergents containing high levels of sodium.

There has been a reassessment of domestic water consumption in Israel in recent years due to the fact that the costs and environmental impacts of desalination are so high. Friedler & Galil (2003) evaluated the technological aspects of greywater recycling in multi-storey buildings (particularly for toilet flushing) with a view to providing sustainable solutions. There have also been agricultural initiatives in peri-urban areas in Palestine examining the use of small-scale trickling filters for the treatment of greywater for use in home gardens (Mohammed, 1998).

Research in Zimbabwe by Nyakutsikwa (1993) into greywater treatment units provided some basic design philosophies for on-site treatment by screening, sedimentation, filtration, biological and chemical processes, which can be applied to all greywater treatment facilities:

- Treatment facility to have little or no disruption to life and habits of users.
- Construction of unit to be simple and affordable.
- Facility to be reliable and easy to maintain.
- Unit must be economical in terms of capital and operating costs.
- Treatment process must achieve desirable quality for intended use.

Similarly, the basic requirements for the use of treated effluent are that it should be clear and free of colour, odourless (not offensive to user), pathogen free (so as not to cause diseases), and non-corrosive.

A number of technologies have been used worldwide for greywater treatment varying in both complexity and performance (Jefferson et al., 1999) – these range from systems for single households (e.g. disinfection of greywater so that it can be used for toilet flushing, without odour problems) to physical (e.g. filtration), biological (e.g. membrane bioreactors) to natural treatment systems (e.g. constructed wetlands or reedbeds). The choice of technology depends on the limitations for discharge and use of the end product, as well as the operational costs involved (Müllegger et al., 2003). Ludwig (2000) has prepared a simple system selection chart for domestic greywater use and has graded the system types according to ease of construction / use and optimum application.

Winblad & Simpson-Hébert (2004) summarised the purpose of greywater treatment and disposal systems within the context of ecological sanitation, as:

- To use greywater as a resource for plant growth etc.
- To avoid damage to buildings and surrounding areas from inundation and waterlogging
- To avoid the creation of bad odours, stagnant water and breeding sites for mosquitoes and other insects
- To prevent eutrophication of sensitive surface waters
- To prevent contamination of groundwater and drinking water reservoirs.

The successful management of greywater involves the proper design of the different technical components as well as consideration of legal aspects and user participation in the operation and maintenance of the systems. Simple household-based methods like soil infiltration can be used to manage greywater in rural areas but when planning systems for urban, high density areas the following collection and treatment components need to be considered (Winblad & Simpson-Hébert (2004):

1. Control at source – usually consists of employing methods to reduce the amount, and improve the quality, of greywater produced. These methods include controlling the volumes of water used, educating people about the effects of using certain products (e.g. the use of environmentally-friendly household chemicals should be encouraged) as well the correct design of disposal systems.
2. Pipe systems – used to collect the greywater and transfer it to where it will be treated and used. In general greywater systems can make use of smaller diameter pipes compared to blackwater. These systems need to have either flushing pipes and/or traps to prevent the blockage of pipes and a means of evacuating air and odours. In smaller systems the pipe system outlay should be designed in such a manner that the discharge points are in direct contact with the ground.
3. Pre-treatment – required when greywater is collected in larger pipe systems or stored for longer periods and used to trap the suspended solids in greywater by using gravity,

screens, seals or filters. The most common and effective form of pre-treatment is through the use of septic tanks although different pre-treatment devices based on screens, seals and filters are also available commercially.

4. Treatment – used to remove those substances that would degrade easily to cause bad smells as well as to reduce the level of micro-organisms, organic pollutants and heavy metals. Treatments range from extensive land applications to intensive applications, as follows:
   - Sorption and irrigation techniques – include mulch basins, trenches, wetland irrigation and pressure pipe irrigation.
   - Rapid infiltration methods – include soil filters and artificial filter media.
   - Biofilter reactors – include trickling filters and bio-rotors.
   - Aquatic systems – reedbeds, ponds and wetlands.
5. End uses – after treatment, greywater is used for irrigation or returned directly to the soil, with the following end uses:
   - Discharge to surface water – in order to maintain attractive and stable aquatic ecosystems, the concentration of oxygen-consuming substances and nutrients in the greywater should not be too high.
   - Percolation to groundwater – reliable treatment methods should be used to remove suspended solids, BOD and bacteria, and the water should be allowed to percolate through an unsaturated zone of at least 1m in depth with a safety zone between percolation fields and wells.
   - Use in irrigation – water should be applied sub-surface and crops should be chosen with care (i.e. only crops where leaves or stems are not eaten raw or under-cooked).

It should be noted that there are limitations in all of the above treatment technologies and techniques, not only in their designs, but also in their usage over time. Ongoing monitoring and evaluation of any greywater treatment system is essential in order for it to work successfully. Examples of some of the commercially available greywater treatment and disposal systems that are used worldwide are shown in Appendix B.

## 2.6 Use of greywater in South Africa

Greywater irrigation is used to a small degree in the more affluent areas of South Africa for general garden watering and limited vegetable production, as well as in certain low-income, peri-urban and rural settlements. Greywater irrigation in rural areas where water consumption is at subsistence or near-subsistence levels has enabled yard crop production to take place on a modest scale, and has shown that greywater could be of critical importance for low-income agricultural purposes during periods of low rainfall. The study by Alcock (2002) revealed that there is a lack of information on greywater as a specific resource and as an irrigation technique, especially for low-income households in South Africa. He did however conclude that greywater could be used for yard vegetable and fruit tree cultivation provided that several precautions are strictly observed.

There have been very few scientific investigations to date into the use of greywater for irrigation in South Africa. One study by Beukes (2001) showed that the use of greywater had a positive effect on plant growth and yields, specifically for tomatoes and beans over two seasons. It seemed that the soap present in the water provided benefits in terms of pest control and disease prevention. Salukazana et al. (2005) investigated plant growth and the microbiological safety of plants that were being irrigated with greywater from a low-income peri-urban community in Durban. Preliminary results have showed that greywater could represent a potentially important resource for food production in poor peri-urban communities, with minimal additional risks to health associated with consumption of the irrigated produce. Further work is required however into the sustainability of the practice and the medium to long-term effects that greywater irrigation may have on soil quality. There are also still unanswered questions regarding the health risks associated with using greywater from impoverished communities (and particularly high-density settlements) to irrigate food products, where community health and overall immunity to disease is severely compromised. A detailed discussion of the health aspects of greywater use is given in Appendix C. It is important to note that greywater use should be seen in terms of its contribution to sustainable water development and resource conservation without compromising public health or environmental quality (Al-Jayyousi, 2004).

There have been a number of innovative irrigation methods designed for the use of greywater, including the Wagon Wheel Irrigation System developed by the Institute for Deciduous fruit, Vines and Wine (Infruitec-Nietvoorbij) at the Agricultural Research Council (ARC), which has been installed at a number of sites in South Africa (Albertse, 2000). The tower garden is another interesting concept (derived from a project in Kenya), which consists of vegetables growing around the sides of a column of soil surrounding a central stone-packed drain within a shade cloth or fertilizer bag (Crosby, 2004). Greywater is poured on top of the stones and filters slowly through the soil column. These systems were designed specifically for low-cost, small-scale irrigation with greywater, but there are also commercial greywater systems being used in high-income sewered areas, e.g. the Garden / Water Rhapsody systems and the X-S Water system (Alcock, 2002). Refer to Appendix B for further details on these and other commercially-available systems.

Khosa et al. (2003) described an on-farm study using the ‘Drum and Drip’ micro-irrigation system (an adapted low-cost irrigation system for use on smallholdings) in two settlements in the Limpopo province. The research showed however that vegetable production based on the use of recycled water by means of this system was not an unqualified success. Users considered recycled water to be unhygienic, and could not be convinced otherwise. Furthermore the use of saline water also led to clogging and rusting problems in the irrigation system. There were however some overall positive effects - participants have continued to grow irrigated vegetables and are using the recycled water in other ways.

As part of their Upgrading of Informal Settlements programme, the City of Cape Town hosted a workshop on “Greywater in informal settlements” in October 2004, the aim of which was to identify and assess the technology currently being employed by the municipality to mitigate the current problems with greywater disposal (City of Cape Town, 2004a). The main purpose of the methods being employed is to provide “safe, accessible and environmentally-friendly disposal of the greywater whilst being cost-effective”. The following means of disposing and / or reusing greywater were highlighted at the workshop and are examples of the most widely-used methods employed by local authorities throughout the country:

1. Standpipe and soakaway – this system functions optimally in good soil permeability where there is a low water table, flat topography and soft, “pickable” soil. This form of greywater disposal has very low cost implications.

2. Standpipe and catchment slab – it is possible to use this combination where a high water table is present, but the runoff from the catchment slab has to be connected to a sewer system and therefore has medium cost implications.

3. Standpipe and gulley – the standpipe and gully combination requires that the topography is at a sufficient gradient to allow efficient drainage. This also requires that the system be linked up to the sewer and has medium cost implications.

4. Kerb inlets and stormwater channels – kerb inlets to stormwater are usually used when there is no other suitable alternative for greywater disposal and are placed within the road reserves. They have low capital cost implications but the biggest disadvantages of this system are that they tend to accelerate the deterioration of the road surface and also result in environmental damage to rivers from the polluted stormwater discharges. Similarly, where open stormwater channels exist in informal settlements, they are often misused for the disposal of greywater and other household waste, which ultimately leads to poor environmental health conditions. There are high costs involved with the maintenance of both kerb inlets and stormwater channels, as there is a need for regular solid waste collection in order to prevent blockages.

5. Wash troughs – these have a high frequency of usage within South African informal settlements, providing communal facilities for laundry and other washing activities and thereby isolating the waste stream to a particular area. The wash troughs should be sited on gently sloping ground so as to allow for the greywater to drain efficiently, either to infiltration on surrounding land (away from dwellings) or to a sewer system. Disadvantages of this system include the relatively high capital costs as well as the potential to create poor environmental health conditions if not properly managed. It does however provide an opportunity for reusing the water in some form of irrigation, particularly in the case of community gardening projects.

6. Innovations – various innovative greywater disposal and / or treatment technologies have been tested and used in the various informal settlements in the Cape Town Metropolitan area, including the following:

    - Greywater sand filters
    - Grease traps
    - Sub-soil and french drains

- Wetland systems
- Tower gardens

## 2.7 Strategies for sanitation provision

The basic level of sanitation service in South Africa was defined in the “Water supply and sanitation policy white paper” (DWAF, 1994) as a “ventilated improved pit (VIP) toilet or equivalent”. The definition “basic level of service” was later replaced in the “White paper on basic household sanitation” (DWAF, 2001a) by the term “adequate sanitation”, which states that the service should promote health and safety, and that it should be attainable and sustainable socially, economically, environmentally and technically (Austin et al., 2005).

Greywater management is totally dependent on the level of provision of effective services (water and sanitation) and the strategies for sanitation provision in particular are relevant in terms of determining the possible extent of the greywater “problem”. Despite enabling national policies, institutional initiatives to develop delivery frameworks for basic sanitation have been slow because of a lack of consensus in water services and related units within local authorities (Lagardien & Cousins, 2004). A planning and implementation framework for basic sanitation services has therefore been developed and the emergent theme has been that the policies of local authorities should be aligned with legislative and national policy requirements. Research into the difficulties of provision and maintenance of services in dense settlements has reiterated that service provision has historically not involved detailed discussions with communities. Stimulating demand for services through health and hygiene education is accepted as a key aspect of sanitation projects and will ensure that the services are not doomed to misuse, vandalism or failure. It has also been noted that where the method of service provision employs local capacity the systems stand a greater chance of being sustained. A partnership that seeks to increase local responsibility will therefore maximise local roles in the interests of sustainability and the alignment of role-players in approaching delivery to informal settlements is thus essential. The study by Lagardien resulted in a draft policy document for rudimentary services to informal settlements, based on the National Sanitation Policy.

The sanitation policy and protocol for appropriateness for use as developed by the City of Johannesburg, as well as other existing legislation and policy, were reviewed in a study by van Ryneveld (2003). This study concluded that the critical issue in the provision of sanitation to low-income settlements concerns pollution from on-site sanitation, which is managed by both the Department of Water Affairs and Forestry (DWAF) and the Department of Environment Affairs and Tourism (DEAT). Local authorities are compelled to remain financially sustainable in respect of the provision of services to low-income settlements, and must comply with applicable environmental legislation. The recommended approach for addressing environmental sustainability is to adopt a health focus for the short term (less than 10 years), try to minimise diffuse pollution (from e.g. greywater) in the short to medium term (3 to 20 years), and initiate further research for longer term. In order to clarify the roles and responsibilities of the various role-players in the demand-responsive (rather than supply driven) approach which should be adopted with respect to sanitation provision, a framework of rules needs to be established through which demand can be expressed. The rules under which the community can get sanitation, the decisions the community must make, and the contracts that are likely to be established between the community and the service provider all need to be determined.

## 2.8 Water quality in dense settlements

The Department of Water Affairs and Forestry's "National strategy for managing the water quality effects of settlements" (DWAF, 2001b) was one of the outputs of a project that was jointly funded by DWAF and the Danish Government via their Danish cooperation for environment and development (DANCED) program. DWAF initiated the study looking into the links between pollution, community perceptions and local government capacity, which ran in parallel with test cases on water quality in dense settlements. The research formed part of DWAF's overall approach towards Water Resource Management (WRM). The National Strategy is one of the supporting strategies of the Catchment Management Strategy (CMS), which will in turn give effect to the National Water Resource Strategy (NWRS) that underpins the Government's goals of poverty alleviation and economic growth. The report identified the underlying causes and costs (health, environmental etc. ) of pollution, the legal considerations and various financing interventions.

DWAF has the constitutional mandate to legislate measures for the protection of water resources and can assist local government in identifying problems and indicating how waste services should be provided in order to protect the resource. The NWA provides a means of intervening where there are existing water quality problems, and the Water Services Act and Municipal Systems Act provide the means to integrate the recommendations of the strategy with municipal planning and budgeting processes. The notion of the "equitable share" becomes relevant in this respect, where local authorities are entitled to a share in revenue raised at national level and are thus able to fulfill the objectives of the National Strategy even if their funding resources are not sufficient.

The Dense settlements project noted that local government capacity influences the way in which waste removal services are supplied and maintained and that capacity gaps (i.e. the gaps between what is required to operate waste management services and what is available within local government) can contribute to pollution problems. The role of women is critical in the management of water quality effects as they are primarily involved in polluting activities in dense settlements and are thus best placed to identify polluting behaviour. The research also clearly showed that social and institutional problems could contribute to pollution.

Schoeman et al. (2001) investigated the extent of the causes and consequences of contaminated runoff from high-density urban developments and attempted to develop guidelines for the management of this urban runoff. In this report greywater was not in itself considered to be a particular problem in terms of urban runoff, but could contribute to the total pollution load – the litter and faecal pollution associated with greywater from low-cost, high-density settlements was stated as the main contributors to urban runoff problems. It was noted however that further research is required into pollution sources and pathways, and the role of greywater in this regard needs to be determined.

In order to ascertain the extent of groundwater contamination from developing urban settlements Wright (1999) studied the magnitude of contamination, the major contaminants and contributors to contamination, and the establishment of guidelines for the protection of groundwater. He concluded that all existing informal settlements, and particularly those that are poorly managed, should be considered as sources of contamination. The groundwater from the aquifers around the study sites in Cape Town, Gauteng and Durban was found to be contaminated with nutrients, pathogenic micro-organisms and biodegradable organics at all of the sites studied. The major sources of groundwater pollution were found to be on-site sanitation, seepage from garbage and greywater disposal, communal water supply sites, communal meeting sites, informal trading sites and stormwater drainage systems. The most significant variables with respect to urban groundwater contamination were found to be type of housing, hydro-geological setting, importance of groundwater and type of sanitation.

The report recommended that Third World type urban development (e.g. informal settlements) should not be allowed in the vicinity of major aquifer systems and that it is the responsibility of DWAF, together with the local authority concerned, to ensure that this does not happen.

## 2.9 Sustainable sanitation

Rapid urbanisation is occurring throughout the developing world, creating a demand for housing, infrastructure and services. Sanitation services present a particular problem, especially in informal areas where local sanitation problems are often solved at the expense of the wider environment. Sustainable sanitation practices seek to resolve this, whilst still being affordable for the poor (Bernhardt Dunstan & Associates, 1998). The study by Tayler & Parkinson (2003) went on to explore options for institutionalising strategic approaches to sanitation provision in urban areas, with the emphasis on services rather than facilities alone. Inadequate sanitation is only one aspect as low-income settlements also tend to have poor drainage and no solid waste services, which adds to the problem. Strategic planning should allow for a range of actions in order to achieve the overall goals in accordance with relevant policies – sanitation services should be equitable, environmentally acceptable and operationally sustainable. The strategic approach should establish the demand for improved services, then inform it in terms of what is possible, and finally respond to this informed demand (this could require capacity building).

This view was supported by Holden (2001) who stated that sustainability is only achieved when the community wants and accepts the level of service provided, is able to pay for it and can maintain it locally. In this context sanitation includes containment and safe disposal of excreta, refuse and greywater, as well as the provision of a sufficient quantity and quality of drinking water. Good sanitation is essential for primary health care, and the disposal of greywater is only considered a problem if it is mixed with blackwater (i.e. is contaminated) or if the settlement is densely populated. It was shown that simple locally based technologies can effectively be used for treating / disposing of greywater. There should thus be an integrated approach to sanitation where the solid waste management, stormwater drainage, excreta disposal and greywater management services are all linked (Tayler & Parkinson, 2003). When developing plans for sanitation improvements, the options that the local situation offers for integrated action should also be explored. A key finding of the research was that the widespread adoption of strategic approaches at a municipal level is unlikely to occur unless the policy context is supportive to such approaches. Also important are the prevailing local attitudes and assumptions.

Similarly, the study by Manase et al. (2001) concluded that the major cause of poor sanitation in informal settlements is the lack of strong, transparent and effective linkages between sanitation agencies and the urban poor. Guidelines were produced giving suggestions for ways of ensuring cost-effective and sustainable improvements in sanitation, including the following:

- social (socio-cultural and political factors) – health and hygiene messages should be linked to cultural beliefs and practices.
- institutional – there needs to be a comprehensive sanitation policy targeted at poor urban areas where the relationship between Local authorities (LAs), Non governmental organisations (NGOs) and Community based organisations (CBOs) must be clearly defined.
- financial – tariffs should be based on the cost of providing services and the willingness of communities to pay.
- technical and environmental – communities should choose technologies and service levels which they understand and want.

Sustainable development indicators (SDIs) are tools that can be used to measure progress and warn of future trends in sustainable development. Twenty SDI's were evaluated in a study by Morrison et al. (2001) of an urban water system in King William's town, and applied to the four environmental and technical system components that were identified, i.e. freshwater resources, drinking water, wastewater systems, and sewage sludge. Fifteen SDIs were identified as being useful, with the reuse of water having a high reference value as an indicator. This means that efficient reuse of water indicates a high level of sustainability of the system. Other SDIs that could be used to monitor sustainability include raw water withdrawal, raw water quality and drinking water consumption.

## 2.10 Productive uses of water

There are two principles of the demand responsive approach that apply to sustainable water supply and sanitation, i.e. water as an economic and social good, and management of water at the lowest appropriate level with users involved in planning and implementation of projects. Research on the productive uses of water at a household level by Pérez de Mendiguren (2003) gives an outline of the South African policy and institutional requirements in this regard. Previously disadvantaged communities have to compete with other key sectors if they want to gain access to water over and above the basic needs level, i.e. for productive uses. The ability to access this water will also depend on the availability of the supply as well as their ability to carry the costs of the water – this can in turn be enhanced by promoting income-generating activities. The study differentiated between areas where the level of domestic supply was good ("best-case") and those where there was no reticulated supply and the minimum RDP standards were not met ("worst-case"). The productive use of greywater was not specifically considered for this research; however instances of use of greywater were noted, e.g. watering of fruit trees in "worst-case scenario" villages. Information was derived on the income possible from the productive uses of water and it was concluded that an extra 17*l*/c.d can result in an increase of approximately 14% in personal income. It is therefore important that alternative ways of providing water for productive uses (e.g. through the use of greywater) are explored.

Sustainable water management concepts have also been studied by Wilderer (2003) who stated that the costs and time needed for the installation of conventional sewers and wastewater treatment plants are tremendous, and the use of potable water to transport pollutants is not feasible in many areas. Decentralised water and wastewater management, as well as on-site systems and source separation of waste streams should therefore be considered. In this context the principles of ecological sanitation (Ecosan) are applicable, where human excreta is regarded as a resource and not simply a waste product destined for disposal. Ecosan technologies take cognisance of the principles of environmental sanitation (keeping the environment safe and clean and preventing pollution) while using recycling concepts. Ideally, they enable the complete recovery of all nutrients from sewage to the benefit of agriculture, minimise water pollution, and maximise the economic use of water (Earle, 2001).

The ecological sanitation approach can also be broadened to cover all organic material (e.g. kitchen and food wastes that can be composted) as well as greywater that is generated in households, which can be treated using biological systems such as evapotranspiration beds and constructed wetlands. This was demonstrated in a community sanitation study that took place in Senegal (Weisburd, 2000) where dry sanitation toilets have been installed. Twelve to fifteen houses are grouped around common open spaces and subsurface-flow reedbeds have been located in these spaces for the communal disposal and treatment of greywater. For Ecosan to be sustainable in higher density settlements however, some form of institutional support for the disposal of faecal matter, organic waste and greywater is likely to be required (e.g. in the form of neighbourhood composting stations managed by municipal cleansing services), as reuse on-site is generally not feasible (Austin et al., 2005).

## 2.11 Social aspects to sanitation issues

Sanitation is a major development problem and one that integrates health, water, wastewater and poverty alleviation. Poverty tends to result in the natural processes in the body becoming humiliating and dehumanizing expenditures of time and other scarce resources. There is a wealth of relevant research on the question of social aspects and attitudes towards sanitation issues. One of the most comprehensive databases for this kind of research in Africa is the Drawers of Water Dataset, which is based on changing water use patterns in East Africa from 1967 to 1997. In Uganda for example, Tumwine (2002) reported the following changes in per capita water use in non-reticulated and reticulated households from 1967 to 1997. Overall, mean per capita water use in the non-reticulated households improved from 12.3*l*/d in 1967 to 18.3*l*/d in 1997. For the piped households, there was a general decline in mean per capita water use from 108.3*l*/d in 1967 to 58.5*l*/d in 1997. Despite this decline, per capita water use in reticulated urban households is still 2.4 times higher than for non-reticulated households in rural areas.

The activities that consumed the most water in the piped households in the study were toilet flushing, bathing and washing, while for the non-reticulated households bathing and washing were the leading water use activities. Clearly a lot of water could be saved by using dry sanitation technologies but washing and bathing as the main sources of greywater can also provide a major source of water for recycling. It can be assumed that basic water use behaviours in Ugandan and South African households are comparable.

Another study that was based on the Drawers of Water Dataset is the report by Thompson (2000) which analyses changes in water supplies at 16 sites in nine East African urban centres including the key cities of Nairobi and Dar-Es-Salaam between 1967 and 1997. Both high and low income settlements were covered and show the rise of private-sector providers as a result of structural adjustment policies during the 1980s. Contrary to expectations, privatisation did not result in improved services as water buyers were spending almost two hours a day collecting water from the kiosks and this water was nearly twice the price of piped water.

The kind of long-term perspective exemplified by the Drawers of Water Project does not yet exist for studying water use patterns in areas of illegal, informal and probably temporary settlements in South Africa. Some of the non-sewered areas in which the current greywater research has been conducted fall into this category of informal settlements.

The connection between water and poverty has been regularly highlighted by researchers. Saleth et al. (2003b) developed an analytical framework using a schematic representation of some of the most important layers and pathways that underlie the water-poverty-gender nexus. The researchers attempted to indicate the approaches and strategies for using water as a key instrument to address poverty and gender concerns; and identify research gaps to set the direction for ongoing and future research in the water-poverty-gender interface. According to the Department of Water Affairs Annual Report of 2004/2005, Programme 3: Water Services, State of Water Services Report (DWAF, 2005a), there are still 16 million people in South Africa without access to basic sanitation services, the vast majority of which live in rural areas. Inadequate sanitation is one of the major factors in the spread of infectious diseases and if most of the people living in rural and peri-urban communities of South Africa do not have adequate sanitation it can be expected that their health will be seriously compromised. DWAF is presently developing and refining a manual on rural sanitation, a draft of which has already been prepared. The manual is aimed at community fieldworkers and health workers, and is premised on the need to tackle the problem of inadequate sanitation through the building of community-based democratic organisation. The manual is to be field-tested in rural areas and will form the basis for training community-based trainers for a sanitation initiative in the country.

The study of water use and the strategic management of greywater and other wastewater management issues straddle cultural, political, economic and social questions emanating from development practice generally. In development studies the problem of technology transfer and the interconnections between new knowledge and behavioural change in diverse areas like agriculture, forestry or health are particularly relevant.

The need to link water, health, sanitation and environmental protection has always been recognized in development planning and the priority given to the provision of clean drinking water in South Africa is thus based on age-old principles. What is not well thought out however is the long-term management of wastewater, especially in informal settlements without adequate drainage. One rationale for this project therefore is to fill the information gaps and to provide baseline data for the study of greywater generation and management in the non-sewered areas of South Africa.

## 2.12 Wastewater use in agriculture

Many international studies show that using untreated wastewater as an irrigation resource for urban agriculture is common in the low-income countries of Asia and Africa. Such farming methods are clearly a health hazard and would not be accepted in the affluent countries of Europe and North America but are an essential economic activity in poor countries, ones that provide rice, vegetables and other foods to the urban poor, sometimes accounting for as much as 50 percent of urban vegetable supply. Despite all the potential and actual health problems with the use of untreated water, urban farming using waste water for irrigation creates employment and provides affordable food for some of the urban poor. For the farmers, the nutrients in the wastewater make it possible to minimize fertilizer costs while providing them with a constant supply of water which they would otherwise not have. The spin-off in improved nutrition may however be nullified by poor health caused by eating contaminated food.

Saleth et al. (2003a) make a different, if not unique, attempt at a quantitative evaluation of the multifarious linkages between irrigation and rural poverty by taking a systems approach and using cross-section data pertaining to 80 agro-climatic sub-zones of India for two time series, i.e. 1984-85 and 1994-95. They first developed an analytical framework to depict the most important pathways and layers of irrigation-poverty linkages as mediated though three key systems: the water system, the agro-economic system and the socio-economic / demographic system. These pathways and linkages were then translated into an econometric form in terms of a system of simultaneous equations defined by a set of irrigation-related, agro-economic, socio-economic and demographic variables. By estimating this system of equations in the context of the agro-climatic sub-zones of India for the two time points, this study empirically evaluated the mechanics and dynamics of irrigation-poverty linkages. Based on an analysis of the empirical results, the researchers concluded by identifying some of the analytical, methodological and policy issues crucial for understanding and promoting the overall poverty alleviation impacts of irrigation. The South African situation seems to be somewhere between the freshwater irrigation preferences of the affluent countries and the desire to improve income generating and water conservation practices among the poor in developing countries. At the moment, there is no large-scale agricultural tradition based on wastewater reuse comparable to the ones in Asia for example.

Greywater use in gardening is well developed in many countries throughout the world. A pilot project in Palestine is attempting to optimise the design of small-scale trickling filters for the treatment of greywater for use in home gardens in the hilly, low-density peri-urban areas of the West Bank, for presentation to policy-makers and other donors (International Development Research Centre, 2006). The individual or small collective (10-15 homes) systems can be built from recycled shampoo containers and use local materials such as waste gravel or waste such as crushed plastic bottles as filter media. The treated greywater from a properly operating system can be used safely for irrigating any products in home gardens, including raw vegetables. If accepted by the Palestinian National Authority and implemented across appropriate areas of the West Bank, the systems will not only reduce the amount of total waste (black and greywater) contaminating the sensitive aquifers in the West Bank, but by reusing wastewater, will help address the diminishing fresh water availability per capita in the region. The systems could also help Palestinians, often affected by border closures, to maintain a secure food supply. There are some parts of the northern and Western Cape areas of South Africa that might be as dry as those of the Middle East but the technologies described above may take time to become common in South Africa for demographic, cultural or economic reasons.

Another study that critically reviews experience worldwide in the use of wastewater for agriculture was completed by Scott et al. (2004). The book defines and elaborates on wastewater use in agriculture through a series of peer-reviewed papers. It places particular emphasis on the use of untreated wastewater by means of field-based case studies from Asia, Africa, the Middle East, and Latin America to address the environmental and health impacts and risks. In a first step toward better understanding the global extent of wastewater use in agriculture, a methodology was developed and applied for selected countries to quantify the magnitude of wastewater use in agriculture.

## 2.13 Water services development and planning

Given the South African government’s desire to provide clean water to all citizens and given the high levels of poverty and unemployment, how can the poor afford water? What is the impact of global neoliberal policy on their access to this vital resource? Secure Water (2004), is attempting to understand the implications to the poor of the shift to a demand-responsive approach (DRA) to water supply and sanitation development. They intend to apply the tools of Sustainable livelihoods and the household economy approaches (HEA) in making the DRA more pro-poor in its implementation and development. Recognizing that there are aspects of financial cost recovery which are important to ensure the sustainability of interventions, the project nonetheless challenges many of the assumptions around which current contingent valuation processes are based, as well as other tools of demand assessment.

Shandler & Granger (1997) drew on experience in water resource planning in the Western Cape in identifying the major trends in conflicts associated with the contending imperatives of social justice, economic growth and natural resource conservation. The paper sought to analyse the trends by identifying conflicts rooted in class, race, and geographical and economic sector factors and extending this to make tentative conclusions on appropriate methodologies for those engaged in processes of water systems analysis, integrated catchment management and water demand management strategies.

It is a common complaint among researchers that reliable data are difficult to obtain in poor countries, especially in Africa. Although South Africa has the resources to maintain government and other public statistics of a high quality, there are many local municipal authorities that may be unable to keep up with the demands of researchers. In a Brazilian study Heller (1999) presented the results of research in Betim, Brazil, which looked at the connection between water supply, wastewater management, excreta disposal, environmental management and health. The paper demonstrated the limits of official statistics on service provision especially on the accuracy pertaining to the recipients and argued for data collection and research to ensure that environmental sanitation services were made to address health risks more comprehensively.

## 2.14 Economic aspects of greywater management

The potential economic costs of the effects of poor water quality in South Africa have been estimated at R3 billion per year, with the bulk of the costs emanating from densely populated areas with low service levels (DWAF, 2001d). These costs are probably only a fraction of the total and are an estimate of:

- Direct health costs – specifically the treatment of diarrhoea
- Indirect health costs – productivity losses
- Water treatment costs downstream

There are therefore compelling arguments for local authorities to contribute to the prevention of pollution through better operation and maintenance of services (DWAF, 2001e). In a recent report released jointly by the Stockholm Water Institute (SIWI) and the World Health Organisation (WHO) it was noted that investments in the water and sanitation sector can generate economic benefits that considerably outweigh costs, accelerate economic growth and contribute to human development (SIWI / WHO, 2005). Given the obvious importance of water and sanitation to public health, the economic policies that governments pursue in the area of water utilities have direct consequences in poverty alleviation and development activities as a whole. A country cannot achieve development if its population’s health is compromised by pollution and other environmental hazards (Solo, 1999).

The impacts resulting from the poor management of greywater are felt more strongly by the poor than by the rich. This is primarily due to the health impacts related to greywater disposal; the poor are likely to have lower resistance and a greater tendency to contract disease. The implications of poor greywater disposal are therefore likely to be worse in low-income communities. A lack of financial capacity in local authorities can also lead to increased risks of pollution in settlements, which in turn contributes to increased incidence of disease and consequent increased costs to all spheres of government.

The use of greywater as a substitute for fresh water may provide some economic benefits in areas where potable water supplies are restricted, but the potential negative impacts (health and environmental) from such use must be taken into account. The total volume of greywater available for use in South Africa is insufficient to make a meaningful contribution to the country's water shortage as a whole. It could, however, make a local difference in the more arid areas of the country, particularly where housing is not excessively dense. The outcome would depend on both the geographic and socio-economic characteristics of the areas involved. The cost-benefit analysis of any greywater use proposal would need a full evaluation of the alternatives, and recognition of the risk factors involved. This could include:

- Reducing water demand, thus generating less greywater.
- Making greywater a useable resource – e.g. irrigation into tower gardens (see Appendix B14), watering of trees etc. This entails the substitution of greywater for raw water and is therefore water saving.

## 2.15 Privatisation of water and sanitation utilities

During the 1980s structural adjustment policies were adopted by African and other countries at the behest of the IMF and World Bank to balance their budgets as a precondition for obtaining loans with which to finance their development projects. The two Washington-based multilateral financial intuitions aggressively promoted the private sector as a more efficient provider of public services, policies which have had a devastating effect on African hospitals, schools, and water and sanitation services.

Supporters of the privatisation campaign presented the process as an empowering one for the poor in low-income countries. Solo (1999) demonstrated that in some Third World countries small-scale providers of water and sanitation were able to provide a cost effective and good quality service, contrary to popular wisdom, and suggested ways in which public policy could further strengthen these services. Given the obvious importance of water and sanitation to public health, the economic policies that governments pursue in the area of water utilities has direct consequences in poverty alleviation and development activities as a whole. A country cannot achieve development if its population's health is compromised by pollution and other environmental hazards.

The World Bank's enthusiasm for privatisation may be justified as a means of improving efficiency in service delivery in affluent countries but in less developed African countries the only alternative to state provision of services is unpredictable and unaccountable informal sector operations. As a Kenyan study demonstrates (Katui-Katua & McGranahan, 2002) a project to extend water supply networks in Nairobi's oldest informal settlement using small informal-sector private businesses has proved to be a failure. The authors did not place all the blame on privatisation as such since the Kibera project was unlike most schemes involving large companies, but the problems of dependency on foreign funding and inadequate consultation were highlighted. In other words, projects imposed from above and from outside are generally not sustainable.

It has been argued (Listorti, 1999) that the lack of consideration given to health and the absence of health professionals in decision-making processes in most development projects compromises the development process. The report by Listorti showed that health improvements for lower costs could result from improved infrastructure as opposed to investments in health care. Another way of putting it is that prevention is better than cure and that clean water and better housing can significantly lower the costs of caring for the sick by reducing the number of sick people. But what is the best institutional arrangement for managing water and sanitation infrastructures?

Mwangi (2000), like most African researchers, argues that the state is the best option for the provision and management of water and sanitation services. Using the case of Nakuru in Kenya to show the limitations of partnerships between municipalities and local external groups in water, sanitation and waste management services he concludes that increased state support and capacity building at local levels is essential for the sustainable management of water and sanitation.

Although an attractive idea, partnership between the state, local communities and civil society (i.e. NGOs) is often fraught with management problems. In a study from India, Hobson (2000) described a communal toilet construction programme in the city of Pune involving a partnership between the municipal corporation and 8 NGOs. The paper evaluates some of the many difficulties involved in making this partnership work.

Budds & McGranahan (2003) assessed the extent of water privatisation in developing countries since the 1990s when this was widely promoted as part of the neoliberal policies known as the Washington Consensus, and came to the conclusion that benefits for low-income communities are few and far between. Privatisation should not be promoted globally as the monitoring of private sector providers is inadequate in many poor countries and low-income communities are not a priority.

Parkinson & Tayler (2003) give examples of functioning systems and suggest that the decentralisation of wastewater and faecal sludge management to previously un-serviced areas provides an opportunity for local stakeholder participation in environmental and health improvements. The proviso for success is that a concerted capacity building effort is required. South Africa’s non-sewered areas are very likely to have similarly inexperienced communities that will require a lot of training as a part of the process of introducing any new waste water management technologies. Taken together, these two papers would seem to argue for a stronger role for municipal authorities in the provision of water and sanitation services and in capacity building activities in the concerned communities. With South Africa experiencing rapid and sometimes unpredictable urbanisation patterns, many of the rural poor who are relocating to the cities will require state support for a long time in order to make the transition form country to urban living.

## 2.16 Summary and conclusions

The literature review has shown that, although there is a wealth of research available on greywater internationally, it is not always applicable to the disposal and use of greywater in a South African context, particularly in non-sewered areas. This appears to be due to the following conditions, which are specific to South Africa:

- Geographical / environmental conditions, i.e. climate, water resources etc.

- Financial situation – SA is classified as a middle-income country, as opposed to the countries where much of the greywater research has been done, i.e. high-income (developed) or low-income (developing) regions.
- Historical background and the backlogs as a result of unequal distribution of resources
- Government policy stance with respect to service delivery
- Human resource capacity
- Cultural norms and beliefs

Studies have shown that greywater, which is generated through inadequacies in the water and waste management services, is a major problem in low-income settlements in South Africa and represents a significant health and environmental threat (Wood et al., 2001). It is generally accepted that the systematic use of greywater in certain settlements could provide benefits both in terms of irrigation and where inappropriate greywater disposal and surface ponding is evident (Alcock, 2002), but caution should be applied when considering this use of greywater, specifically in high-density settlements.

There is a noticeable gap between government policy on water provision and the long term sustainable water management challenges for the country's cities. Research is thus required to establish a baseline for policy making and urban planning upon which decisions can be based pertaining to the interrelated challenges of poverty alleviation, sustainable livelihoods, managing water and sanitation and the governance of rapidly expanding urban settlements.

It has been shown that the management of greywater should be included at the planning stage in the provision of services to and the development of settlements. It is vital that the communities themselves are involved in this decision-making process, as well as in the implementation and operation of the water supply / sanitation systems, in order to ensure the success of these services. As noted above, although South Africa may learn from other countries such as Australia, the USA, or even other African countries, it appears to have a unique set of conditions which will require locally developed solutions to local problems based on partnerships between municipal authorities and local communities.

# 3. Methodology

Following the literature review, on-site surveys were conducted in 39 selected communities in SA, using standardised greywater survey questionnaires (see Appendix A). Greywater management is affected by sociological, environmental and institutional factors, which necessitated the collection of large quantities of data and the use of specialist knowledge in order to understand the range of issues. In each community that was visited, surveys of current and potential greywater management and recycling activities were carried out, and local practices pertinent to water use and management examined, to determine their impact on greywater disposal and use.

The questionnaires were piloted at two survey sites in the Western Cape before being used for the remainder of the survey, and included specific questions on the following:

1. General household information – house type, income, occupation, no. in household etc.
2. Available services – sanitation type, distance to water source, water use, detergent use etc.
3. Greywater management – disposal methods, opinions on use etc.
4. General site characteristics – existing greywater management systems, soil type, topography, environmental considerations etc.

Answers to the questions were recorded on the questionnaire sheets during the interviews, and were then entered into a computer, in MS Excel format, for later analysis.

Volumes of greywater were calculated from the amount of water consumed per household. In the absence of any formal metering, the figures for water consumption were based on estimates given by the occupants themselves (usually determined by the number of buckets of water collected during each day). General observations were also made of the physical surroundings, climate, topography, use of groundwater etc. as well as any environmental considerations related to the settlement. Sampling of typical greywater discharges was undertaken to determine its chemical and microbiological quality.

The results of these site surveys have been recorded as case studies and are described in detail in Appendix D.

## 3.1 Site selection

It was critically important that the communities surveyed in this project were representative of the different types of communities to be found in the non-sewered areas of South Africa. What made this particularly difficult to achieve was the fact that there are a large number of these communities, spread over a vast geographical area, and there were only resources to survey a limited number of them. Site selection started in the Western Cape province and was an evolutionary process that developed over time, culminating in a procedure for site selection that was used for the remainder of the country.

The two preliminary sites (Clanwilliam and Redhill) were chosen mainly for their familiarity (Clanwilliam is the subject of ongoing social anthropology class projects) and convenience of access. Four additional sites were selected after completing a transect through a portion of the Western Cape. It was apparent that these sites might still not be representative, and a more scientific method of choosing sites was required. It was therefore decided to attempt to determine the suitability of sites by assessing data from the National Census (Statistics South Africa, 2001) and/or the Environmental Atlas that would help in identifying the range of different non-sewered communities.

### 3.1.1 Site selection using Census 2001

The following key aspects were judged to be the most important in terms of identifying representative communities for inclusion in the study:

1. Geographic distribution / representivity defined by:
   - Non-sewered population
   - Spread of language / ethnic groups
   - Split between urban and rural communities
2. Water consumption (litres per person per day)
3. Density of population (people per hectare)
4. Soil type (permeability)
5. Topography (slope)
6. Environmental sensitivity, including groundwater

Detailed information on all of these aspects was not available from Census 2001 (Statistics SA, 2001), but it was possible to use the Census data as a means to characterize sub-places that were likely to generate greywater. Sub-places are the lowest settlement level in the Census place name hierarchy, and correspond to suburbs, wards, villages, farms or informal settlements. The first level of data filtering was to determine all areas without on-site waterborne sanitation (i.e. non-sewered) and this was achieved by selecting out of the Census data on sanitation those sub-places that had pit latrines (with and without ventilation), bucket toilets, or none. The combined total numbers of households per settlement that fell into this category were then filtered further according to other selected criteria as shown in Table 3.1.1.

Various categories within Census 2001 were grouped together so as to reduce the numbers of criteria to be assessed. Thus, water supply was divided into two categories; piped water inside the yard (on-site water) or any other off-site water (all other Census water categories except piped water inside dwelling). Two categories of income were considered; all those less than R19 200 per annum, assuming that this figure represents sub-economic living conditions, and the next Census category (R19 201 to R38 400). Three categories of dwelling types were taken into account so as to represent the various structures that exist in non-sewered settlements. In order to determine which of the selection criteria to use, separate spreadsheets were produced, for each of the six districts in the province of the total number of households without sanitation by race and one of each of the following criteria:

- Water supply (Piped water inside yard or Off-site water)
- Annual Income (<R19 200 or R19 201 to R38 400)
- Dwelling type (RDP or Traditional or Informal)

From this the types of settlement were sorted and ranked according to the percentages of total numbers of households they represented in each district. An analysis of these figures (as well as of the total numbers of households themselves) showed a high degree of correlation between water supply, income and dwelling type, suggesting that the same (or similar) households were being included in each count. It was therefore decided to adopt water supply as the data "filter" when attempting to differentiate the settlements and identify potential sites for the surveys. A distinction was made between piped water inside the yard and off-site water (which included all forms of communal water as well as other water supply not inside the house) owing to the fact that it was assumed that greywater volumes are likely to be higher from households with on-site water.

**Table 3.1.1: Criteria examined from Census 2001**

| Criteria for site selection | Census 2001 categories |
|---|---|
| **Water supply** | |
| 1. Piped water inside yard | • Piped water inside yard |
| 2. Off-site water | • Piped water on community stand: distance <200m from dwelling<br>• Piped water on community stand: distance >200m from dwelling<br>• Borehole<br>• Spring<br>• Rain-water tank<br>• Dam/Pool/Stagnant water<br>• River/Stream<br>• Water Vendor<br>• Other |
| **Annual Income** | |
| 1. <R19,200 | • No Income<br>• R1 - R4,800<br>• R4,801 - R9,600<br>• R9,601 - R19,200 |
| 2. R19,201 - R38,400 | • R19,201 - R38,400 |
| **Dwelling Type** | |
| 1. RDP | • House or brick structure on a separate stand or yard |
| 2. Traditional | • Traditional dwelling/hut/structure made of traditional materials |
| 3. Informal | • Informal dwelling/shack in back yard<br>• Informal dwelling/shack NOT in back yard |

The numbers of households without on-site waterborne sanitation per sub-place within each district were thus sorted by water supply and race. The criteria chosen for attempting to characterise the different types of settlements are shown in Figure 3.1.1 and are those that are likely to have an influence on the generation and management of greywater. Filtering of the data was however only possible to a third level due to restrictions on the querying capabilities of the Census search engine.

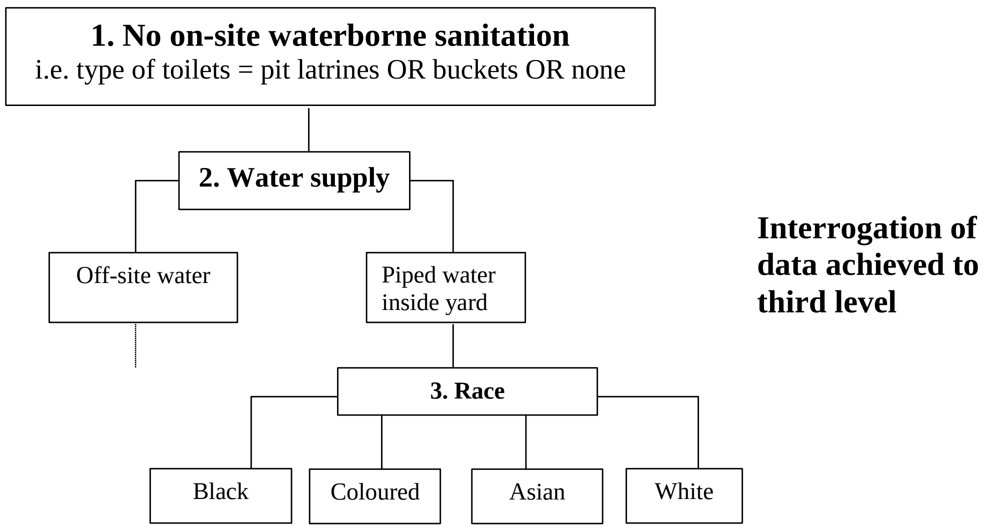


**Figure 3.1.1: Identification of non-sewered settlements**

Thirty settlements per district that fulfilled the following criteria were then highlighted for possible inclusion in the site surveys:

- Significant numbers of households with piped water inside the yard in relation to the numbers of households using "other" sources of water, as greywater volumes are likely to be higher in these areas.
- Representative split of racial groups across the settlements where possible.
- All significant districts in the province represented.

The representation of these groups was determined by comparing the number of households per category with the totals in each district. Table 3.1.2 shows the total number of households without on-site waterborne sanitation per district and Table 3.1.3 reflects the percentages of total numbers of households without on-site waterborne sanitation per district.

Table 3.1.4 gives an indication of the relative number of households per province in South Africa with piped water inside the yard (on-site water) as opposed to off–site water. It appears from the Census 2001 figures that approximately 75% of non-sewered households make use of "other" sources of water while 25% have on-site water. In spite of the desire to attempt to identify settlements with on-site water however, very few of the survey sites that were ultimately selected throughout the country had piped water inside their yards. This research has thus focused mainly on informal settlements with off-site water provision, usually in the form of communal standpipes.

**Table 3.1.2: Total number of households without on-site waterborne sanitation in the Western Cape (Statistics South Africa, 2001)**

| Rank | Description of category (all without sanitation) | Total no of households in district | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Boland | West Coast | Central Karoo | Cape Town | Eden | Overberg | Total |
| 1 | Black, Off-site water | 6045 | 2429 | 56 | 75618 | 7401 | 3468 | 95017 |
| 2 | Coloured, Piped water inside yard | 5782 | 14068 | 976 | 4183 | 4435 | 1757 | 31201 |
| 3 | Coloured, Off-site water | 4008 | 9846 | 590 | 5979 | 7412 | 1140 | 28975 |
| 4 | Black, Piped water inside yard | 1647 | 1427 | 42 | 2465 | 697 | 636 | 6914 |
| 5 | White, Off-site water | 51 | 135 | 6 | 243 | 162 | 30 | 627 |
| 6 | White, Piped water inside yard | 36 | 114 | 3 | 78 | 108 | 24 | 363 |
| 7 | Indian/Asian, Off-site water | 0 | 28 | 0 | 57 | 9 | 0 | 94 |
| 8 | Indian/Asian, Piped water inside yard | 3 | 19 | 0 | 33 | 6 | 0 | 61 |
| Total | | 17572 | 28066 | 1673 | 88656 | 20230 | 7055 | 163252 |
| % of total | | 11 | 17 | 1 | 54 | 12 | 4 | 100 |

**Table 3.1.3: Percentages of households per district in the Western Cape without on-site waterborne sanitation (Statistics South Africa, 2001)**

| Rank | Description of category (all without sanitation) | % of total no of households in district | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Boland | West Coast | Central Karoo | Cape Town | Eden | Overberg | Ave |
| 1 | Black, Off-site water | 34 | 9 | 3 | 85 | 37 | 49 | 36 |
| 2 | Coloured, Piped water inside yard | 33 | 50 | 58 | 5 | 22 | 25 | 32 |
| 3 | Coloured, Off-site water | 23 | 35 | 35 | 7 | 37 | 16 | 25 |
| 4 | Black, Piped water inside yard | 9 | 5 | 3 | 3 | 3 | 9 | 5 |
| 5 | White, Off-site water | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 6 | White, Piped water inside yard | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 7 | Indian/Asian, Off-site water | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | Indian/Asian, Piped water inside yard | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 3.1.4: Total number of households in SA per province without on-site waterborne sanitation (Statistics South Africa, 2001)**

| Description of water supply category (all without sanitation) | Total no of households in province | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | KZN | EC | LI | NW | GP | MP | FS | WC | NC | Total | % of total |
| Black, Off-site | 906763 | 872075 | 708646 | 417916 | 305147 | 280081 | 194806 | 95017 | 15563 | 3796014 | 73.5% |
| Black, On-site | 200443 | 83657 | 280384 | 168523 | 136599 | 162316 | 169991 | 6914 | 14014 | 1222841 | 23.7% |
| Coloured, On-site | 522 | 11276 | 400 | 1435 | 1165 | 405 | 2631 | 31201 | 19522 | 68557 | 1.3% |
| Coloured, Off-site | 1450 | 12700 | 571 | 3059 | 2239 | 693 | 3098 | 28975 | 15392 | 68177 | 1.3% |
| White, Off-site | 549 | 378 | 237 | 322 | 975 | 249 | 228 | 627 | 260 | 3825 | 0.1% |
| White, On-site | 291 | 162 | 210 | 246 | 1098 | 225 | 292 | 363 | 169 | 3056 | 0.1% |
| Indian/Asian, Off-site | 1716 | 75 | 75 | 75 | 93 | 66 | 12 | 94 | 21 | 2227 | 0.0% |
| Indian/Asian, On-site | 1090 | 33 | 51 | 36 | 78 | 30 | 9 | 61 | 24 | 1412 | 0.0% |
| Total numbers | 1112824 | 980356 | 990574 | 591612 | 447394 | 444065 | 371067 | 163252 | 64965 | 5166109 | 100.0% |
| % of total | 29% | 26% | 26% | 16% | 12% | 12% | 10% | 4% | 2% | 100% | |

The City of Cape Town (CoCT) also provided the project team with a list of informal settlements in the metropolitan area, with full details on the level of services within each settlement (City of Cape Town, 2004b). This document had been prepared for the CoCT's workshop on greywater in informal settlements, which was held in October 2004 as part of the City's Upgrading of Informal Settlements Project. The document proved to be particularly useful in terms of updating the information from the Census as well as highlighting problem areas in the vicinity of Cape Town, and was also used to confirm the suitability of sites chosen for surveys.

Table 3.1.5 shows the list of the 30 potential sites for the WC Province, with the eight sites finally chosen highlighted in grey. The choice of these sites was discussed wherever possible with relevant personnel from the Local Authority concerned so as to confirm the suitability of the site for surveys.

**Table 3.1.5: Potential sites for surveys in the Western Cape**

| Name of sub place | Total households with no sanitation by water supply and race | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Piped water inside yard | | | | Off-site water | | | | Total | | | |
| | Black | Coloured | Asian | White | Black | Coloured | Asian | White | Black | Coloured | Asian | White |
| **Cape Town district** | | | | | | | | | | | | |
| Philippi | 279 | 51 | 0 | 0 | 13580 | 185 | 0 | 6 | 13859 | 236 | 0 | 6 |
| Khayelitsha | 82 | 0 | 0 | 0 | 8799 | 15 | 0 | 0 | 8881 | 15 | 0 | 0 |
| Langa | 107 | 0 | 0 | 0 | 4297 | 3 | 3 | 0 | 4404 | 3 | 3 | 0 |
| Wallacedene | 87 | 9 | 0 | 0 | 1799 | 325 | 0 | 0 | 1886 | 334 | 0 | 0 |
| Khayelitsha Site C | 50 | 0 | 0 | 0 | 759 | 0 | 0 | 3 | 809 | 0 | 0 | 3 |
| Houtbaai | 12 | 3 | 0 | 0 | 491 | 0 | 0 | 0 | 503 | 3 | 0 | 0 |
| Airport Informal | 6 | 3 | 0 | 0 | 287 | 164 | 3 | 0 | 293 | 167 | 3 | 0 |
| Somerset West SP | 3 | 67 | 0 | 0 | 242 | 78 | 0 | 0 | 245 | 145 | 0 | 0 |
| Bellville NU | 41 | 141 | 0 | 0 | 205 | 149 | 0 | 0 | 246 | 290 | 0 | 0 |
| Sir Lowry's Pass | 9 | 6 | 0 | 0 | 176 | 255 | 6 | 0 | 185 | 261 | 6 | 0 |
| Red Hill | 6 | 0 | 0 | 0 | 156 | 30 | 0 | 0 | 162 | 30 | 0 | 0 |
| Phillipi East | 0 | 37 | 0 | 0 | 45 | 39 | 0 | 0 | 45 | 76 | 0 | 0 |
| Masiphumelele | 33 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 33 | 3 | 0 | 0 |
| Mandela Park | 15 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 30 | 0 | 0 | 0 |
| Phillipi AH | 0 | 18 | 0 | 3 | 30 | 205 | 0 | 0 | 30 | 223 | 0 | 3 |
| Macassar | 0 | 140 | 0 | 0 | 27 | 200 | 0 | 0 | 27 | 340 | 0 | 0 |
| **Boland district** | | | | | | | | | | | | |
| Rolihlahla | 3 | 3 | 0 | 0 | 281 | 169 | 0 | 0 | 284 | 172 | 0 | 0 |
| Worcester NU | 280 | 1131 | 0 | 0 | 159 | 440 | 0 | 3 | 439 | 1571 | 0 | 3 |
| Fairyland | 0 | 0 | 0 | 0 | 126 | 36 | 0 | 0 | 126 | 36 | 0 | 0 |
| **Overberg district** | | | | | | | | | | | | |
| Rooidakkies | 15 | 0 | 0 | 0 | 430 | 106 | 0 | 0 | 445 | 106 | 0 | 0 |
| Kleinmond SP | 9 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 6 | 0 | 0 |
| **Eden district** | | | | | | | | | | | | |
| Thembalethu | 12 | 3 | 0 | 0 | 1729 | 65 | 0 | 0 | 1741 | 68 | 0 | 0 |
| Dam se Bos | 51 | 0 | 0 | 0 | 605 | 166 | 0 | 0 | 656 | 166 | 0 | 0 |
| Bossies Gif | 0 | 0 | 0 | 0 | 469 | 47 | 0 | 0 | 469 | 47 | 0 | 0 |
| Oudtshoorn NU | 3 | 403 | 0 | 0 | 18 | 1198 | 0 | 15 | 21 | 1601 | 0 | 15 |
| **West Coast district** | | | | | | | | | | | | |
| Malmesbury NU | 288 | 1454 | 0 | 3 | 525 | 1883 | 5 | 21 | 813 | 3337 | 5 | 24 |
| Clanwilliam NU | 285 | 116 | 401 | 2473 | 862 | 3335 | 3 | 0 | 3 | 6 | 6 | 12 |
| Moorreesburg NU | 128 | 22 | 150 | 557 | 372 | 929 | 0 | 0 | 0 | 0 | 6 | 6 |
| Van Rhynsdorp NU | 0 | 0 | 0 | 271 | 134 | 405 | 0 | 0 | 0 | 0 | 0 | 0 |
| Koekenaap SP | 3 | 0 | 3 | 364 | 19 | 383 | 0 | 0 | 0 | 0 | 0 | 0 |

### 3.1.2 Site selection for the remainder of South Africa

Once the lists of potential sites in the different districts in each province had been produced, it was however discovered that the service status, populations, and even the names of settlements in the various areas had changed since 2001, due mainly to the large influx of people into the major cities of South Africa and the consequent "mushrooming" of informal settlements to accommodate their housing needs. There has also been a strong drive in some provinces (e.g. Western Cape and Gauteng) to upgrade sanitation facilities to waterborne sewerage systems, as part of the Reconstruction and Development Programme (RDP) housing projects. This meant that the Census 2001 data was not always able to give a precise indication of the numbers of non-sewered households in specific areas.

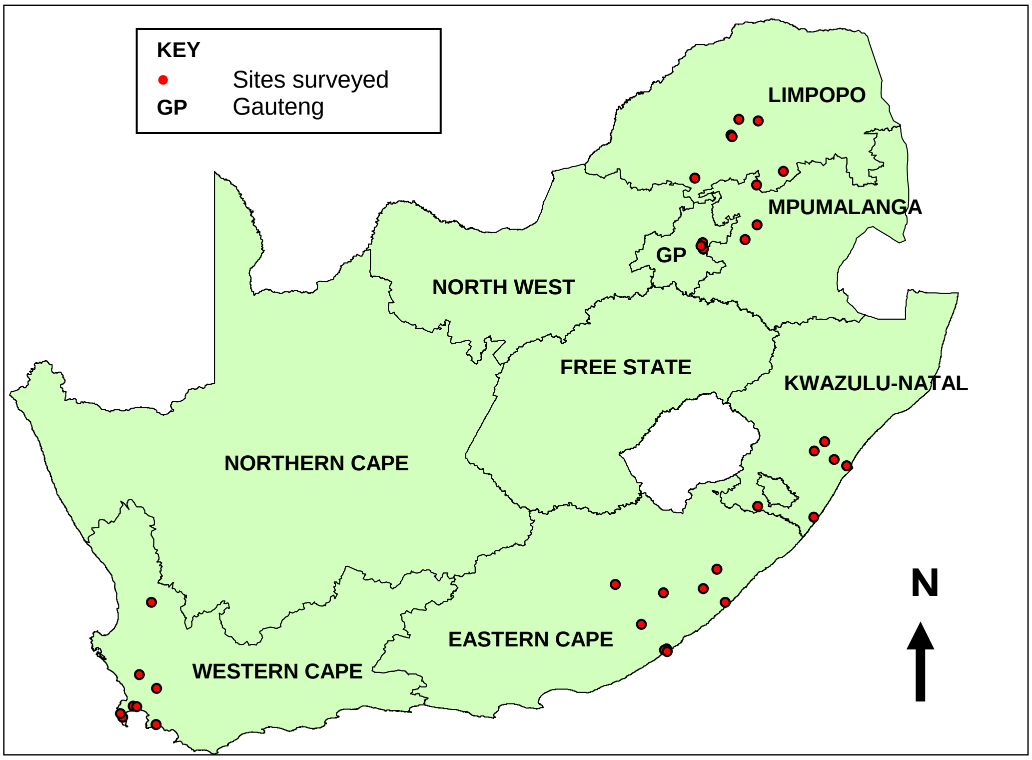


**Figure 3.1.2: Location of settlements chosen for on-site surveys**

In order to be able to select the most representative sites for the on-site surveys outside of the WC, a combination of four different approaches was adopted:

1. Census 2001 data – lists of highlighted sites in the various districts of each province were produced and used as the starting point for the selection of representative sites.
2. Discussions with Local Authorities (usually the housing or planning department) were held to determine the suitability of selected sites and confirm the current status of water supply and sanitation services in the area.
3. Ad-hoc / informal discussions with local residents (e.g. at taxi-ranks) were used to identify specific sites and obtain first-hand knowledge of living conditions within the settlements.

4. 1:50 000 topocadastral maps were used to identify settlements in areas where there were specific environmental concerns. DWAF geohydrological maps depicting groundwater conditions on a regional basis (1:500 000 scale) were used to try and highlight areas with known aquifers. It was not possible to pinpoint specific groundwater information to the survey sites that were selected, but any use of groundwater as a supply source was noted during the interview process.

By combining these approaches, sites were selected in six of the nine provinces in SA representing the range of problems associated with greywater disposal in different non-sewered settlements. Figure 3.1.2 shows the locations of the settlements that were visited.

## 3.2 Survey procedures

Once the target communities had been selected, the following steps were taken prior to the surveys:

1. Information was obtained on the geographic location and water supply / use of the selected site in order to gain some insight into the general dynamics of the settlement, particularly in respect of levels of services.
2. The relevant local authority was contacted for the names of the Councilor and/or Local Authority official(s) responsible for the settlement, and to obtain any background information on water supply, sanitation issues, strategies regarding greywater management etc. (see Settlement Characteristics questionnaire in Appendix A).
3. Where possible, meetings were convened with the relevant officials and community leaders in the area to discuss the aims of the research as well as the expected outcomes.
4. Community representatives were identified where necessary with a view to using these people as translators and intermediaries during the survey process if required.
5. The survey team always included a person who was fluent in the predominant language of the settlement, to facilitate first-hand communication with the community and act as an intermediary where necessary.
6. The greywater sampling arrangements were confirmed and arrangements made for sample bottles and instructions with the laboratory where necessary, before the surveys.

The following steps were followed when conducting the on-site surveys and/or interviews, of which there were between 2 and 10 per site (depending on the size and dynamics of the settlement in question):

1. The questions in the Greywater Survey Questionnaire form (see Appendix A) were used to obtain the required information from inhabitants regarding the generation of greywater and its management in the selected settlement.
2. Photographs were taken to record the observations at each place where an interview was held and of any other interesting activities in the settlement related to greywater. Detailed notes were taken to identify the position of any photographs taken.

3. A data sheet was completed for any water quality sampling that was undertaken, giving full details on the location of the sample and instructions for the analysis thereof. The type of analyses required depended on the settlement in question, and was determined before the survey began. See Appendix A for an example of the data sheet for the sampling.

Sampling comprised both field-testing as well as the collection of samples for further testing in the laboratory. As a rule, 1 – 5 samples of the typical greywater being generated were tested from each site together with 1 – 2 samples of the potable water in the settlement (either from the most-used tapstands in the vicinity of the greywater samples, boreholes, stored water or river water etc.). In order to reduce analytical costs, field test kits were used to measure pH, Electrical Conductivity, Total Phosphorous (as P), Dissolved Oxygen and Ammonia Nitrogen ($NH_3$). These variables were chosen based on their value as a water quality indicator. Information in this regard was obtained from selected chemistry and water quality reference books and articles (e.g. Sanders et al., 1987; DWAF, 1998). The reasons for the choice of water quality variables are as follows:

- pH – the pH of a sample determines the availability and toxicity of the specific chemical elements present in the sample, e.g. in alkaline (pH >7) conditions certain metals like aluminium may occur as unavailable hydrated hydroxides whilst in acidic (pH <7) conditions they form available and highly toxic ions.
- Conductivity – a measure of the ability of a solution to conduct an electrical current, used as an indicator of the amount of dissolved material (specifically salts) in the sample.
- Phosphates – the primary reasons for testing for phosphates are that phosphate is an algal nutrient (associated with the eutrophication of water bodies), and is indicative of pollution, e.g. from detergents, fertilizers, sewage etc. Polyphosphates (usually sodium tripolyphosphate) are used in detergents as water softeners in order to provide the alkaline solution which is necessary for effective cleansing, and are therefore found in large amounts in greywater.
- Ammoniacal Nitrogen – when dissolved in water, ammonia ($NH_3$ – highly toxic) reacts to form ammonium ($NH_4^+$ – less toxic), the quantities of each depending on the pH and temperature of the sample. Water contaminated with ammonia should not be allowed to enter any surface or ground water system. The field test kits measured total ammonia-nitrogen, which is ammonia plus ammonium.
- Dissolved Oxygen – the measurement of the amount of oxygen dissolved in the water relates to the amount of oxygen available for living organisms. Low levels of dissolved oxygen may indicate organic pollution of the sample.

Control samples were collected at most sites for analysis in a registered laboratory, and in some instances, to test for selected parameters that could not be analysed in the field, e.g. Chemical Oxygen Demand, Oil & Grease, Sodium, Boron and *Escherichia coli* (E.Coli):

- Chemical Oxygen Demand – this is used as a measurement of organic contamination in wastewater, and is determined by measuring the equivalent amount of oxygen required to oxidise organic matter in the sample.
- Oil & Grease – these represent a class of materials which can be extracted from water using organic solvents, and can be of biological (animal fat, vegetable oil) or mineral (petroleum hydrocarbons) origin, or they can be synthetic compounds. Greywater from kitchen processes generally has higher levels of Oil & Grease, and this can lead to clogging of soil surfaces, leading to smells etc.
- Sodium – high levels of sodium in greywater (derived from the soluble salts in detergents) that is used for irrigation can cause reduced crop yields and quality due to sodium uptake through the roots and leaves of sodium-sensitive plants, impaired soil physical conditions (reduced soil permeability) and an increased tendency for hardsetting (DWAF, 1996). The measurement of the sodium adsorption ratio (SAR) is often used to predict whether a given water is suitable for irrigation and can be defined as the potential of a given irrigation water to induce sodic (i.e. high sodium) soil conditions. It is calculated by using the concentrations of sodium, calcium and magnesium in water. SAR therefore tends to increase with increasing salt content (or electrical conductivity).
- Boron – Boron is a naturally occurring element which forms borates in combination with oxygen and other elements, and is found in soaps, antiseptic agents and detergents. Boron is an essential macronutrient for plants, but different species require different boron levels for optimum growth, and in some plants there is only a narrow margin between deficiency and toxicity. Sensitive plants (e.g. citrus, fruit trees, grapes) should not be exposed to water containing more than 0.3 mg/l boron (DWAF, 1996).
- E. Coli – gives an indication of pollution by faecal matter from warm-blooded animals. The number of E. Coli in a given volume of wastewater can be used to indicate the level of risk to human health where there is contact with this wastewater. Examples of the different pathogens associated with faecal contamination and poorly treated wastewater are given in Appendix C (see Table C1), which provides a detailed discussion on the health aspects of greywater use.

Section 4.4 provides further details on the results of the sampling that was undertaken during the course of the site surveys.

## 3.3 Information management

Good information management is vital if greywater is to be successfully managed. In this project Information Management was split into two aspects: internal data flow and external data flow. The internal data flow related to the communication between the various specialists who were collecting information and the external data flow related to the communication to the wider community.

Data gathered in the surveys was integrated into a simple MS Access database and then combined with the relevant spatial information. GIS was used to produce maps to facilitate an understanding of the key issues. The data came in two forms: survey information (environmental and social) and spatial information. Survey information was collected in the form of answers from the standardised questionnaires, observations, water samples etc.; and spatial information about the physical environment was mainly collected using existing information from Government departments, such as the Department of Land Affairs. All information was transferred from paper form to Excel spreadsheets and an MS Access database and then integrated into the GIS. The following type of information was collected (where available):

- Quantity of greywater – linked to water consumption
- Density of population / housing density
- Soil type (particularly in respect of drainage conditions)
- Topography – general indication of average slopes
- Levels of service within community – water supply and sanitation
- Socio-economic status of the community
- Quality of the greywater and source (drinking) water
- Local governance – both formal and informal
- Culture / Religion – optional questions in survey
- Spatial patterns/ urban planning – observations only
- Ownership / land tenure / history (cf. land invasions)
- Environmental sensitivity of the area surrounding the selected community, particularly in respect of possible pollution of water resources
- Proximity to major metropolitan areas – classification of urban, peri-urban and rural settlements
- Representivity in terms of geographical distribution around the country, language and / or race

For certain sites in the Eastern Cape and KwaZulu-Natal, GPS co-ordinates were recorded during data collection. For the other sites, the boundaries used for the collection of Census data were employed. The centroid of the sub-place (the smallest demarcation used in the Census) containing the survey site was then used as the geographic location of that site. To link the attribute data to the spatial data, a PostgreSQL/PostGIS spatial database was created. PostgreSQL is an established and widely-used open source database management system (DBMS) which provides spatial data storage and querying capabilities through the PostGIS extension package. The spatial capabilities of these systems rely on established open source GIS packages such as GEOS (spatial querying), GiST (Generalised Indexed Search Tree, a spatial indexing package) and proj4 (reprojections). After standardizing the spelling of site names to match those found in the Census data, the spreadsheet containing the attribute data was exported as a list of comma-separated values, and this information was inserted into the database and linked to the spatial data stored for each site.

Quantum GIS (QGIS), a lightweight, open source desktop GIS, was used to view the data in the database and to produce the initial thematic maps. Unfortunately, its presentation capabilities were ultimately not as good as those of ESRI's ArcMap 8. The data in the database was thus exported to shapefiles so that the final maps could be created using ArcMap 8.

One of the challenges for the data collection process was that the collection and integration of data was done by independent teams. This meant that no particular group was completely aware of the needs of other groups, which resulted in having to iteratively amend information. Some of the base data was acquired from the Department of Land Affairs, Census 2001 (plus various updates) and the Department of Health. This resulted in having data at different levels of scale and with different numeration codes. The South African government is working towards developing a framework which will result in clearer instructions on the data capturing requirements, and this should help to standardise data. However, during this research effort, information such as incidence of waterborne diseases at district level was impossible to attain. Greywater management is closely related to a number of governing departments and it is unclear who keeps data about which aspects. For example, ensuring that the people of South Africa can drink the provided water without risk to their health is the responsibility of the Department of Health; however water quality tests are done by the Department of Water Affairs.

The collected data was transferred into the GIS system and was combined with information received from Census 2001 and other statistical information. Due to the varying levels of scale it was not always possible to integrate the statistical data with the information collected at community level. Since communities very rarely collect their own information, Census data is also not verified at this level and it became clear that it was not always possible to rely on the information that was provided by Census. Updated census figures from the Non-financial Census (Statistics South Africa, 2004) and the General Household Survey (Statistics South Africa, 2005) were however useful in terms of determining overall changes in the numbers of non-sewered households in South Africa.

The development of a system to manage information effectively has thus proved to be a challenge in a country like South Africa where there is a large variety of different types of human settlements. For long-term sustainable management of community greywater information, a decentralised system for data collection and information management would be required.

## 3.4 Summary

The main aim of this study has been to understand the use and disposal of greywater in the non-sewered areas of South Africa. This has included aspects such as quantifying the greywater problem and developing options for the management thereof, both in terms of reducing health and environmental risks, as well as possibly providing benefits to communities through the controlled use of greywater as a resource. It was essential therefore that the methodology for the study included the identification of key variables affecting greywater use and disposal, as well as the determination of ways in which these variables could be controlled. The process described in Section 3.1 was followed in order to be able to select settlements for site surveys that would represent the range of different non-sewered sites throughout South Africa.

The database that was developed was used for first-level querying of the data collected during the site surveys, as well as for map production with the use of the GIS link. It was found that there were limitations in the availability and validity of settlement data throughout the country as a whole. This meant that the database could not be used as a tool to identify specific areas in South Africa where greywater disposal could be problematic, although it was useful in determining overall greywater impacts at a provincial scale. In order to be able to properly assess the extent of the greywater problem in non-sewered areas down to community level, it is clear that improved data management by the SA Government is required, and that there should be national coordination on this issue. Once this is achieved, it will be possible to further investigate the potential use of GIS and spatial information technology for the management of greywater in South Africa.

As can be seen, the formulation of the methodology for this type of research was a challenging process and there were several difficulties and constraints that had to be overcome, including the following:

- The challenges of conducting country-wide surveys from the Cape Town project base
- The unrealised expectation that GIS and related spatial data could be used more effectively in the research project
- The scale of the site surveys and the wide range of different conditions that were encountered

It is worth noting therefore that the methodology continued developing during the course of the research, with valuable lessons being learnt along the way.

# 4. Summary of findings from site surveys

This chapter summarises the findings from the site surveys that were conducted, the results of which were used to assess the extent of greywater impacts in South Africa, and determine the required management options to deal with these impacts. It became clear during the analysis of the data that was collected that a large variety of conditions occur in the non-sewered settlements of South Africa. It was not possible to determine specific trends or correlations between the influencing factors in greywater generation and disposal, which highlighted the fact that the greywater issue in non-sewered areas is extremely complex. The overall impacts resulting from greywater have however been assessed, and options for greywater management determined.

The full results of the site surveys conducted as part of this research are presented as case studies in Appendix D, and include details on the site description, social and environmental findings, greywater disposal and water quality data. Some of the more strategic environmental and social observations from these site surveys are presented below.

## 4.1 Environmental impacts from greywater in non-sewered areas

The site surveys identified a variety of direct and indirect impacts on the biophysical environment that can be attributed to greywater run-off from different types of settlements. Direct impacts were evident in the poor water quality of ponded water, streams and wetlands found in close proximity to non-sewered homesteads. Indirect impacts were inferred from observations including the presence of oil, grease and organic substances found on soil surfaces; grass and plant vegetation destroyed by being inundated with wastewater and interviewees who suggested that young children face health risks because they are in contact with greywater. Certain communities also commented on a perceived increase in flies and mosquitoes as a result of wastewater ponding and high concentrations of organic material. Key concerns with respect to the biophysical environment include:

- the impact of greywater on the biota of water bodies
- a deterioration in the aesthetics of stream, river and wetland environments
- a deterioration in water quality that might affect downstream users using water for consumptive and recreational purposes and those who depend on water quality to support livelihoods (e.g. the tourism and transportation industries).

Field observations revealed extensive inundation of wastewater on soil surfaces at certain sites, and greywater was observed being disposed not only into river systems but also directly into sensitive estuaries and marine environments. In the absence of groundwater analysis, it cannot always be proved that the groundwater is being contaminated by greywater, but it is highly likely and the long term potential for a significant deterioration of groundwater quality should be monitored. The collection of a long term data set and analysis of groundwater for selected areas throughout South Africa should therefore become a matter of urgency. This is particularly important in dolomitic areas where the poor drainage conditions could lead to the formation of sinkholes. It is recognised in this study that generalisations about settlement size and density fail to account for the underlying soil conditions on which many sites are situated. For example it is well established that porous and fractured rock accelerates surface to groundwater flow. Alternatively, where surface soils consist of permeable sands with an underlying fractured bedrock, then attenuation of the pollution is limited and the risk of groundwater pollution is high.

The chemistry of greywater varies considerably according to the type of cleaning products used, the volume of water used in the process, the number of rinses involved, the time taken for these agents to dissolve, and the state or condition of the objects, material or bodies being cleaned. The variability of these factors accounts for the wide range of water quality obtained in this study. The study findings estimated that about 75% of the total household water is disposed of in some manner with the remaining 25% being used consumptively, e.g. for drinking and cooking purposes. It was found that most greywater is disposed onto the ground as a matter of convenience. The vast majority of interviewees reject the practice of using greywater for irrigation. The reasons for this vary considerably, but most of the sample population felt that greywater is "dirty" and could not be used.

It is instructive to consider the types of cleaning agents that are typically used in households so as to infer the potential damage to the environment. Information on the contents of cleaning agents typically used in non-sewered settlements as stated on the packaging is presented in Table 4.1.1.

**Table 4.1.1 Typical cleaning products used in non-sewered settlements**

| **Soaps** | **Contents (as stated on the packaging)** |
|---|---|
| Sunlight family soap | Sodium tallowate; Sodium palm state; Aqua; Sodium palm kernelate; Titaniumdioxide; Sodiumcarbonate; Tetrasodium EDTA; Etidronic acid; Sodium chloride; Aloe barbadensis; Glycerine; Perfume; CI 11680; CI 74260 |
| Sunlight cleaning liquid | 20-40% Anionic detergents; <15% solubilisers; Other – perfume and colourants |
| JIK cleaning liquid | 'Becomes ordinary salt, oxygen and other harmless substances thereby safeguarding the environment. Safe septic' |
| Handy Andy liquid | <5% non-toxic surfactants; 5 - 8% anionic surfactants; 7-15% abrasive agent |
| Omo washing powder | <5% polycarbonates & cationic surfactants; 5 - 15% silicates & soda ash; 15-30% anionic surfactants & phosphates |
| Sunlight washing powder | 5% polycarbonates & clay; 5 – 15% silicate & soda ash; 15 – 30% anionic surfactants & phosphate |

While a chemical analysis of cleaning products was not undertaken, the information provided on the packages of these products identifies that salts are dominant in all these cleaning agents. Furthermore, in-situ analysis of dishwashing and laundry water samples indicated that total phosphate levels were often extremely high (e.g. over 400 mg/*l*). Likewise, Total Kjeldhal

Nitrogen (TKN) levels were also found in places to be over 400 mg/*l*. It can be anticipated that there may be a large impact on water bodies where excess nutrient loads flows directly into rivers, stormwater systems and wetlands. The use of the typical reagents listed in Table 4.1.1 together with the fact that people tend to dispose of greywater onto the ground or vegetation wherever convenient, is therefore likely to modify and possibly permanently damage soils and water bodies.

Some generalizations may be made with respect to the environmental impacts that were observed during the site survey process:

- The data collected from interviews at settlements which have a low population density in rural areas that are furthermore situated some distance from water bodies, suggest that the environmental impacts are minimal under these circumstances. In these situations greywater is generally being dispersed regularly on porous soils with little or no inconvenience to households. It can be concluded therefore that rural settlements situated on relatively flat, well-drained soils do not have an obvious greywater management problem.
- Low density rural settlements situated on hilly topography, and in close proximity to water bodies, pose a greater risk to the pollution of water resources. Fieldwork conducted in the KwaZulu midlands and in the Valley of a Thousands Hills (also KZN) identified the flow of greywater run-off from the upper sources of streams as a contributor to the poor water quality found in valleys. The situation had sometimes been exacerbated by the behaviour of upstream users. For example, some interviewees living in upper catchments wanted to construct drains to remove wastewater directly from their dwellings and into nearby rivers. They felt water security had increased in recent years through the provision of tapstands and they no longer needed to use rivers to access their water source (and therefore no longer needed to maintain the quality of the river water). The consequences of such behaviour could be severe.
- Without doubt; dense, non-sewered informal settlements pose the greatest risk to the biophysical environment and to human health. It has been shown that although households in high-density settlements often consume less water per capita than less densely-settled areas, the disposal of wastewater to the ground surrounding the houses leads to ponding and run-off which is often exacerbated by water leakage at the tapstands, due to leaking or broken taps. This run-off is frequently channelled into stormwater drains. In some cases settlements are serviced by stormwater drains and canal systems that direct wastewater directly into water bodies. Such canals are frequently unsightly, unhealthy and contribute to the overall deterioration of the urban environment. Many interviewees living in close proximity to these situations suggested that the streams and rivers that had deteriorated so badly should be contained in closed pipes so as to avoid further risks to their children and improve the aesthetic environment.

The following two case studies highlight the potential biophysical impacts from different types of settlements:

1. Low density rural settlement situated in a hilly topography and in close proximity to water sources.

KwaShange (Appendix D3.3), south west of Pietermaritzburg is an excellent example of a sparsely populated rural settlement in a hilly topography. Water samples were collected from homesteads in the upper section of the catchment and from streams in close proximity of these homesteads. The streams feed the Msunduze River which flows into Henley Dam, a key storage dam of potable water for Pietermaritzburg. Figure 4.1.1 shows the location of the site and the connecting river system to the Henley Dam.

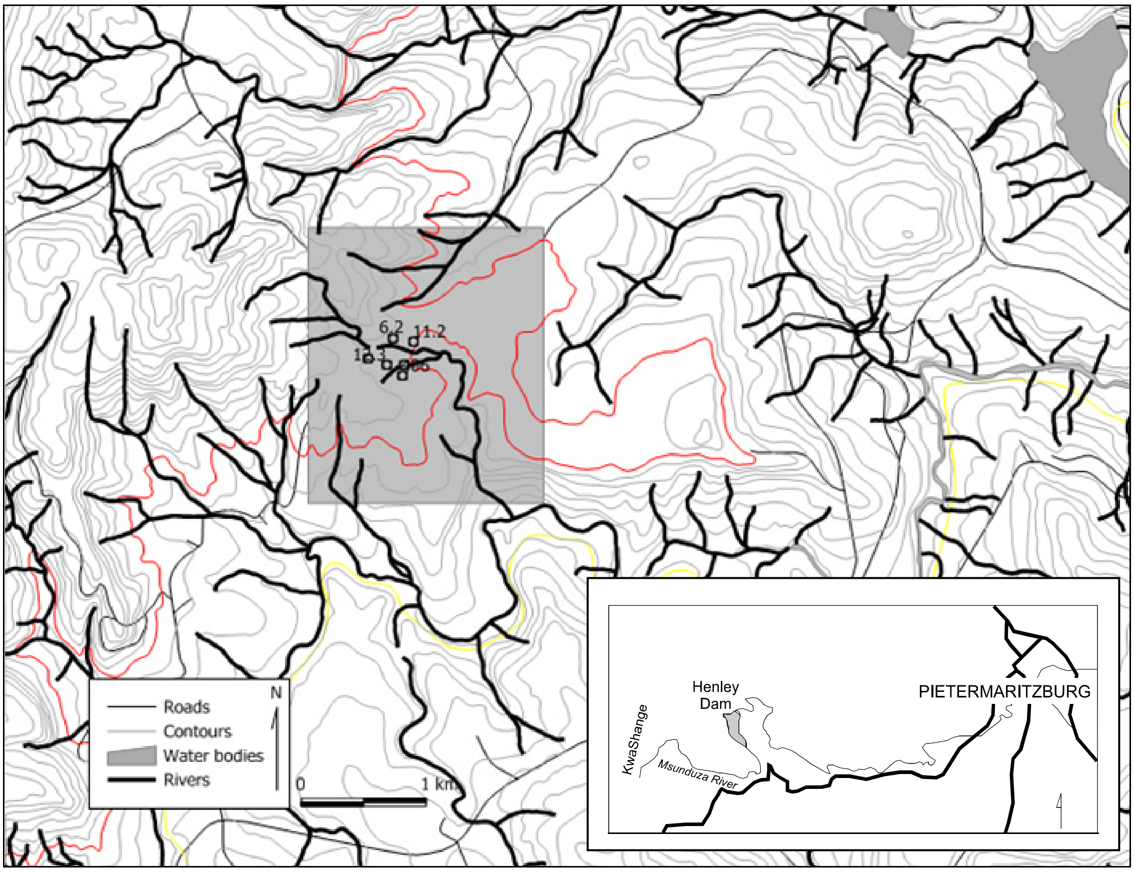


**Figure 4.1.1: KwaShange, south west of Pietermartizburg**

Electrical Conductivity and Total Phosphorous are highlighted in the accompanying maps (Figures 4.1.2 and 4.1.3) to illustrate the relatively high level of salts and phosphorous in laundry and kitchen water. The EC and Total Phosphorous in the Msunduze River were 132µS/m and 5.2mg/*l* respectively. The pollution of the stream appears to be minimal, but an accumulation of phosphorous could be detrimental to the biota and water quality especially in ponds and lakes.

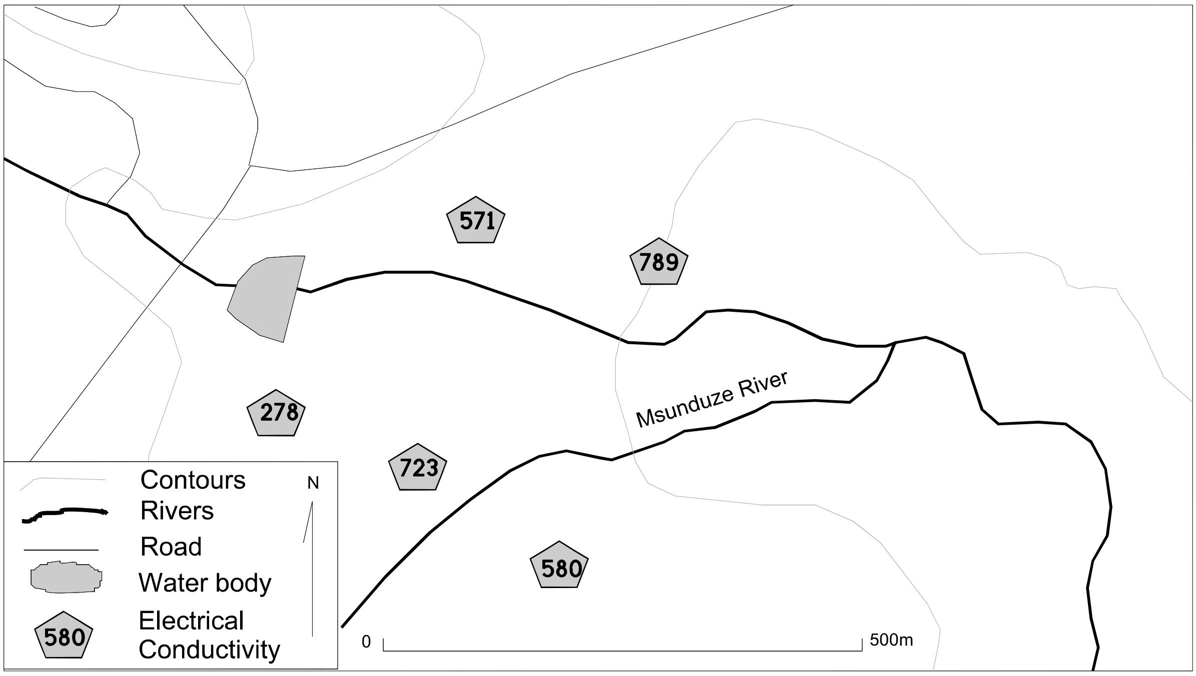


**Figure 4.1.2: Electrical Conductivity, EC (µS/m) in samples collected from homesteads in KwaShange and the Msunduze River**

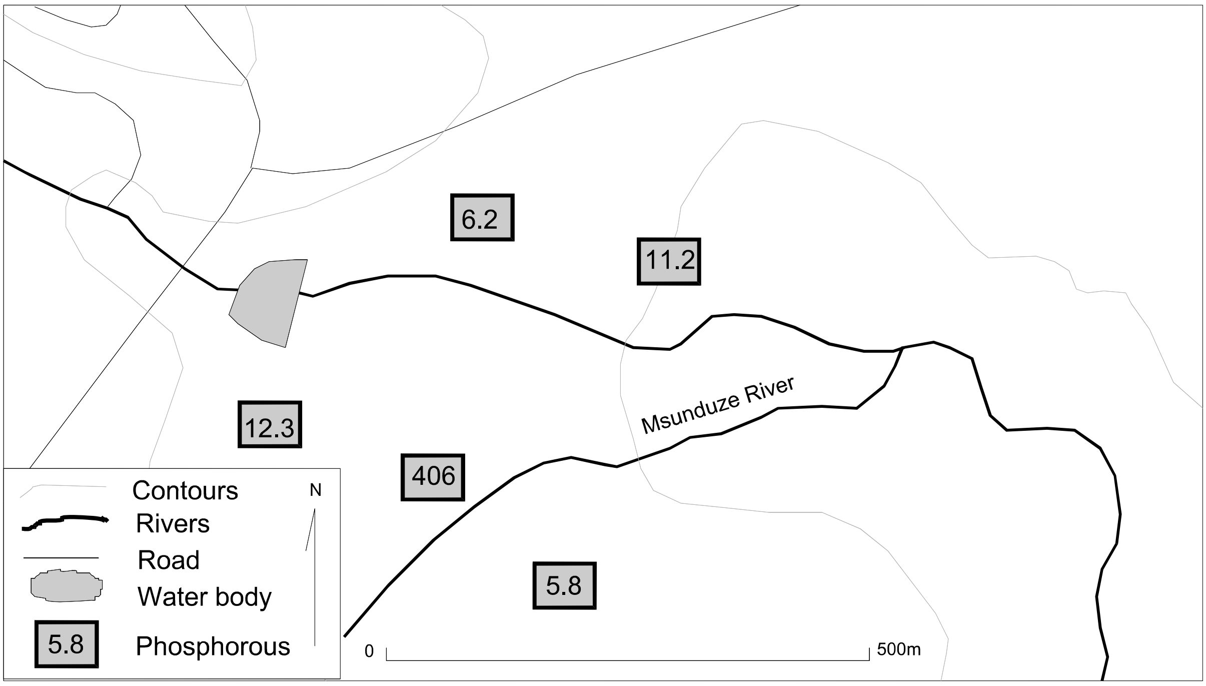


**Figure 4.1.3: Total Phosphorous as P (mg/l) in samples collected from KwaShange**

2. High density peri-urban informal settlement: Cato Manor, Durban

In contrast to the previous example, high-density, non-sewered settlements appear to have a much greater impact on the biophysical environment. The Cato Manor site (Appendix D3.6) illustrates how residents, struggling to survive in difficult circumstances, have little respect for streams and rivers abutting their homesteads. In this situation, streams were viewed simply as a means of disposal for solid and liquid waste, as confirmed by some interviewees.

Figure 4.1.4 illustrates the site and situation of Cato Manor. It should be noted that run-off from this settlement is directed to the Mkhumbane River which releases its load via the Umbilo Canal into the Durban harbour.

Figure 4.1.5 and Figure 4.1.6 both show relatively high levels of EC and Total Phosphorous. Of concern is that these levels remain high in the Mkhumbane River (EC – over 800µS/m; Total Phosphorous – over 20mg/*l*). These levels are indicators of high levels of pollution.

The study findings have identified high density, non-sewered settlements in close proximity to water bodies as a primary cause of impacts on the biophysical environment. These sites and situations must be clearly identified and some form of technological and strategic intervention must be implemented as a matter of urgency.

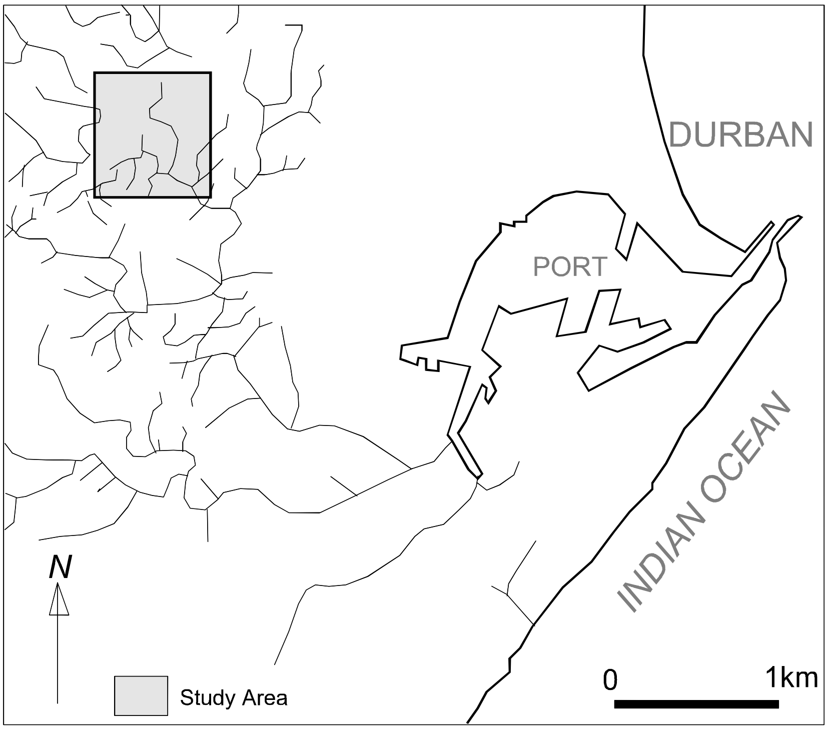


**Figure 4.1.4: Site location of Cato Manor, Durban**

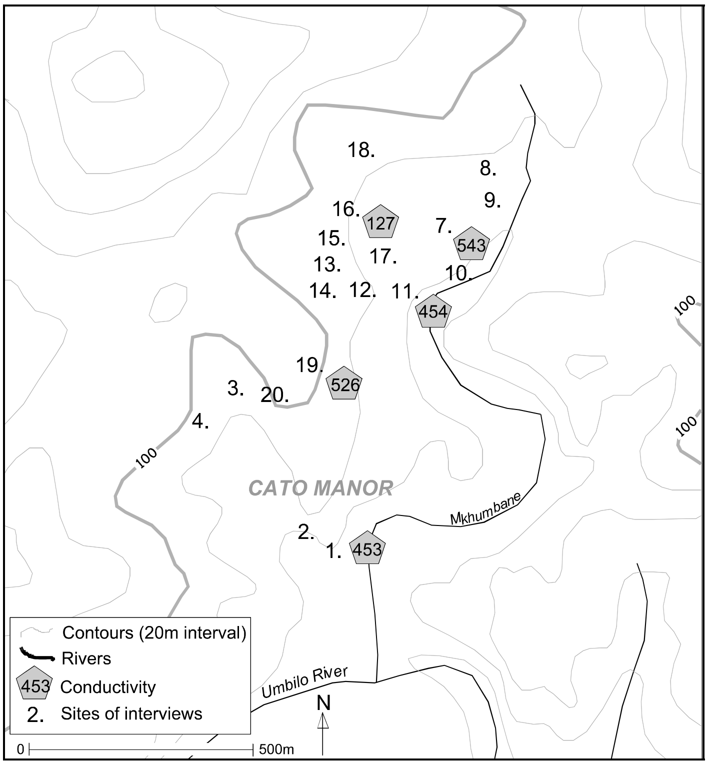


**Figure 4.1.5: Cato Manor study showing sites of 19 interviews and Electrical Conductivity measurements (µS/m)**

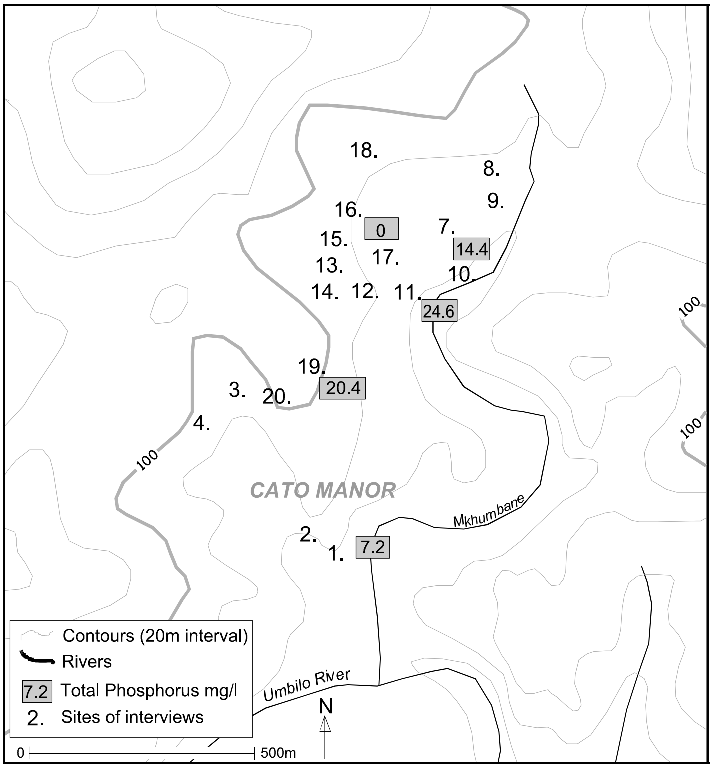


**Figure 4.1.6: Cato Manor study showing the sites of 19 interviews and Total Phosphorous as P (mg/l) at selected sites**

# 4.2 Social impacts associated with greywater in non-sewered areas

South Africa currently provides safe drinking water to some 87% of the population and adequate sanitation to about 67% (DWAF, 2005a). The residents of non-sewered settlements are almost without exception in the low-income category and constitute the minority that still lack adequate services. The literature on poverty in South Africa suggests that many poor people in rural and urban areas depend on grants for their income. As a consequence of poverty but also owing to the long tradition of paternalistic local government both in the homelands ruled by chiefs as well as in urban compounds and townships, people expect local authorities to play the leading role in providing and maintaining services and even in managing community assets. The development of a vibrant civil society at community level is a work in progress and much still needs to be done. Although this study is about wastewater management, it is clear from the interviews that were conducted that poverty issues are closely related – access to water and sanitation is almost always discussed together with access to other basic services like adequate housing, electricity, a safe environment, employment and education.

## 4.2.1 Results of social surveys

Most interviewees did not have regular paid employment and relied on grants, casual work, gifts from relatives and other forms of aid for survival. Education levels varied but were generally relatively low. In general rural and peri-urban residents appeared more content with their situation than residents of urban settlements and it seems interviewees who have made rural settlement a lifestyle choice make up for the inconvenience of the greater efforts required to fetch water daily with a more peaceful and less stressful communal life.

There were few signs of water use practices being influenced by cultural or religious beliefs, although notions of pollution based on the witchcraft paradigm (see text box) that sees neighbours as potential perpetrators of harm caused some urban households to throw away any water in the house that had been stored in containers overnight.

***The Witchcraft Paradigm and Community Life***

*The social sciences remain baffled by the persistence of witchcraft accusations, divination and cleansing or witch eradication in modern society. The main reason for the lack of understanding is that researchers have by and large failed to escape their own narrow ethnocentrisms. The use of the notion of a witchcraft paradigm in the context of this research supports the point that Ashforth (2002) makes regarding Soweto (as well as other parts of the country that have similar social problems). He claims that a certain lack of trust pervades society, based on the belief that misfortune comes from outside the person, outside the village and outside the family group. It is suggested that especially in urban multi-cultural communities, such a "presumption of malice makes it difficult to build networks of trust" and that this has practical implications for civil society, especially when a high prevalence of misfortune makes suspicions of witchcraft all the more plausible.*

The significance of this lack of trust for the poor development of community-based governance is obvious. In fact, even settlements with well-organized political lobbying structures, like Redhill (see Appendix D1.2), displayed this lack of trust and revealed a divided community which is more likely to respond to household rather than community-level interventions. If residents share little and have shown no communal spirit in tackling problems like leaking water pipes for example, can they be expected to maintain communal toilets, taps or greywater drains? A key role will have to be played by local authorities in this regard until such stage as the tradition of civil society participatory politics takes root.

When asked what they would like to see change in their lives many respondents prioritized “proper houses” which have electricity and waterborne sanitation. These concerns were seen as the most pressing needs in resident's lives. When asked who should play the leading role in this development the answer was invariably the “government". Even the malfunctioning of water supply was seen as a matter for the municipalities to correct. If greywater use is to become essential for managing the water supplies for drought-prone towns or to alleviate the health concerns over wastewater being disposed on the ground, it must be championed by the municipalities first. The fact that recycling is not the main concern of people in these settlements appears to be based on a sense of entitlement. This has resulted as a consequence of the Government's stated policy regarding the delivery of waterborne sanitation in fully serviced homes to as many citizens as possible and in line with South Africa's long tradition of paternalistic municipality management, especially in black townships. Most people consider alternative water provision and wastewater management techniques as temporary measures only, and expect to have waterborne sanitation and a continuous supply of potable water in their homes in the near future.

The concept of water recycling embedded in Government policies may be viewed with suspicion if citizens think that they will be getting an “inferior” product. Similarly, dry sanitation and other alternatives to waterborne sanitation, though perfectly “adequate”, may turn out to be politically unacceptable. It is therefore important to understand the specific local authority approaches to greywater management and their sanitation/water supply strategies and explain these to the local citizens.

In different parts of the country researchers found that socio-economic circumstances such as levels of income seem to influence the amount of water used per household, the types of detergents, frequency of laundry habits and amount of greywater generated. The need for sustained environmental education and mobilisation was evident in rural areas where rivers were being used as sewers and in urban settlements where stormwater drains were similarly being used to carry away the greywater and other wastes. The leading role in this process will need to be played by the municipal authorities in concert with local community leaders.

### 4.2.2 Discussion on social impacts

One of the questions posed during the interviews was aimed at determining whether the residents of non-sewered settlements thought that greywater was usable in any form. It was found that although people were generally aware of the concept of recycling, the use of greywater as such was a new concept to them and their responses to questions about its usability were therefore hesitant. More information will be required before their perceptions can be taken as a serious measure of their opinions. At present there is “trial and error” greywater use being carried out by individuals in some areas but most people do not regard it as a resource. It should also be noted that a lot of reuse already takes place before water is discarded as greywater and this in itself constitutes a form of water recycling. It will be difficult for local authorities to support the use of greywater around the household on an institutionalized basis however, as controls would have to be put in place to ensure that health and environmental risks are minimised.

In the very high-density urban settlements that were visited, such as Freedom Square near Tembisa and parts of Khayelitsha in Cape Town, there was little space for gardening and greywater was perceived to be a problem rather than a potential resource for recycling. As usually happens when a large number of people are disposing their wastewater on the ground, streams of water have formed, which in this case could end up in other people's shacks. Greywater was also carried from homes and deposited in the runoff from the standpipes or in stormwater drains near the main road. Many women did their washing at the standpipes and dumped their laundry water into the overflow from the taps. Smaller amounts of greywater from the kitchens were usually just thrown onto the sand near the houses. In one case it was noted that a woman whose house was situated near a stormwater manhole was using the manhole as a soakaway and throwing large amounts of laundry water into it. Some plastic bags and other solid waste also ended up in the manhole owing to the fact that the main refuse dump was on the outskirts of the settlement, near the toilets.

In all of the settlements visited it was found that people have access to drinking water and some form of basic sanitation. Even in the Eastern Cape (arguably the poorest of the rural provinces) the DWAF-defined "adequate access to water services" of 25*l*/c.d within 200m of the dwelling has been provided for most people. In some rural settlements, however, women still walk relatively long distances to water points, or collect water from springs or uncovered wells. Needless to say such water is likely to be of a poorer quality. This research on greywater disposal in the non-sewered areas in South Africa, though exploratory, has highlighted that a number of challenges still remain in water and sanitation service provision in this country:

- Access to "adequate sanitation" still lags behind the supply of potable water which seems to have been given higher priority in the provision of basic services by the Government (even in terms of the target dates that have been set);
- Not all the water and sanitation facilities recently provided by local authorities have remained in working order and the question of sustainability needs prioritising;
- Whilst people should take responsibility for their own environmental health, local authorities still need to be seen as playing the leading role because they have the resources to do so.

In areas where drainage was particularly poor, a number of health problems were identified by residents, including mosquito infestation, smelly stagnant water and children falling ill after playing in the water. In urban settlements like Khayelitsha in Cape Town stormwater drains were routinely used for greywater disposal and, when questioned about this practice, some city officials were of the view that this is the best possible solution for getting wastewater out of the residential areas. The pressures that this may create on the streams and wetlands further downstream needs to be further researched.

It was found that some people do dispose of greywater in specific places in certain areas and this suggests that, with community approval, management systems could be implemented successfully. Many interviewees were conscious of water shortages and indicated a willingness to conserve water if the authorities showed them how this could be achieved. The overwhelming impression however, was that greywater was dirty, even toxic, and could not be used. Even if tests show that it can be used for growing certain crops, education campaigns would be necessary to effect attitude and behaviour change.

## 4.3 Quantity of greywater generated in non-sewered areas

One of the objectives of this study was to quantify the greywater generated in South Africa. The generation of greywater is directly related to the consumption of water in a household and is dependent on a number of factors including the level of service provision, tolerance of residents to pollution and the communities' level of awareness of health and environmental risks. It is assumed that greywater accounts for virtually all water use in non-sewered areas except for that which is used for drinking purposes, that which is used consumptively in cooking, and the water that remains on the surfaces of washed articles.

As reported previously in the literature review, water consumption in low-income households without waterborne sewerage is markedly less than in Western-style households and is primarily dependent on the availability of a standpipe to the house (Alcock, 2002). The estimated water consumption for households with a standpipe in the yard is of the order of 30 – 80*l*/c.d. Multiple tap households will use substantially more water than those with access to only one tap. Where water has to be carried from an external source (greater than 250m to the source), a mean consumption of 9 – 50*l*/c.d can be expected. This was confirmed by Cairncross (1990) who also noted that locating a water supply point on the property, i.e. in-house or yard tap, could increase consumption by as much as 2–3 times compared to having to walk to fetch water. Alcock estimated that the available greywater generated per person on site could be of the order of 25 – 75*l* per day.

It appears that one of the few SA studies to have conducted actual measurements of greywater production in low-income settlements was the work that was done as part of the Water Research Commission (WRC) Project No. K5/1440, "Drainage in rural and peri-urban townships" (Stephenson et al., 2006). Seven households were provided with 200*l* drums for the disposal of their greywater so that the daily volumes of greywater produced could be measured. The average water consumption from communal standpipes in Kwamathukuza, Newcastle was found to be 153*l*/du.d (29*l*/c.d), with greywater comprising about 87% of this, or 133*l*/du.d (25*l*/c.d).

Table 4.3.1 summarises the figures obtained for water consumption during the on-site surveys throughout SA and also provides estimates for the volumes of greywater produced in these settlements, based on the average greywater return factor of 75%.

**Table 4.3.1: Water consumption and greywater generation figures from on-site surveys**

| Name of settlement | Province[1] | On- or off-site water | Average per capita water use, *l*/c.day | Average household water use, | Average household greywater produced, *l*/du.day[2] |
|---|---|---|---|---|---|
| Clanwilliam | WP | Off | 25 | 65 | 50 |
| Redhill | WP | Off | 18 | 75 | 60 |
| Fairyland | WP | Off | 13 | 75 | 55 |
| Kleinmond | WP | Off | 19 | 105 | 80 |
| Sweet Home Farm | WP | Off | 13 | 70 | 55 |
| Masiphumelele | WP | Off | 18 | 100 | 75 |
| Khayelitsha RR | WP | Off | 15 | 55 | 40 |
| Lingelethu | WP | Off | 11 | 55 | 40 |
| Silvertown | EC | Off | 22 | 70 | 55 |
| Bongweni | EC | Off | 26 | 160 | 120 |
| Orange Grove | EC | Off | 27 | 60 | 45 |
| Phakamisa Park | EC | Off | 13 | 80 | 60 |
| New Payne | EC | On | 17 | 80 | 60 |
| Mputhi | EC | Off | 11 | 75 | 55 |
| Mthento | EC | Off | 11 | 150 | 115 |
| Mpathi | EC | Off | 25 | 100 | 75 |
| Emahobeni | EC | Off | 12 | 45 | 35 |
| Zolani | KZN | Off | 27 | 85 | 65 |
| Boboyi | KZN | Off | 15 | 110 | 85 |
| KwaShange | KZN | On | 16 | 95 | 75 |
| Emambedwini | KZN | On | 11 | 80 | 60 |
| Emaqedini | KZN | On | 17 | 100 | 75 |
| Cato Manor | KZN | Off | 28 | 95 | 70 |
| Leeufontein | LIM | Off | 38 | 150 | 115 |
| Manapyane | LIM | Off | 20 | 150 | 115 |
| Jane Furse | LIM | On | 24 | 180 | 135 |
| Doornkraal | LIM | Off | 54 | 135 | 100 |
| Mothlakaneng | LIM | Off | 41 | 140 | 105 |
| Seshego Zone 5 | LIM | Off | 27 | 115 | 85 |
| New Pietersburg | LIM | Off | 63 | 130 | 100 |
| Mahwelereng | LIM | Off | 34 | 145 | 110 |
| Mashati | LIM | On | 30 | 165 | 125 |
| Winnie Park | LIM | Off | 27 | 140 | 105 |
| Tlhalampye | LIM | Off | 27 | 130 | 100 |
| Masakhane | MP | Off | 24 | 115 | 85 |
| Doornkop | MP | Off | 22 | 120 | 90 |
| Mayfield Ext | GP | Off | 21 | 95 | 70 |
| Freedom Square | GP | Off | 42 | 110 | 80 |
| Barcelona | GP | Off | 20 | 95 | 70 |
| **SA average** | | | **23** | **104** | **80** |
| **Average off-site water** | | | **24** | **102** | **78** |
| **Average on-site water** | | | **19** | **117** | **88** |

Notes:
1. WC – Western Cape, MP – Mpumalanga, LIM – Limpopo, EC – Eastern Cape, KZN – KwaZulu-Natal, GP - Gauteng
2. Based on the assumption that an average of 75% of the water consumed ends up as greywater

Owing to the fact that the time spent conducting surveys at a settlement was usually limited to one day or less, it was not possible to accurately measure the volumes of greywater being produced. In the absence of actual measurements of greywater production, the only feasible way for the researchers in this project to determine volumes of greywater in non-sewered areas was to apply a factor to the amount of water consumed per household and multiply this by the number of households in a particular settlement.

The estimated household water use determined in the site surveys was found to vary from 20*l* to 200*l*/du.d. This does not reflect the total water delivered to the settlements however, as leaks, under-reporting etc. are not accounted for. Only 6 of the 39 settlements visited had piped water in the yard and it was not possible from this limited sample to verify the assumption (Cairncross, 1990) that on-site water supply significantly increases consumption. It is interesting to note though that eThekwini Municipality are currently supplying water to many settlements in the metropolitan area by way of 200*l* on-site tanks, which are automatically filled on a daily basis. This means that these households are effectively consuming twice the amount of water that is consumed in non-sewered settlements throughout SA (the average household water consumption figure from the site surveys is approximately 100*l*/du.d).

The range of figures varies widely for both water consumption and greywater generation, as seen in the site surveys as well as the literature, with figures for greywater return factors ranging between 65% and 85%. In the absence of definitive measurements of greywater generation, the decision was taken to adopt an average greywater return factor of 75%. This figure was then applied to the average water consumption figures to give quantities of greywater produced in each settlement. In order to quantify the total amounts of greywater generated throughout SA, modified population estimates from Census 2001 were used (see Section 4.3.1), together with the average water consumption figures obtained from the on-site surveys.

### 4.3.1 Census updates

The Census 2001 data that was used to calculate the overall quantities of greywater being produced in non-sewered settlements had to be modified to take into account the changes in service status, population numbers, names of settlements etc. that have occurred, particularly in the major urban areas, since 2001. In order to do this, certain categories in Census 2001 were compared with later studies; the Non-financial Census of Municipalities, 2002, 2003 & 2004 (Statistics SA, 2002, 2003 & 2004) and the General Household Survey, GHS 2004 (Statistics SA, 2005) and the percentage differences in numbers of non-sewered households in each province were then applied to the Census 2001 data.

Table 4.3.2 shows that the overall total number of non-sewered households in SA have decreased by a factor of 3% between Census 2001 and the latest Census updates released in the Non-financial Census 2004 (Statistics SA, 2004) and the 2004 General Household Survey (Statistics SA, 2005), which estimates that approximately 20 million people in SA are without access to on-site waterborne sanitation. These figures also tie in with those in the latest Department of Water Affairs Annual Report, 04/05 (DWAF, 2005a) which reports that a further 1.3 million people were served with basic sanitation facilities during the year under review, and that the percentage access to sanitation services has increased from 64% to 67% of the population.

**Table 4.3.2: Comparison of Census data**

| **Criteria** | **Census 2001** | **Non-financial Census 2002** | **Non-financial Census 2003** | **Non-financial Census 2004** | **GHS 2004** | **Diff 2001/2004** |
|---|---|---|---|---|---|---|
| Population | 44 800 000 | | | | 46 500 000 | +3.7% |
| Nos of households | 11 205 711 | 11 237 275 | 12 018 221 | 12 200 000 | 12 196 000 | +8.1% |
| Households with w/borne sanitation | 5 812 998 | 5 417 000 | 6 097 717 | 6 989 571 | 6 968 000 | +16.6% |
| Non-sewered hholds | 5 392 690 | 5 820 275 | 5 920 504 | 5 210 429 | 5 237 000 | -3.0% |
| % non-sewered | 48.1% | 51.8% | 49.3% | 42.7% | 42.9% | -5.4% |

Notes:
1. 2005 population figures estimated at 46 900 000; i.e. population growth rate approx. 1% per annum since 2001
2. Total no. households in 2004 was 12 196 000, average household size is 3.8 persons
3. Areas of largest % non-sewered include Limpopo, KZN and Eastern Cape
4. Internal migration patterns show a shift to three main areas: Gauteng, W. Cape and KZN have positive net migration; E. Cape and Limpopo have largest negative net migration

The factor of 3% cannot be applied across all provinces, however, as there have been large differences in the numbers of people moving between provinces, as well as the levels of service provision in the different provinces. This can be seen in Table 4.3.3 which shows the 2004 General Household Survey (Statistics SA, 2005) figures for non-sewered households in each province (with the percentage differences) and the corresponding calculated greywater volumes.

The large decrease in numbers of non-sewered households in the Western Cape and Gauteng provinces is indicative of the strong drive towards providing waterborne sanitation for as many households as possible, even though there have been large influxes of people into these two provinces. KwaZulu-Natal on the other hand, has experienced an increase in the numbers of non-sewered households owing to the fact that whilst they have also experienced positive net migration into the province, dry sanitation options such as urine diversion toilets are being widely used rather than waterborne sewage systems.

The figures should be considered with caution however, as they are only an estimate and may not include areas that have been nominally provided with services (and are therefore considered to be sewered in the Census data) but where the services are dysfunctional. This was found to be the case in many of the areas visited during the on-site surveys and these settlements were therefore included in the study as they function essentially as non-sewered. The figures are also based on the average household water consumption figures from non-sewered areas with mainly off-site water supply. We have assumed that 25% of the non-sewered households in SA with access to on-site water supply (Table 3.1.4) consume approximately twice the average amount of water than those that use off-site water (i.e.

200*l*/du.d). The total volume of greywater that is generated on a daily basis in the non-sewered areas of SA (based on an average 75% return factor) can therefore be estimated at just over 500 000 $m^3$ per day. This amounts to approximately 185 million $m^3$ per year – equivalent in volume to a medium sized dam such as Voëlvlei near Cape Town, or approximately 50% of the current water demand of that city. The estimated return figure of 75% has little bearing on this outcome. The corresponding figures for total greywater volumes in non-sewered areas using the upper (85%) and lower (65%) limits for the return factor, as per the literature, would be approximately 575 000 $m^3$ and 440 000 $m^3$ per day respectively, which are not significantly different from the initial estimate. This illustrates the relatively limited potential for the use of greywater as an alternative water resource at a country-wide scale, and suggests that potential benefits from greywater use would only be from irrigation at the household level to supplement nutrition requirements. On the other hand, these figures highlight the fact that greywater disposal in dense non-sewered areas is likely to result in significant health and environmental impacts, particularly in dense urban environments where large volumes of greywater are generated.

**Table 4.3.3: Total quantities of greywater in the non-sewered areas of South Africa**

| Province | Total no. hholds Census 2001 | Non-sewered hholds Census 2001 | Non-sewered hholds GHS 2004 | % diff | Ave water cons. (*l*/du.day) | Greywater volumes ($m^3$/day) |
|---|---|---|---|---|---|---|
| W. Cape | 1 173 303 | 162 473 | 85 000 | -48% | 75 | 4 781 |
| E. Cape | 1 512 664 | 1 016 668 | 1 151 000 | +13% | 90 | 77 693 |
| N. Cape | 206 844 | 69 819 | 64 000 | -8% | 105 | 5 040 |
| Free State | 733 302 | 393 850 | 324 000 | -18% | 105 | 25 515 |
| KwaZulu-Natal | 2 086 251 | 1 219 474 | 1 303 000 | +7% | 95 | 92 839 |
| North West | 929 000 | 603 438 | 545 000 | -10% | 105 | 42 919 |
| Gauteng | 2 651 247 | 484 533 | 298 000 | -38% | 100 | 22 350 |
| Mpumalanga | 733 135 | 452 866 | 418 000 | -8% | 120 | 37 620 |
| Limpopo | 1 179 965 | 989 569 | 1 049 000 | +6% | 145 | 114 079 |
| **Total for off-site water supply, 75%** | **8 404 284** | **4 044 517** | **3 927 750** | **-3.0%** | **105[1]** | **309 310** |
| **Total for on-site water supply, 25%** | **2 801 427** | **1 348 173** | **1 309 250** | **-3.0%** | **200[2]** | **196 387** |
| **Grand total** | **11 205 711** | **5 392 690** | **5 237 000** | **-3.0%** | **-** | **505 697** |

Notes: 1. Average provincial household water consumption for households with off-site supply, from site surveys
2. Estimated water consumption for households with on-site supply

## 4.4 Quality of greywater in non-sewered areas

The average values for greywater qualities for the settlements surveyed in each province; Western Cape (WC), Mpumalanga (MP), Limpopo (LIM), Eastern Cape (EC), KwaZulu-Natal (KZN) and Gauteng (GP) are summarised in Table 4.4.1. Samples of greywater were taken from a variety of washing activities taking place in the different settlements. Samples of water from the closest source (standpipe, borehole, river etc. ) were also tested so that their quality could be compared to that of the greywater samples being tested.

# Table 4.4.1 Greywater quality at survey sites

| Name of settlement | n | Prov# | Average values for greywater samples | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | COD (mg/l) | DO (mg/l) | pH | $NH_3$ (mg/l) | TKN (mg/l) | Tot P (mg/l) | Oil & Grease (mg/l) | Cond (mS/m) |
| Clanwilliam | 0 | WC | - | - | - | - | - | - | - | - |
| Redhill | 10 | WC | 1470 | - | 7.6 | - | 20 | 27 | 176 | 155 |
| Lingelethu | 4 | WC | 6190 | - | - | - | - | - | - | - |
| Fairyland | 3 | WC | 2320 | - | - | - | 60 | 88 | 30 | - |
| Kleinmond | 2 | WC | 3510 | - | - | - | 110 | 146 | 29 | - |
| Masiphumelele | 3 | WC | 7850 | - | - | - | 130 | 98 | 242 | - |
| Khayelitsha RR | 5 | WC | 3580 | 3.7 | - | - | - | - | - | - |
| Sweet Home | 3 | WC | 8490 | - | - | - | 172 | 144 | 307 | - |
| Masakhane* | 5 | MP | - | - | 7.3 | 3+ | - | 5+ | - | 1040 |
| Doornkop* | 3 | MP | - | - | 9.6 | 3+ | - | 5+ | - | 126 |
| Mashati* | 2 | LIM | - | - | 10.4 | 3+ | - | 5+ | - | 289 |
| Manapyane* | 1 | LIM | - | - | 9.3 | 3.0 | - | 5 | - | 112 |
| Tlhalampye* | 2 | LIM | - | - | 9.3 | 3+ | - | 5+ | - | 461 |
| Leeufontein* | 1 | LIM | - | - | 10.9 | - | - | - | - | 770 |
| Jane Furse* | 1 | LIM | - | - | 10.3 | 2.9 | - | 1.6 | - | 389 |
| Winnie Park* | 1 | LIM | - | - | 10.1 | 3+ | - | 5+ | - | 234 |
| Seshego Zone 5* | 3 | LIM | - | - | 8.6 | 3+ | - | 5+ | - | 140 |
| Mahwelereng* | 2 | LIM | - | - | 9.1 | 0.5 | - | 5+ | - | 90 |
| Doornkraal* | 1 | LIM | - | - | 9.7 | 3+ | - | 5+ | - | 489 |
| New Pietersburg* | 1 | LIM | - | - | 8.9 | 3+ | - | 5+ | - | 1530 |
| Mothlakaneng* | 2 | LIM | - | - | 9.4 | 3+ | - | 5+ | - | 196 |
| Mpathi | 0 | EC | - | - | - | - | - | - | - | - |
| Mthento | 0 | EC | - | - | - | - | - | - | - | - |
| Emahobeni* | 2 | EC | - | - | 7.8 | 3+ | - | 2.9 | - | 381 |
| Mputhi* | 2 | EC | - | 0.2 | 8.9 | 2.0 | - | 1.3 | - | 783 |
| Phakamisa Park* | 2 | EC | - | - | 8.8 | 3+ | - | 1.9 | - | 514 |
| Bongweni* | 1 | EC | - | - | 7.8 | 3.0 | - | 3.5 | - | 916 |
| New Payne* | 1 | EC | - | - | 7.7 | 2.6 | - | 4.5 | - | 113 |
| Silvertown* | 1 | EC | - | - | 8.0 | 3+ | - | 5+ | - | 189 |
| Orange Grove* | 1 | EC | - | - | 7.6 | 2.2 | - | 5+ | - | 764 |
| KwaShange | 8 | KZN | - | 0.1 | 9.1 | 12.5 | 56 | 57.4 | 730 | 59 |
| Emambedwini | 8 | KZN | - | 0.6 | 9.9 | 8.5 | 39 | 112.4 | 1365 | 567 |
| Emaqedini | 5 | KZN | - | 0.6 | 8.7 | 5.7 | 7 | 115.6 | 397 | 70 |
| Boboyi | 10 | KZN | - | 0.6 | 9.5 | 3.0 | 20 | 34.4 | 1948 | 128 |
| Zolani | 9 | KZN | - | 1.2 | 8.8 | 3+ | 45 | 37.6 | 1947 | 199 |
| Cato Manor | 3 | KZN | - | 0.6 | 8.8 | 7.6 | 164 | 7.5 | 108 | 54 |
| Barcelona | 0 | GP | - | - | - | - | - | - | - | - |
| Mayfield Ext | 1 | GP | - | 0.6 | 9.8 | 21.8 | 43 | 240.0 | 1484 | 653 |
| Freedom Square | 0 | GP | - | - | - | - | - | - | - | - |
| **Average** | | | **4770** | **0.9** | **8.8** | - | **72** | - | **730** | **366** |

Notes:
1. * indicates sites where analyses were conducted with field test kits only
2. + indicates extent of measurement range for field instrument
3. WC – Western Cape, MP – Mpumalanga, LIM – Limpopo, EC – Eastern Cape, KZN – KwaZulu-Natal, GP - Gauteng

Only limited microbiological sampling was conducted (samples were tested using the membrane filtration method, SABS SM 221) and accurate counting was not done (organisms were only counted up to 1,800 counts per 100 ml). The samples generally showed levels of faecal contamination in the greywater samples above 1,800 organisms/100 ml however, indicating that, without treatment, the greywater is likely to be a health hazard.

The water quality figures obtained have been compared to the ranges of values quoted in international literature for greywater from mixed sources (Eriksson et al., 2002), as well as the available South African data on low-income settlements, as can be seen in Table 4.4.2. The results from this study indicate a large variability and highlight the differences in the quality compared with greywater from sewered areas in developed countries. The figures show particularly high levels of pollution emanating from the use of household chemicals and detergents and suggest that greywater from non-sewered areas is generally unfit for use except under controlled conditions.

**Table 4.4.2 Comparison of greywater quality results**

| Variable | This study (2005) | Eriksson et al. (2002) | Källerfelt & Nordberg (2004) | Pollution Research Group (2005) | Stephenson et al. (2006) |
|---|---|---|---|---|---|
| pH | 3.3-10.9 | 5.0-8.7 | 6.1-7.0 | 5.8-6.3 | - |
| Conductivity (mS/m) | 28-1763 | 32-2000 | 83-132 | 144-148 | - |
| $PO_4$-P | 0.7-769 | 0.6-68 | 14.8-56.2 | 11 | 0.3-18.9 |
| COD | 32-11451 | 13-549 | 530-3520 | 1135 | 999-1625 |
| Suspended solids | - | 6.4-330 | 69.0-1420 | - | 265.2-1261 |
| Oil & Grease | 8-4650 | 3.1-12 | - | - | - |
| TKN | 0.6-488.0 | 2.1-31.5 | - | 24-30 | - |
| Ammonia Nitrogen | 0.2-44.7 | 0.03-25.4 | - | 20 | - |
| Sodium | 96-1700 | 29-230 | - | - | - |

Note: Values are quoted in mg/*l* if not stated otherwise.

Of interest are the ranges of values obtained for COD and Oil & Grease which highlight the extent of risks that could arise from the use of this type of greywater, particularly in respect of the resultant impacts on soils and plants. Levels of phosphorous and sodium were also particularly high in certain cases. Further investigation is required into the effect of detergent use on the quality of greywater and how this impacts on the use of the greywater as a resource. Methods of reducing levels of phosphorous and sodium in greywater should also be investigated.

Boron analyses were only undertaken on the greywater samples from only two of the study sites (KwaShange and Redhill), and one of these samples (Redhill sample 1A) produced a measurable amount of Boron (1.9mg/l). More sampling needs to be conducted in order to fully understand the impacts of Boron in greywater where it is to be used as irrigation water.

One observation from the site surveys that could explain these high levels of chemicals was that, in the absence of hot water, residents of low-income settlements tended to leave the ubiquitous green detergent bar (e.g. “Sunlight soap”) in the laundry water for several hours, resulting in large amounts of detergent dissolving in the water. Further discussion on water use and greywater management practices which may be responsible for the sometimes “extreme” greywater quality results that were obtained can be found in the case studies in Appendix D.

No attempt was made to try and calculate pollution loads (e.g. mass balances) with the water quality data owing to the fact that neither the greywater volumes nor the water quality analyses were considered to be accurate enough for these calculations. Instead, the water quality sampling results merely serve to provide a general understanding of the overall quality of the greywater emanating from non-sewered areas, particularly in respect of its nutrient loading and oxygen demand.

Table 4.4.3 lists the guidelines for the evaluation of water quality for irrigation produced by the Food and Agricultural Organisation of the United Nations (FAO). These may be used as a first step in indicating the quality limitations of the greywater for irrigation purposes.

**Table 4.4.3: Water quality guidelines for agriculture (Ayers & Westcott, 1994)**

| Water parameter | Usual range in irrigation water | Range at which restrictions on use for irrigation are imposed | | |
|---|---|---|---|---|
| | | None | Slight to moderate | Severe |
| Electrical conductivity, EC (mS/m) | 0 – 300 | <70 | 70 - 300 | >300 |
| Total Dissolved solids, TDS (mg/l) | 0 – 2000 | <450 | 450 - 2000 | >2000 |
| Nitrate Nitrogen, $NO_3$-N (mg/l) | 0 – 10 | <5 | 5 - 30 | >30 |
| Ammonia Nitrogen, $NH_4$-N (mg/l) | 0 – 5 | - | - | - |
| Phosphate Phosphorous, $PO_4$-P (mg/l) | 0 – 2 | - | - | - |
| Boron, B (mg/l) | 0 - 2 | <0.7 | 0.7 – 3.0 | >3.0 |
| pH | 6.5 – 8.4 | - | - | - |
| Sodium Adsorption Ratio (me/l) | 0 - 15 | >2.9 | 1.3 - 2.9 | <1.3 |

## 4.5 Greywater management options

Greywater management options are required to assist communities and municipal authorities in determining how greywater can safely be disposed in their areas. The main assumption in the development of these options is that non-sewered areas do not have waste removal mechanisms for greywater. In order to prevent major health and environmental impacts resulting from greywater disposal in these areas, the most important issues are therefore to ensure that:

- there is no ponding of the greywater,
- that it does not get into surface water systems, and
- that it is not allowed to build up in the soil to such an extent that it becomes a hazard.

Various factors were identified as being important (to greater and lesser degrees) when considering greywater management options in non-sewered areas. Figure 4.5.1 gives a brief overview of the most critical factors to be evaluated and lists the disposal options, which, owing to the fact that there are no formal conveyance systems for the removal of greywater in non-sewered areas, are limited to some form of beneficial use, either on- or off-site (e.g. irrigation), disposal on-site (e.g. throwing on the ground) or disposal off-site.

Beneficial use of greywater is considered to be the most sustainable disposal option, but in reality is rarely achieved as there are two critical issues regarding greywater quality that must be resolved before any reuse initiative can take place:

1. Health aspects – adequate controls must be in place to ensure that the risk of infection from any pathogenic organisms present in the greywater is negligible.
2. Soil conditions – conditions should be suitable, or measures should be put in place, to prevent damage to the soil resulting from the long-term application of greywater with high levels of salinity.

The above issues imply that there is a need for strong institutional support and monitoring if the beneficial use of greywater is to be considered.

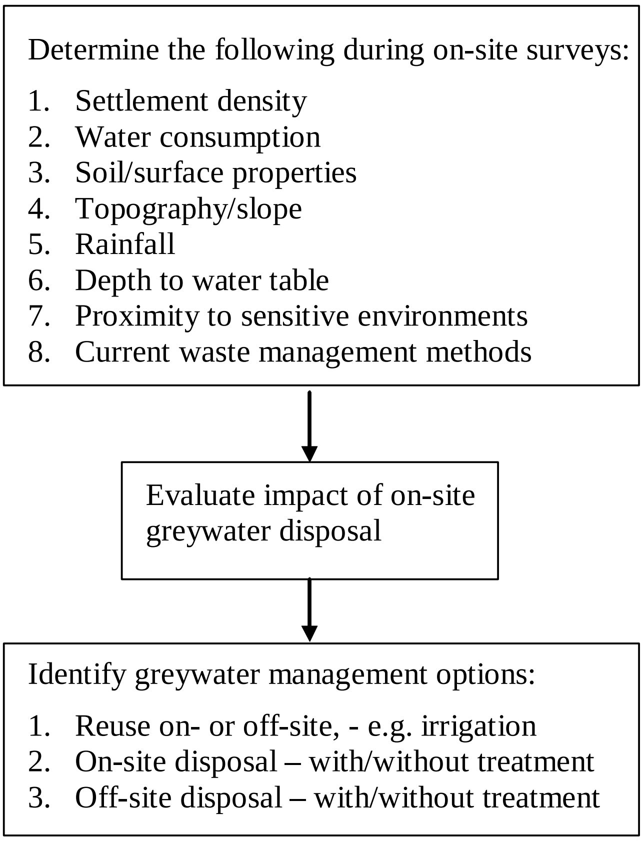


**Figure 4.5.1: Greywater management flowchart**

One of the areas where this option is being considered is eThekwini Municipality in Durban, KwaZulu-Natal. eThekwini are attempting to encourage home-based food gardening in order to deal with some of the poverty issues in the area and have determined that the minimum plot size that would be required for this is 350m$^2$. Households are supplied with their Free Basic

Water (FBW) allowance of 6 000*l* per household per month (200*l* per day into tanks) and eThekwini have calculated that only a very small portion of the plot ($10m^2$, based on annual net evaporation figures) is required as a sacrificial on-site greywater disposal area. The home-based gardening initiative that has been linked with on-site greywater disposal is possible in Durban owing to the fact that there is sufficient space to be able to provide micro-holdings that are situated on fertile, well-drained, and usually well-watered land. The Durban situation is somewhat different to other places in SA however, and different environments will require separate greywater management solutions, e.g. the method of matching greywater generation with plot sizes is not possible in the winter rainfall regions of South Africa where there is negative net evaporation for parts of the year.

As noted previously, on-site disposal of greywater is widely practiced throughout the non-sewered areas of South Africa and appears to be an acceptable option in areas with low to medium settlement densities and well-drained soils, although the long-term environmental impacts of this still need to be assessed. Off-site disposal of greywater is the only remaining option for those areas where the settlement characteristics, e.g. high densities, clay soils, high water tables etc. , are such that on-site greywater disposal would create significant environmental and health impacts – see Section 4.5.2 for further discussion on these settlement characteristics.

The factors that need to be quantified before making any decisions with respect to greywater management include the following:

1. Water consumption, measured in litres per household (or dwelling unit, du) per day – the issue of greywater is inseparable from that of water supply as all water that is supplied to a settlement which is not consumed must be disposed of in some manner. The general premise is that if the volume of water supplied is low and the settlement density is not too high then greywater disposal in the vicinity of the dwellings may be possible.

2. Settlement density, measured in dwelling units (du) or numbers of households per hectare (ha) – this has been determined as being a key driver with respect to greywater management owing to the fact that large numbers of people living in densely-populated settlements generate increased volumes of waste, which cannot easily be disposed of in the limited available space.

3. Soil / surface properties – these relate to the drainage conditions of a particular area and are not necessarily directly related to the soil properties themselves. They are affected by settlement densities and previous practices with respect to greywater disposal (e.g. the build-up of grease and "scum" on soil surfaces, as well as the impact of high pedestrian traffic in built-up areas that can cause hardening and reduce the soil's ability to drain efficiently).

4. Topography / slope – it is difficult to quantify the impacts from different slopes but it is accepted that very steep slopes could be problematic due to their potential for erosion, and flat, low-lying areas could result in ponding of the greywater.

5. Rainfall – it is clear that it is easier to manage greywater in areas with low rainfall but the specific impacts of varying rainfall are difficult to quantify. The issues are mostly to do

with the conveyance of polluted surface water to low-lying areas, and when rainfall causes the ground to become waterlogged.

6. Depth to water table – when groundwater is close to the surface the ability of soakaway systems to absorb water is restricted and the potential for groundwater pollution is increased. The risk of groundwater pollution is even higher in dolomitic areas and where porous and fractured rock conditions accelerate surface to groundwater flow.
7. Proximity to sensitive environments – indiscriminate greywater disposal should not take place in settlements that are adjacent to environmentally sensitive areas like rivers, wetlands, unprotected boreholes etc., or within floodplains.
8. Current waste management methods – the various options for greywater disposal depend on whether there are any existing initiatives to manage the system, e.g. infiltration beds or soakaways at standpipes, sacrificial areas for greywater disposal etc.

### 4.5.1 Options for decision-making

There are various ways in which greywater management options may be evaluated. The first option is to attempt to use the above criteria in a multi-criteria decision-making (MCDM) tool, in order to identify settlements which, based on their characteristics, could have potential greywater management problems. The MCDM tool allows users to assign scores for particular settlements for each of the selected criteria and also to weight these criteria in relation to each other. The result is a summation of the various scores for each of the criteria in a settlement, giving a total score which reflects the best option for greywater management in the area. There are limitations to this process however, the most important of which is that the selection and weighting of the criteria is subjective, and the factors are difficult to quantify. Also, it appears as though many of the criteria relate better to each other as products rather than summations, plus there are a host of inter-connections that cannot be modelled by way of the MCDM tool. This option was therefore abandoned.

The site surveys showed that settlement density together with the consumption of water per dwelling unit appear to be the most critical factors in determining the extent of the greywater management problem. Although the level of service with respect to water supply to informal settlements can vary widely, only two categories seem to have any influence on the amounts of water consumed – having a tapstand on the property or having to walk to fetch water (irrespective of distance). Given that, in the absence of sewerage, greywater disposal is generally through a form of on-site drainage, consideration was then given to some sort of infiltration equation e.g. Green & Ampt (Green & Ampt, 1911), Horton (Horton, 1933), or even Darcy’s Law (Darcy, 1856). None of them, however, can adequately cater for the situations pertaining in the settlements that are typical of the non-sewered areas in SA. Apart from the fact that infiltration parameters are exceptionally difficult to estimate owing to the gradual blockage of the surface with fine particles, fats and greases from the greywater that is then compacted by human activity, other important factors such as ground slopes, the impact of rainfall and evaporation patterns, proximity to sensitive environments and current waste management methods are ignored. This approach was thus also abandoned. In the end, therefore, the project team decided that the only quantity that could sensibly be calculated is the quantity of greywater per hectare ($G_G$) that needs to be managed:

$$G_G = QD \qquad [4.1]$$

where, $G_G$ is the greywater generation rate, *l*/ha.day
Q is the greywater produced per household (water consumption x 75%), *l*/du.day,
D is the density of households per hectare, du/ha,

As will be seen in Section 4.5.2, other local factors that may impact on greywater management options must then be taken into account so as to assess their relevant influences on the disposal practice.

### 4.5.2 Greywater assessment

Greywater generation rates for non-sewered settlements in SA and the likely impact of changes in service levels with respect to water supply (e.g. higher water consumption leading to increased generation of greywater) can be calculated by using Equation 4.1, with figures for settlement densities acquired from local authorities, and average water consumptions from on-site surveys (Table 4.3.1) as applied to particular types of settlements.

Settlement density is the simplest criteria to establish and, because it has such a significant impact on greywater management, there have been a number of studies looking at appropriate management practices required to minimise pollution effects from settlements with varying densities. Recommendations on management options for the greywater emanating from settlements of different densities were made in "Managing the water quality effects of settlements: Planning to avoid pollution problems" (DWAF, 2001g) and have been used in conjunction with water consumption figures to determine ranges of greywater generation rates for this project, with associated recommended management practices:

- Low density – <500*l*/ha.day (generally equates to densities of <10 du/ha and plot sizes >800m$^2$). Soakaways installed at water collection points and standpipes should be sufficient to protect water resources and prevent health risks.
- Low / medium density – 500-1,500*l*/ha.day (equates to densities of 10-30du/ha and plot sizes 800-300m$^2$). Soakaways must be installed at tapstands and in-home or yard connections should be connected to an on-site disposal system.
- Medium / high density – 1,500-2,500*l*/ha.day (equates to densities of 30-50du/ha and plot sizes 300-150m$^2$). If yard connections are supplied as recommended by DWAF, on-site disposal systems should be installed, otherwise formal washing areas with disposal options are required.
- High density – >2,500*l*/ha.day (equates to densities of >50du/ha and plot sizes <150m$^2$). There should be off-site disposal of all effluent.

It should be noted that greywater impacts increase exponentially in very dense settlements due to the fact that the amount of open space decreases markedly with housing density in these areas; off-site disposal of greywater is thus recommended for areas where the settlement densities are >50 du/ha. There are other criteria which could also affect the decision to dispose of greywater off-site and further recommendations in this regard are indicated in Table 4.5.1.

**Table 4.5.1: Recommendations regarding off-site disposal of greywater**

| **Criteria** | **Off-site disposal of greywater recommended** |
|---|---|
| Settlement density (du/ha) | When density >50 du/ha |
| Greywater generation (*l*/ha.day) | When $G_G$ >2,500*l*/ha.d |
| Soil/surface properties | Surfaces hard-packed / impervious (heavy clay / rock) |
| Topography | When slopes >30% |
| Depth to water table | If depth to water table <1m |
| Proximity to sensitive environments | Within floodplains (e.g.1:50year) |

The information regarding settlement density and average household water consumption gained from the on-site surveys has been used to determine greywater generation rates for the settlements visited (Table 4.5.2). Greywater generation rates may then be used to determine management options by way of a series of rule-based flow diagrams (decision trees) which ask relevant questions for each of the various additional criteria to assess the viability of the various options. An example of a decision tree based on greywater generation rate is shown in Figure 4.5.2. Such decision trees would enable the decision-maker to make a final decision about off-site disposal, or direct further questions (in subsequent flow diagrams to be developed) in order to establish alternative management options.

Using the sites in the Western Cape as an example it can be seen that, based on the greywater generation rate, on-site disposal of greywater is not recommended for Sweet Home Farm (3,150*l*/ha.d) and Khayelitsha RR (2,764*l*/ha.d). This was evident during the surveys of these sites, where indiscriminate disposal of greywater was clearly having negative impacts (both health and environmental) in the settlements. Masiphumelele (2,175*l*/ha.d) falls into the category where on-site greywater disposal may be considered but once the other criteria had been assessed, e.g. proximity to sensitive environments (the settlement is on the edge of a wetland), it became clear that off-site disposal should be recommended for this area. The greywater generation rates for Clanwilliam (585*l*/ha.d), Redhill (660*l*/ha.d) and Lingelethu (1,196*l*/ha.d) show that on-site disposal of greywater should not pose a problem. This was again borne out by the visits to these areas where it was evident that current methods of greywater disposal were being effectively managed on the whole; soil conditions were such that greywater ponding was not evident, dwelling densities were relatively low and there was no nearby surface water which could be affected. The situation was different for Fairyland (1,913*l*/ha.d) and Kleinmond (1,969*l*/ha.d) however; even though the figures for greywater generation fell into the category where on-site disposal could be considered. The higher settlement densities combined with specific environmental conditions at these sites, such as proximity to sensitive river systems, have resulted in situations where it is inadvisable to have on-site disposal of greywater unless it can be treated and / or properly managed.

**Table 4.5.2 Water consumption and greywater quantities for survey sites**

| Name of settlement | Province | Settlement density (du/ha) | On- or off-site water | Average water use (*l*/du.day) | Greywater generation rate (*l*/ha.day)[1.] |
|---|---|---|---|---|---|
| Clanwilliam | WP | 12 | Off | 65 | 585 |
| Redhill | WP | 11 | Off | 75 | 660 |
| Fairyland | WP | 34 | Off | 75 | 1913 |
| Kleinmond | WP | 25 | Off | 105 | 1969 |
| Sweet Home Farm | WP | 60 | Off | 70 | 3150 |
| Masiphumelele | WP | 29 | Off | 100 | 2175 |
| Khayelitsha RR | WP | 67 | Off | 55 | 2764 |
| Lingelethu | WP | 29 | Off | 55 | 1196 |
| Silvertown | EC | 20 | Off | 70 | 1050 |
| Bongweni | EC | 5 | Off | 160 | 600 |
| Orange Grove | EC | 30 | Off | 60 | 1350 |
| Phakamisa Park | EC | 8 | Off | 80 | 480 |
| New Payne | EC | 10 | On | 80 | 600 |
| Mputhi | EC | 8 | Off | 75 | 450 |
| Mthento | EC | 3 | Off | 150 | 338 |
| Mpathi | EC | 1 | Off | 100 | 75 |
| Emahobeni | EC | 10 | Off | 45 | 338 |
| Zolani | KZN | 20 | Off | 85 | 1275 |
| Boboyi | KZN | 5 | Off | 110 | 413 |
| KwaShange | KZN | 3 | On | 95 | 225 |
| Emambedwini | KZN | 4 | On | 80 | 240 |
| Emaqedini | KZN | 5 | On | 100 | 375 |
| Cato Manor | KZN | 25 | Off | 95 | 1781 |
| Leeufontein | LIM | 5 | Off | 150 | 563 |
| Manapyane | LIM | 3 | Off | 150 | 338 |
| Jane Furse | LIM | 5 | On | 180 | 675 |
| Doornkraal | LIM | 15 | Off | 135 | 1519 |
| Mothlakaneng | LIM | 25 | Off | 140 | 2625 |
| Seshego Zone 5 | LIM | 10 | Off | 115 | 863 |
| New Pietersburg | LIM | 18 | Off | 130 | 1755 |
| Mahwelereng | LIM | 10 | Off | 145 | 1088 |
| Mashati | LIM | 3 | On | 165 | 315 |
| Winnie Park | LIM | 8 | Off | 140 | 780 |
| Tlhalampye | LIM | 4 | Off | 130 | 375 |
| Masakhane | MP | 6 | Off | 115 | 518 |
| Doornkop | MP | 15 | Off | 120 | 1350 |
| Mayfield Ext | GP | 32 | Off | 95 | 2280 |
| Freedom Square | GP | 162 | Off | 110 | 13365 |
| Barcelona | GP | 25 | Off | 95 | 1781 |
| **Average** | | **20** | **-** | **104** | **1385** |

Note: 1. Based on the assumption that an average of 75% of the water consumed ends up as greywater

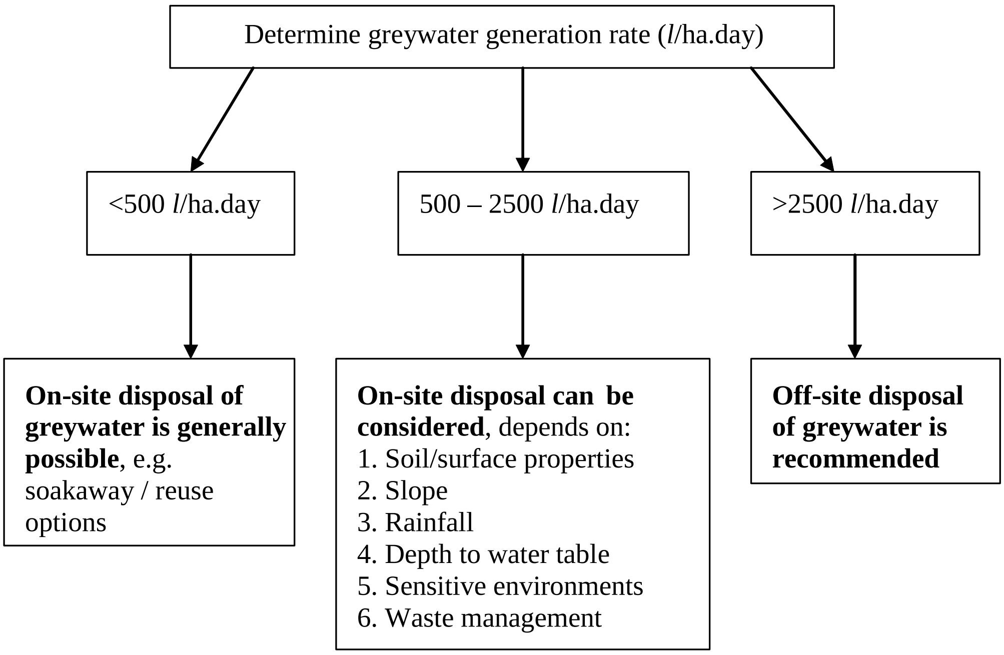


**Figure 4.5.2: Decision tree for determining appropriate greywater management options**

Figures 4.5.3 to 4.5.5 show conditions at Sweet Home Farm, Khayelitsha RR and Masiphumelele where off-site disposal of greywater is recommended, based on the greywater generation rates at these sites. See Section D1 for further details on the greywater management surveys that were carried out at these sites.

**Figure 4.5.3: Flooding at Sweet Home Farm**

**Figure 4.5.4: Greywater stream in Khayelitsha**

**Figure 4.5.5: Tapstand and toilets at Masiphumelele**

## 4.6 Greywater management and treatment systems

Within a South African context and especially in non-sewered areas, a number of factors need to be considered when implementing successful greywater management or treatment systems. These include:

- Availability of infrastructure
- Availability of land
- Distance from dwelling to treatment system
- Cost implications and practicality
- Public perception / acceptability of system

In the drought-prone regions of the developed world emphasis has been placed on implementing treatment systems which encourage the use of greywater, mainly for irrigation purposes. However, precautions need to be taken when using this greywater to take into account the high levels of chemicals from cleaning agents that may be present, as well as the possibility of pathogenic organisms, which may have adverse health and environmental effects. The emphasis therefore has been on the treatment of this greywater to a relatively high quality, with strict guidelines in place regarding its use.

In the South African context, and particularly in low-income, high-density areas where greywater use initiatives are generally not feasible (or affordable), the emphasis for interventions should rather be placed on treatment / disposal systems which ensure that the management of greywater does not have negative health and environmental impacts. The provision of emergency water supplies to informal settlements in particular generates significant volumes of greywater that either gets disposed of into the stormwater system leading to pollution of downstream waterbodies, or gets discharged onto the ground in the settlement resulting in nuisance and / or health impacts.

Greywater appears to have a similar organic loading to that of a low to medium strength influent municipal sewage with characteristics similar to tertiary sewage effluent in terms of the biodegradability and the physical pollution it contains (Jefferson et al., 2004), although as was seen during the site surveys, the quality can vary widely. Biological treatment systems would thus be deemed appropriate, but the selection of technology is complicated by the variability of the load, the high COD:BOD ratio together with a nutrient and micro-metal imbalance which implies that the biological processes might experience problematic performance and operational difficulties (Jefferson et al., 2004). Advanced biological treatment is in any case not appropriate for most of the non-sewered areas in South Africa due to the high costs involved, although simpler alternatives can be used to decompose the organic material in greywater, e.g. mulch beds, where the greywater is diverted into a shallow pit filled with gravel and leaves. Trees may also be planted over these mulch beds to aid in the uptake of greywater. Further discussion of the various greywater treatment and/or disposal options that have been used both worldwide and in South Africa is presented in Appendix B.

A typically appropriate greywater management system in a densely-settled urban / peri-urban environment would consist of the following components (City of Cape Town, 2005), as shown in Figure 4.6.1:

- Intake – usually in close proximity to where the water is being used.
- Sediment and fat traps – these are also located close to the greywater intakes.
- Conveyance – after the sediment and fat has been removed, conveyance to the appropriate disposal system can be done using small bore gravity pipelines.
- Disposal or Use – there are a number of options which can be explored, including irrigation of individual and community gardens, if properly managed.

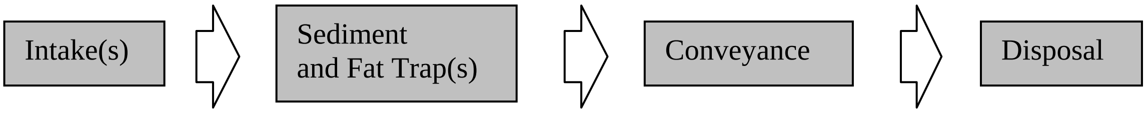


**Figure 4.6.1: Typical components of a greywater management system**

It is important that greywater intakes are situated close to where the water is being used as it appears that whereas people are prepared to walk long distances to fetch water, they will seldom walk far to throw the greywater away. The City of Cape Town recommends a maximum walking distance of 25m to a greywater disposal point in informal settlements, equating to approximately 30 dwelling units to each disposal point. Gravity connection to sewer is the preferred option for disposal of greywater although soakaways may be provided in areas where the soil is permeable and the water table is low all year round.

Although greywater disposal in more rural environments is generally not a major cause for concern, there are health and environmental concerns with respect to greywater disposal in these areas also:

- Mosquitoes and flies breeding in pools of stagnant water – people would rather toss the greywater onto one selected spot so that the number of breeding areas are restricted.
- Food stuffs and fats are problematic both from a blockage perspective and also because they attract flies and mosquitoes.
- Settlements with poorly draining soils (e.g. shales and clays) are a problem owing to the fact that the greywater does not soak into the ground.

The residents of these areas have come up with a variety of ways of dealing with the above issues, particularly with respect to the nuisance factors like mosquitoes, smells etc. For example in Wartburg, KwaZulu-Natal people were observed using a tar-based disinfectant (“Madubula”) around their homes as an insect repellant. In Freedom Square, Gauteng residents have agreed amongst themselves that all greywater be carried to a nearby stormwater canal to prevent ponding around shacks. In some instances however, these management interventions are having negative environmental effects as illustrated by the people who were observed during the site surveys doing their washing in the river because they were not permitted to do so at the tapstands.

At a more strategic level, it appears that greywater management has been neglected in the service delivery planning process for non-sewered settlements in South Africa and the consequences of this non-functioning service delivery model are evident in the greywater disposal issues that have been highlighted during the course of this research. Based on the results of the site surveys, there is significant risk involved with the disposal of greywater, particularly in the high-density urban settlements. In these areas, greywater should be considered a sanitation rather than a drainage issue, and managed / treated accordingly so as to reduce any negative impacts. It is important that there is strategic planning with respect to service delivery, technology choice, budgets, implementation / education etc. at central as well as local government level. Further discussion on these strategies is given in Chapter 5.

## 4.7 Comparison with DWAF "Dense Settlements" project

The findings from the site surveys undertaken in this study have been compared with the experiences from the case studies that were conducted as part of the DWAF project on "Managing the water quality effects of settlements" (DWAF, 2001h). While greywater disposal was not the main focus of the DWAF project, it was seen as part of the overall pollution problem in densely populated and poorly serviced settlements, and was therefore taken into account during the test case studies. Of the 12 settlements visited in the course of the DWAF project, 5 were noted as having major pollution problems resulting from greywater (sullage), which required further intervention by the test case steering committee (TCSC) in order to address these issues. The specific findings from the 5 settlements were as follows:

1. Cairn, Mpumalanga – The most important pollution problem in this community is bush toileting resulting from inadequate sanitation facilities. Further pollution issues are likely to result in the future from the current improvements being made to the water supply service, as there are no facilities for the disposal of greywater.
2. Kliptown, Gauteng – Most of the Kliptown community do their washing at the standpipes and there is a constant flow of greywater running to the river. The TCSC constructed about 200 greywater drainage points at all the standpipes and washing areas, and these have been connected to a sewer main at the edge of the settlement. This has eliminated the flow of greywater in the roads and significantly reduced the downstream bacterial and nutrient load in the river. Most importantly, inhabitants have reported reduced odours, fewer flies and a reduction in diarrhoea in their children.
3. Burlington Halt, KwaZulu-Natal – Greywater disposal is either in the streets or into open stormwater drains along the roads and this causes major erosion problems in the settlement.
4. Rini, Eastern Cape – The greywater problem in this community arises primarily due to the fact that most houses have yard connections, but no greywater drainage points so that greywater is therefore thrown onto the streets before running off to the Kowie River. One of the proposed interventions by the TCSC was the initiation of an awareness campaign focused on the most appropriate disposal of greywater, i.e. onto gardens.

5. Kayamandi, Western Cape – The services in this area comprise communal toilet blocks ("Bus toilets"), backing onto washing areas. Most of the toilets are in a very poor condition and as a result there is a constant flow of faecally-polluted greywater from the toilet blocks to the Plankenbrug River. An awareness campaign was carried out by the TCSC regarding basic hygiene and the causes of sewer blockages, in the hope of improving the situation.

The test cases give an indication of some of the problems that can be encountered in low-income settlements and show that community-based services, i.e. where the community pays directly for the service and provides it themselves, are most successful in addressing pollution problems and maintaining sustainability. The greywater issues that were noted in the settlements visited in the DWAF study compare well with the findings of the site surveys that were conducted as part of this study and confirm that the management of greywater remains a challenge in the non-sewered areas of South Africa.

# 5. Guidelines and strategies to mitigate the impacts of greywater

The generation of greywater from non-sewered, low-income settlements in South Africa has the potential to cause a host of environmental and health problems. The use of this greywater however remains limited for a variety of reasons which include poor water quality, health risks, cultural and religious beliefs, as well as a widespread distrust against its use. On the other hand, water is a scarce resource in this country and the beneficial use of greywater for irrigation could provide economic benefits in terms of food security and standard of living to people living in highly water-stressed areas. Currently a large portion of greywater generated from washing laundry, cleaning dishes and bathing is disposed onto ground surfaces close to dwellings and thus any potential benefits through controlled use are being lost. It is worth noting that the water being used at the dwellings is very often recycled before it gets disposed as greywater, i.e. greywater is already recycled water in many cases. Further details on the health aspects of greywater use are presented in Appendix C.

It is vitally important that greywater disposal or use is properly managed. It is the role of Government to develop policies that inform greywater management at a strategic level, while municipalities should be charged with the responsibility of managing greywater problems at a local level in cooperation with communities.

In order to try and understand the disposal and use of greywater in the non-sewered areas of South Africa, this study has therefore attempted to identify the behaviour of residents in various low-income settlements with respect to greywater generation and management, and relate this to the quantity and quality of the greywater being produced. The research aims *inter alia* to inform communities, municipal planners and policy makers in the non-sewered areas in South Africa of the potential problems and, given this current state of knowledge, advise them on greywater management.

The evidence suggests that there may be limited opportunities for the beneficial use of greywater but that this needs to be managed carefully. Greywater use initiatives become increasingly difficult as settlement density increases and the quality of the greywater decreases, with limited water availability leading to higher concentrations of pollutants (such as pathogenic organisms and inorganic salts). There are therefore two central questions regarding the strategic management of greywater:

1. Is it possible to use greywater for limited household agriculture, i.e. as a beneficial resource?
2. What needs to be done in a crisis situation when the greywater becomes a health hazard, e.g. in densely populated settlements?

## 5.1 General strategies related to greywater use and disposal

If "strategy" is defined as a general approach towards achieving a long-term goal, e.g. in order to raise awareness of health-related sanitation issues there should be the provision of education about sanitation and health risks to all people, then certain recommendations can be made regarding the strategies required to direct greywater disposal and use in non-sewered settlements. The strategies must consider the multi-dimensional nature of the greywater problem, the time frames involved, the social and infrastructural structures in place, the settlement types etc. This is complicated by the fact that many non-sewered areas are in informal settlements which are by nature temporary and are often fragmented with respect to social structures. Under these circumstances, it is only possible to propose short-term management interventions, although recommendations can be made for the planning of future settlements. It is also necessary to differentiate between urban and rural environments.

The main distinguishing feature with respect to greywater management between urban and rural environments is settlement density, and generally it is in the high-density urban areas that the greywater management problems become chronic, particularly with respect to potential health risks. This is mainly because it is difficult for people in these areas to manage the impacts from greywater disposal in urban environments. It appears from both the literature and the on-site surveys that the disposal of greywater can generally be effectively managed where there is sufficient space for disposal, e.g. in rural areas, at least in terms of the impacts felt by the residents themselves on health and general aesthetic conditions of their immediate environment. It is difficult though to assess the cumulative environmental effects of indiscriminate greywater disposal in rural areas, and the recommendations for future research include the investigation of longer-term environmental impacts on groundwater, wetlands and rivers.

In densely-populated settlements the most important control in terms of greywater management seems to be the household water supply. Many are informal settlements where the services are generally temporary with water supply often very limited. The potential impacts of improving and / or increasing the levels of water supply to these areas must thus be taken into account when considering strategies to mitigate impacts. Although there will undoubtedly be benefits to communities in terms of improved hygiene control, increasing the water supply to settlements will also have the effect of increasing the amount of greywater that is generated, which then needs to be disposed of. Local authorities should provide disposal systems for the greywater that is generated in these areas – recommendations in this regard include having a greywater disposal point at every tapstand and encouraging washing activities to take place at these points. The management of these tapstands and sanitation facilities requires dedicated attention so as to maintain adequate services. The locked toilets, dysfunctional toilet blocks etc. that were noted during the site surveys are examples of inadequate maintenance of sanitation facilities. It is important that local authorities commit themselves not only to the provision of communal facilities but also to the proper operation and maintenance of these systems. It would be prudent in the initial phase of system implementation to plan and budget for a caretaker for the communal water and sanitation facility. This person could be paid by the municipality or the local community and should be tasked with looking after this facility until a sense of ownership has been established or privately-owned facilities have been made available to all households. It is accepted that most people readily take responsibility for their own private property but are less likely to dedicate time and other resources for the preservation of communal facilities.

This sense of ownership, and therefore responsibility, is critical for the success of any sanitation system. Greywater management initiatives are unlikely to be successful unless the recipient communities are involved in the decision-making process, as well as in the implementation and operation of the systems, so as to ensure "buy-in" and thereby enhance the likely success of the service delivery. The issue of ownership is problematic in transient populations like informal settlements however, where there is often no identifiable community structure and therefore no community-based system for taking responsibility for greywater management initiatives. The term "community" assumes a homogeneity that rarely exists in informal settlements. The provision of material possibilities in the form of money, infrastructure, service availability etc. can however encourage people to get involved in working towards the creation of healthy environments. It is essential however that the relevant services be installed within the capacity of the government to deliver, even if these only comprise "emergency services" as in the case of informal settlements, and that a level of ownership is aimed for with respect to any system that is put in place.

### 5.1.1 Possible uses of greywater

The long term needs of South African citizens as far as access to water is concerned, have already been spelt out in key government legislation, with the targets for the provision of basic water and sanitation set out in the Strategic Framework for Water Services (DWAF, 2003) as well as in the Millennium Development Goals (MDGs). Missing from the policies however, are specific goals for the handling of greywater. It is important that the management of greywater is included in the series of targets for the delivery of sanitation services that have been set in terms of the Strategic Framework, particularly in vulnerable areas where waterborne sanitation is not provided. As in other countries with a similar population and water profile, South Africa can do a lot more to conserve and reuse water. In this regard, the management of greywater can contribute both to water conservation and to environmental rejuvenation. The basic strategies for the management of greywater should therefore allow for health improvement, water conservation, use (where possible) and environmental protection.

It is possible that greywater could make some contribution to water conservation and to easing the pressure on sources of potable water by replacing this water in various uses, e.g. pour-flush toilets, irrigation of gardens, lawns, shrubs and trees, dust control etc. The use of greywater for irrigation of food crops however poses certain health challenges about which not enough is known at present. The results of the site surveys showed that there is some resistance to the use of greywater for food irrigation purposes based on *inter alia* local traditions, fears regarding its appearance and perceived poor quality, and also owing to the fact that it has been observed that certain crops (e.g. maize) are not able to tolerate the elevated salt levels and other chemical contaminants in the greywater. The water quality data from the surveys confirmed that this greywater is generally unfit for use except under controlled conditions, but the concept of using certain types of greywater (e.g. first-wash or rinse waters) cannot be ignored. A scoping study has recently been undertaken in this regard (Murphy, 2005) to evaluate the fitness-for-use of greywater in urban and peri-urban agriculture, and another project funded by the WRC (Project K4/1639) is in the process of developing guidelines for the sustainable use of greywater in small-scale agriculture and community gardens. These guidelines will be modeled along the lines of the recently published World Health Organisation guidelines for the safe use of wastewater, excreta and greywater in agriculture (WHO, 2006), the primary aim of which are to maximise public health protection with the beneficial use of important resources. In this regard, the adverse health impacts of wastewater use in agriculture are carefully weighed against the benefits to health and the environment associated with these practices, through the adoption of risk reduction measures.

This use of greywater in agriculture fits in well with the concepts of Ecological Sanitation (Ecosan) which attempts to achieve sustainability by managing human urine and faeces as a resource rather than a waste, with recovery and recycling of the nutrients (Winblad et al., 2004). The difference between the use of toilet waste (e.g. urine and safely composted faecal matter) and greywater (bacteriological issues aside) however, is that toilet waste generally has beneficial levels of nutrients for plant growth without harmful chemical contamination. Greywater on the other hand generally has low levels of nutrients except for phosphorous (usually in the form of polyphosphates which react in water to become orthophosphates) and often has high levels of chemicals from the detergents (salts, metals etc. ), which are potentially harmful to plants. In both cases, the management of the recycling practice is crucial and the precautionary principle needs to be applied, particularly with respect to health issues, e.g. gastro-intestinal disease and HIV/AIDS management. The over-riding principle is that the use of greywater for the irrigation of edible food should not be allowed in non-sewered areas unless the risk factors can be managed within acceptable limits. Unrestricted use of greywater without education on the risks involved and supervision of the practice to ensure adherence to safety precautions is likely to increase the disease burden on those who can least afford it. Further investigation is also required into the effect of detergent use on the quality of greywater and how this impacts on the use of the greywater as a resource - methods of reducing levels of phosphorous and sodium (i.e. salinity levels) in greywater need to be further investigated.

Treatment technologies are available for making greywater potable, but these are generally too expensive for individuals in the non-sewered communities of South Africa where poverty levels are usually high and there remains a heavy reliance on state support. In the long run however, the question of affordable technologies may have to be reviewed in the context of the rising costs of providing adequate amounts of clean water to all citizens. It is also possible that rising incomes due to economic growth may in future make these technologies affordable. This suggests that with the right incentives and suitable environmental and social conditions in situations of inadequate clean water supplies, the usability of greywater can increase.

### 5.1.2 Social conditions conducive for greywater recycling

In the light of the above arguments, most conservation and greywater uses are deemed to be inappropriate for the densely-settled non-sewered areas of urban South Africa. In any case, unplanned areas like parts of Khayelitsha in Cape Town provide little or no room for trees, shrubs or gardens. The first step in making the beneficial use of greywater feasible would thus involve municipal authorities making formal settlement planning possible. In the rural areas, and also some urban poor settlements where a minimum level of planning has provided each household with sufficient space for some expansion or gardening, these interventions might work. This planning is evident in the peri-urban areas around Durban in KwaZulu-Natal where eThekwini Municipality is embarking on a programme to provide each household with 6 000*l*/month (or 200*l*/day) and has planned for the provision of purpose-built soakaways for the on-site disposal of the greywater that is generated on plots that are in the order of 350$m^2$ (eThekwini, 2003).

In "Guidelines for human settlement planning and design" (CSIR, 2000) it is stated that establishing continuities of open space is an important element in the settlement-making process and that these spaces can be used as productive spaces (e.g. urban agriculture) or to absorb the various outputs from the settlements, e.g. stormwater retention, wastewater treatment, solid waste management. The guidelines with respect to fire control (safety distance recommendations for combustible walls) in settlements that have been developed in order to limit the extent and impact of fires on communities are as follows:

- Low fire resistance buildings – 4.5m minimum distance to boundary and 9m minimum distance between buildings
- Low fire resistance but where units of houses are in groups of less than 20 buildings - 2m minimum distance to boundary and 4m minimum distance between buildings.

The provision of such wide spaces between dwellings would result in far lower settlement densities and could create space for greywater disposal. It is worth noting however that the prescribed minimum distances between dwellings are seldom, if ever, adhered to in informal settlements.

Local authorities need to consider greywater disposal in their planning of settlements and must provide disposal systems for the greywater generated in densely-settled areas where on-site disposal is not possible. In the areas where water and sanitation services have been privatized, the company responsible must take charge of greywater removal as part of the sanitation service.

The education and training of communities in greywater management is vital if the residents are going to take responsibility for the systems, but it is also important that the relevant tools be used to provide the incentives for changing the behavioural patterns and habits which may be limiting the success of any new initiatives. Simple solutions, such as planting trees in greywater soakaways are useful ways of demonstrating greywater management initiatives to communities and need to be further explored.

Mara (2006) recommends that dry sanitation (where greywater is tossed onto the ground outside of the dwellings) should be provided in rural areas where there are no space constraints, and simplified sewerage (or conventional waterborne sanitation, depending on maintenance issues) should be provided in urban areas and specifically in high-density environments, where greywater constitutes both an environmental and a health hazard. Installing waterborne sewer systems in informal settlements is seldom possible however (with the exception of temporary systems like containerized toilets connected to small-bore sewers). The temporary nature of these settlements, plus the fact that the land may be "invaded" and is therefore not owned by the local authority, makes the installation of these sewer systems very difficult. Alternative options for temporary and/or emergency greywater disposal, i.e. central collection points, may need to be considered in these cases.

The "National strategy to manage the water quality effects of settlements" (DWAF, 2001b) forms part of DWAF's overall approach towards Water Resources Management and is focused on breaking the cycle of poverty and the prevention of pollution through service provision. It outlines the roll-out of a method of identifying the causes of, and solutions to, pollution within settlements. These aim at reducing or minimizing the production of pollutants at source, and providing a balance between the size and density of the settlement, the Class of the receiving resource, and the Level of Services, whilst still ensuring financial sustainability. The roll-out is taking place through two mechanisms; firstly reactive interventions in priority settlements, and secondly by promoting proactive interventions by planning appropriate services and helping to build capacity in local government. In order to achieve this the National Strategy has identified the need for a "seed funding" facility which aims at providing small amounts of money to identify the causes of pollution using a "Structured-Facilitated" process and helping to identify other local sources of funding that could be used to implement resultant intervention plans.

## 5.2 Management guidelines for the disposal of greywater in non-sewered areas

There are no definitive health regulations or guidelines for the disposal and / or use of greywater in the non-sewered areas of SA, although the City of Cape Town has published draft Greywater Guidelines (City of Cape Town, 2005) specifically for the disposal of greywater in high-density, informal settlements, and eThekwini Municipality have included greywater disposal and drainage issues in their business plan for the delivery of basic sanitation services in the eThekwini Municipal area (eThekwini, 2003). A summary is given here of these guidelines as well as the relevant risk management measures from around the world that are being applied to ensure human health and environmental protection.

### 5.2.1 Planning considerations and guidelines for greywater disposal in non-sewered areas

As previously noted, it is essential to address the potential for greywater generation when planning and developing settlements, and the integration of suitable long-term service provision is necessary in order to alleviate the problems of greywater management (Wood et al., 2001). This is particularly relevant in densely-settled areas where the options for the use of greywater are limited and the focus is on safe disposal only. The following guidelines are suggested when planning for greywater disposal in high-density settlements:

1. Settlement planning

- Avoid establishing settlements on steep slopes in order to prevent erosion and runoff of greywater and stormwater (Wood et al., 2001).
- No development should occur within the 1:50 year floodline (Wood et al., 2001).
- Open spaces should be maintained within the settlements in order to *inter alia* assist in pollution control, absorb rainfall and reduce flooding (Wood et al., 2001).

2. Service provision

- Water standpipes should be provided within 100m of each household (Wood et al., 2001). Reduce water wastage (and concomitant increased volumes of greywater) at standpipes through the use of fittings such as automatic shut-off taps.
- Provision must be made for the collection of greywater and leakage from water standpipes; preferably infiltration beds and soakaways should be provided at the standpipes (or drainage to gravitate the greywater to sewer or an appropriate site for handling and disposal) so that ponding of contaminated water is minimised (Wood et al., 2001).
- In addition to providing a greywater disposal facility at each water supply point, additional disposal points should be installed so as to reduce the walking distance from dwellings to disposal point to a maximum distance of 25m (City of Cape Town, 2005).
- For new standpipes, greywater disposal points with galvanised gratings should be provided (City of Cape Town, 2005).
- Where communal washing facilities are provided, sediment and fat traps are required before disposal of greywater (City of Cape Town, 2005).
- Communal sanitation facilities should be conveniently located (Wood et al., 2001) and must include washing facilities with provision for the disposal of greywater.

3. Greywater disposal

- The preferred option for greywater disposal is by gravity to sewer – the collection and treatment of greywater in ponds or wetlands is not a viable option for many high-density settlements owing to the lack of large open spaces, the health risks and safety considerations (Wood et la., 2001). Alternatives to disposal to sewer can include modified septic tanks (with enzymes) and centralised collection of greywater, e.g. tankers.
- Purpose-built greywater disposal soakaways should be provided for plots that are <350m$^2$ (eThekwini, 2003), but can only be provided in areas where the soil is permeable and the water table is low (City of Cape Town, 2005).
- Should discharge into the stormwater system be considered, further treatment of the greywater is required (City of Cape Town, 2005).

4. Operation and maintenance

- Communities provided with greywater disposal systems should be educated in terms of their purpose and correct use, i.e. greywater systems may not be used for the disposal of blackwater or night soil (City of Cape Town, 2005 & eThekwini, 2003).
- The maintenance of gratings and sediment and fat traps should be programmed to take place on a regular cycle, depending on capacity and usage of system (City of Cape Town, 2005).

### 5.2.2 Risk management measures for handling greywater in non-sewered areas

There are basic handling rules with respect to health issues that should be followed when disposing or reusing greywater in areas where there is enough space for on-site disposal. These guidelines have been adapted from Murphy (2005) and include the following:

- Use natural cleaning products where possible, e.g. phosphate-free, low-sodium, and zero-content boron (Fane & Reardon, 2005; Center for the Study of the Built Environment, CSBE, 2003)
- Do not store greywater for more than 24 hours (and preferably no more than a few hours) before use or disposal (Fane & Reardon, 2005; State of Victoria, 2003)
- Do not dispose of greywater to surface or stormwater or into the groundwater system (State of Victoria, 2003)
- Ensure greywater does not contaminate drinking water sources (State of Victoria, 2003)
- Greywater should not be allowed to leave the boundaries of the property on which it is generated (CSBE, 2003; State of Victoria, 2003)
- Greywater should be withheld from areas where children play, such as lawns (CSBE, 2003; State of Victoria, 2003)
- Do not irrigate with greywater if the soil is already saturated and do not allow surface ponding of greywater (State of Victoria, 2003; Fane & Reardon, 2005)
- Do not use kitchen wash water or water that has been used to wash nappies or other clothing soiled by faeces and/or urine, for irrigation purposes (State of Victoria, 2003; Little, 2004)
- Do not use greywater if anyone on the premises is suffering from an infectious health condition (Little, 2004)
- Always use subsurface irrigation and never hose, spray or mist with greywater (State of Victoria, 2003)
- Avoid watering fruits and vegetables with greywater if they will be eaten raw or under-cooked and always wash and cook food that has been irrigated with greywater (CSBE, 2003; State of Victoria, 2003)
- Wash hands after contact with greywater (State of Victoria, 2003)

## 5.3 Summary

The variety of challenges (e.g. the impact of detergents, the general health of residents and the influence of HIV/AIDS etc. ) with respect to greywater management in non-sewered areas is much greater than has been investigated in this project. It has been possible, however, to develop some initial strategies which have health improvement, water conservation, use (where possible) and environmental protection as the principle objectives:

- Settlement planning is key. The management of greywater should be included at the planning stage for the provision of water services to non-sewered settlements, in collaboration with the affected communities.
- The decision to promote either the disposal of greywater in such a manner so as to avoid negative impacts, or encourage the safe use of greywater in settlements, should be based on the density of the settlement and the quality of the greywater. Greywater produced in high-density informal settlements should NOT be used for the production of edible crops or distributed over surfaces that humans come into contact with.
- Based on the quality of greywater generated in low-income, densely-settled urban areas, it should be managed as a sanitation issue rather than a drainage one. Local authorities should provide greywater disposal systems in densely-settled areas that either treat the greywater on-site so that it meets acceptable limits for discharge, or convey the greywater to a sewerage system. It is vital that the local authorities are committed to the proper operation and maintenance of these systems and that they employ and pay for a community-appointed person to act as caretaker of the facility.
- Education and training of communities in greywater management is vital, together with the provision of “material possibilities” in the form of money, infrastructure, service availability etc.
- Simple technological solutions should be explored further.

# 6. Discussion and conclusions

The site surveys have provided a general overview of the large variety of conditions that occur in the non-sewered settlements in SA, and have highlighted the implications of certain settlement characteristics (specifically settlement density) on greywater management in these areas. The surveys have revealed that greywater is not the primary cause for concern amongst most residents of low-income settlements, and that the provision of toilets, houses, water and electricity are deemed to be more important. Greywater disposal poses severe problems in dense urban settlements and in most cases there are no alternatives to removing this wastewater off-site as quickly as possible so as to avoid major health and environmental impacts. Where this is not being done, open drains and stagnant pools of wastewater become a source of flies, mosquitoes, smells and other serious pollution problems.

There may be opportunities for the responsible beneficial use of greywater in low and medium density settlements (e.g. individual or communal gardening), but health and salinity issues need to be taken into account, and risk reduction measures must be put into place. It is also important that the planning of these settlements includes for the provision of land for the disposal / use of greywater. The acceptability of greywater use initiatives in this country needs to be further considered; it appears that wastewater reuse in Asia is tolerable due to the extremely high population densities and the fact that people have no other option if they want to grow food. Similarly, in the SA situation, greywater is generally only used for agricultural purposes when poverty levels are high and water availability is low (i.e. out of desperation). It was found that most people considered greywater either too dirty for use on food crops or had learnt from experience that the detergents and other residues in the greywater had negative effects on some of the plants (e.g. “scorched” leaves). Greywater use initiatives are therefore not well supported, with most people suspicious of the quality of the greywater and the possible associated health issues.

Some interest was shown in the possibility of using greywater in the future but most people simply did not have the confidence to experiment with it. It is necessary therefore that where greywater-based urban gardening and other reuse initiatives are to be considered, they ought to be part of an education program designed to achieve comprehensive integration of the greywater management process and provide incentives for making this process work.

It is important to note that most of the interviewees believe that the solution to their water supply and wastewater management problems rests with the municipal authorities alone. This appears to be based on a sense of entitlement resulting from the Government’s stated policy regarding the delivery of waterborne sanitation in fully-serviced homes to as many citizens as possible. Most residents of non-sewered settlements therefore consider alternative water provision and wastewater management techniques as temporary measures only. Another issue revolves around the concept of water recycling and Government policies in this regard – people are suspicious that they will be getting an “inferior” product if recycling is introduced. Local authorities need to take this aspect into account when determining their greywater management and sanitation/water supply strategies.

There have been recent press reports about the poor quality of the Berg River in the Western Cape resulting from both sewage and greywater runoff from settlements along the river. Much of the fruit grown alongside the Berg River is exported to the European Union (EU) but the strict quality requirements for irrigation water that are prescribed by the EU are currently not being met. Aside from the obvious environmental and health impacts, there are financial implications resulting from this for fruit farmers in the area which demonstrates the type of emergency situation that can occur with non-existent or inadequate sanitation systems. It appears that local authorities are still not taking greywater into account when considering sanitation, e.g. building communal toilet blocks in informal settlements without providing washing facilities. They should be encouraging as much washing activity as possible around the communal sanitation / water facilities so that there is a single discharge point for all effluent which can then be connected up to sewer systems if available, or discharged to primary treatment or irrigation.

The situation in the settlements along the Berg River has also highlighted the mismatch between Government's targets for the provision of basic water (2008) and sanitation services (2010) to all people, and the fact that no consideration has been given to the disposal of greywater resulting from the Free Basic Water supply, based on the fact that the VIP is the basic sanitation option of choice. On several occasions during the site surveys, residents were observed disposing greywater into pit latrines, a practice which will eventually lead to the failure of these systems. A recent nationwide sanitation sustainability audit conducted by DWAF on the functionality of sanitation projects completed between 1994 and 2003 supports this finding. The report revealed that up to 28% of household sanitation facilities have failed or are in the process of failing (DWAF, 2005b). The implications of doubling water supply to people in non-sewered areas would therefore probably mean that "marginal" areas in terms of greywater generation would be pushed into the category where off-site disposal is required, and this would result in local authorities being pressurised into providing specific greywater management options for this off-site disposal. An increase in water consumption in high density informal settlements will exacerbate the greywater problem in areas where it already constitutes a sanitation rather than a drainage issue. Local authorities must therefore take into account the provision of the necessary sanitation services when planning for increased water supplies to settlements.

One of the issues that were considered throughout the research was whether greywater in non-sewered areas is seen as a problem or a resource. Most of the people that were interviewed did not have enough information upon which to base their opinions one way or the other but in the high-density urban settlements it was generally perceived to be a problem whilst in the more rural areas it was concluded by the researchers that greywater was not perceived as a problem if it flowed away, evaporated or seeped into the soil. It was perceived as a resource if it could help control dust, keep ants, flies and other insects away or if it could be used to irrigate hardier varieties of shrubs and trees. In all the areas that were visited however, there was no indication that any large-scale production of, for example, vegetables, could be undertaken in non-sewered settlements by using greywater for irrigation. A more likely scenario is the small-scale irrigation of food crops to supplement the nutritional needs of single households, provided that the specific conditions for the beneficial use of greywater have all been met, as discussed in detail in Section 4.5.

In addressing the original objectives of this research the following conclusions have been made:

- There is a noticeable gap between Government policy on water provision and the long-term sustainable water management challenges for the country – whilst the water supply interventions are aimed at improving the health of individuals, no attention has been given to the resultant longer-term impacts on environmental health in non-sewered areas.
- Social dynamics and behavioural patterns have a significant impact on the way that communities deal with water supply and wastewater management issues, particularly with respect to greywater disposal. These behavioural patterns (and the drivers associated with them) must be taken into account when assessing specific greywater management options for individual settlements. This is particularly relevant when considering greywater use options in certain areas where potable water resources are limited.
- An estimated total volume of between 440 000 $m^3$ and 575 000 $m^3$ (average 500 000 $m^3$) of greywater is generated on a daily basis in the non-sewered areas of South Africa.
- The quality of greywater in non-sewered areas differs significantly to the greywater that is generated in higher-income, sewered areas in that there is a greater variation in the concentration of the various pollutants and at its most concentrated it should be considered hazardous. There is therefore significant risk involved with the on-site disposal of greywater in non-sewered areas.
- Whilst the links between greywater use and the polluting effects of detergents have yet to be established properly, it has been observed that people living in non-sewered settlements are generally not prepared to use greywater for irrigation purposes as it is considered harmful to certain species of plants. The water quality data from the site surveys confirmed that greywater from non-sewered areas is generally unfit for use.
- Methods of reducing levels of sodium and phosphorous in greywater need to be investigated and the use of high phosphate detergents discouraged if the concept of using certain types of greywater (e.g. first-wash or rinse water) for irrigation purposes is to be considered.
- The determination of greywater generation rates for specific non-sewered settlements throughout South Africa can be used to determine recommended management practices, with off-site disposal of greywater recommended for settlements that have greywater generation rates > 2,500 *l*/ha.d.
- The management of greywater should be included in the series of targets that have been set for the delivery of sanitation services in terms of the Department of Water Affairs and Forestry’s Strategic Framework for Water Services.
- Greywater management should be included at the planning stage for the provision of water services to low-income settlements, as it is closely linked to the levels of service in a settlement, particularly the availability of water supply.

- There are currently no definitive health regulations, guidelines or by-laws in place for the use / disposal of greywater in the non-sewered areas of South Africa. Management options must be put in place to reduce the negative impacts from greywater disposal practices in non-sewered areas, and it is vital that the relevant local authorities take ownership of any greywater management schemes in place.

In summary, it can be stated that, for the typical high-density informal settlements that are mushrooming around the main cities in SA, the greywater is particularly hazardous from a pathogenic and salinity point of view ("dark" greywater) and should be managed as a sanitation issue rather than a drainage one.

It is essential that there is systematic management of greywater in non-sewered settlements both in terms of reducing health risks by eliminating inappropriate disposal and surface ponding, and also to provide benefits in terms of greywater use initiatives. Whilst it is important that communities are educated and empowered with respect to greywater management, it is the responsibility of the local authority concerned to ensure that working systems are in place.

# 7. Recommendations for future research

The following future research needs have been identified in the field of greywater management:

- Detailed long-term surveys of greywater generation, use and disposal, investigating current practices and their consequences, at local community level. This would include accurate measurements of water consumption and greywater generation in specific settlements. This is the subject of a current WRC project (K5/1654).
- Development of guidelines for the management and use of greywater, specifically where it is being used in small-scale agriculture, including careful consideration of risk management in the context of greywater use in informal settlements – this is the subject of a current WRC project (K5/1639).
- Detailed assessment of the quality of the greywater produced by low-income urban communities in South Africa with respect to pathogen loading and microbiological quality, and the health risks posed by such water.
- The identification of preferred methods of communicating greywater management information to authorities and communities (e.g. maps, booklets, flow charts etc. ) so that successful strategies may be implemented, particularly in terms of healthcare programmes.
- The identification of the specific impacts of greywater disposal from non-sewered areas on groundwater quality based on the consideration of specific aquifers, including the collection of a long-term data set and analysis of these aquifers.
- The identification of the specific impacts of greywater disposal on the quality of surface water (wetlands, and rivers) downstream of non-sewered settlements, using tracer studies.
- The identification of the specific impacts of greywater use and disposal on soil conditions through the use of soil salinity surveys.
- Investigation into the links between greywater disposal and the polluting effects of detergents, i.e. the costs associated with the long-term use of various detergents on the environment, and the identification of methods of reducing levels of sodium and phosphorous in these detergents.
- Assignment of financial, socio-economic and environmental cost estimates to greywater problems, and financial cost estimates to the management of future impacts.
- Development of an information system to disseminate the most appropriate technological options for greywater disposal relevant to South Africa.
- Research into the presence and levels of xenobiotic organic compounds (XOCs) in greywater and their environmental impacts.

- Research into the levels of Boron (B) in greywater and how it impacts on the use of greywater as an irrigation resource.

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# Appendix A

## Greywater survey questionnaires

# GREYWATER SURVEY QUESTIONNAIRE

**Section 1: Bio-data**

1. House Number: ____________________________________________
2. Interviewee's Full Name: ____________________________________
3. Gender: __________________________________________________
4. Age: _____________________________________________________
5. Religion: ☐ Ancestral beliefs ☐ Christianity ☐ Islam ☐ Other (specify): ____________
6. Occupation: ☐ None ☐ Formal ☐ Informal (no regular income)
7. Household Income per month (or estimate based on material belongings):

   ☐ None ☐ R1-R400 ☐ R401-R800 ☐ R801-R1600 ☐ R1601-R3200 ☐ > R3201
8. Education attained: _________________________________________
9. Relation to Head of Household: _______________________________
10. Number of people in household: ______________________________

11 Number of children, ages: ____________________________________

12. Type of house: ☐ Traditional dwelling ☐ RDP House/ brick structure ☐ Informal dwelling

13. How long have you lived at the present site? ___________________

**Section 2: Water Consumption Patterns**

14. Distance from your house to water point:

☐ < 10m ☐ 10 - 50m ☐ 50 - 100m ☐ 100 - 200m ☐ 200 - 500m ☐ > 500m

14. Daily water use per household:

☐ < 20*l* ☐ 20*l* – 50*l* ☐ 50*l* – 100*l* ☐ 100*l* – 150*l* ☐ > 150*l*

15. Time taken fetching water per day:

☐ < 15 mins ☐ 15 – 30 mins ☐ 30 – 60 mins ☐ 1 – 2 hrs ☐ > 2hrs

16. The first time you draw fresh water in the day what is it used for? ________________

17. Type of containers used for storing clean water: ______________________________

18. Volume of water that can be kept in the house:

☐ < 20*l* ☐ 20*l* – 50*l* ☐ 50*l* – 100*l* ☐ > 100*l*

19. Other purposes for containers:

☐ Beer brewing ☐ Laundry ☐ Dish washing ☐ Cooking ☐ Other (specify): ________

20. What brands of the following products do you use?

Bath soaps: _________________________Washing powders: __________________

Dish washing liquids: ___________________ Shampoos: ______________________

Other detergents (specify): _______________________________________________

21. How often do you wash your clothes?

☐ Daily ☐ Once a week ☐ Twice a week ☐ More (specify): _________

22. How often do you / members of the family take baths?

☐ Daily ☐ Twice daily ☐ Other (specify): __________________

23. What do you do with the dirty water after use?

☐ Throw away ☐ Water plants ☐ Reuse ☐ Other (specify): _____________

25. If you reuse the water give examples (e.g. using cooking water for dishes or bathing water for laundry): _________________________________________________

**Section 3: Grey water management**

26. Do you think that greywater recycling would be useful in your community? Please give reasons for your answer: ____________________________________________
_______________________________________________________________________

27. Which are the most important services that you think would make life better?

☐ Electricity ☐ Houses ☐ Water ☐ Toilets ☐ Schools ☐ Refuse removal ☐ Other (specify): ________

28. Who do you think should provide these services? ______________________________

29. Do you think greywater is a major health problem in the community? Give examples:
_______________________________________________________________________

30. What would you suggest as the best way of resolving the problem of greywater disposal? ______________________________________________________________

31. Do you have any questions you would like to ask me?

Interviewer: ____________________________Date________________________________

**Section 4: Existing greywater systems (as observed by interviewer)**

32. Do any of the following occur at the water standpipes?

☐ Soak-away ☐ Concrete slab ☐ Gulley ☐ Kerb in-let ☐ Wash-trough

☐ Stormwater Channel ☐ Stormwater manholes ☐ Communal washing/ ablution facilities

☐ Greywater sand filters ☐ Grease traps

33. Are the existing greywater management systems working? If not, why not? Please give comments: ______________________________________________________________
_______________________________________________________________________
_______________________________________________________________________

34. Please ensure that a photograph is taken at the interview site - supply a reference number and description here: _______________________________________________

## ASSESSMENT OF SETTLEMENT CHARACTERISTICS – QUESTIONNAIRE FOR LOCAL AUTHORITY

| Question | Answer |
| --- | --- |
| Name of settlement, and Province | |
| Is this a rural, peri-urban or urban settlement? | |
| Approximate size of settlement (ha) | |
| Approximate no. of dwellings | |
| Approximate population | |
| Predominant type of dwelling (e.g. traditional, RDP, informal) or per-centages of each | |
| How is water supplied to the houses? (e.g. taps in yard, commu-nal standpipes, tanks, river etc) | |
| If Municipality supplies water, what is the average total amount supplied daily/monthly? | |
| What type of toilet facilities are there (e.g. flush, pit latrine, bucket etc)? On- or off-site? | |
| Average annual rainfall in the area (MAP) | |
| Depth to water table in wet season | |
| Distance to nearest surface water body | |
| Is the settlement situated within the 50 or 100year floodplain? | |
| Date | |

**Data sheet for sampling**

Note: Sample code (eg. WC0101) and date of sampling must be indicated on sample bottle

| | | | | |
|---|---|---|---|---|
| **Name of site** | | | | |
| **Sample code** | | Province code | Site number | Sample number |
| | | | | |
| **Coordinates** | Latitude | | | |
| | Longitude | | | |
| **Date of sampling** | | | | |
| **Name of person doing sampling** | | | | |
| **Weather conditions** | | Rain ( ) Cloudy ( ) Clear ( ) Other specify ( ) | | |
| **Sample source** | Tap ( ) Borehole ( ) Well ( ) | Kitchen ( ) Laundry ( ) Other specify ( ) | | |
| **Sample history, i.e. how water has been used** | | | | |
| **On-site observations** | Odour | None ( ) Slight ( ) Strong ( ) Other specify ( ) | | |
| | Appearance | Clear ( ) Opaque ( ) Dark ( ) | | |
| | Colour | | | |
| **Results of field tests** | pH | | | |
| | Conductivity (mS/m) | | | |
| | Ammonia | | | |
| | E. coli | | | |
| | Phosphate | | | |
| **Laboratory analyses required (please tick selected)** | Total Kjeldahl Nitrogen | | | |
| | Turbidity | | | |
| | Nitrate/ Nitrite | | | |
| | Chemical Oxygen Demand | | | |
| | Total Phosphorous | | | |
| | Oil and Grease | | | |
| | Calcium | | | |
| | Magnesium | | | |
| | Sodium | | | |
| | Potassium | | | |
| | Boron | | | |
| | Sulphate | | | |
| | Chloride | | | |
| | Other (please specify) | | | |

| Province Codes: | |
|---|---|
| WC | Western Cape |
| EC | Eastern Cape |
| NC | Northern Cape |
| FS | Free State |
| KN | Kwazulu-Natal |
| NW | North West |
| MP | Mpumalanga |
| GP | Gauteng |
| NP | Northern Province/ Limpopo |

# Appendix B

## Commercial greywater systems

# Commercial greywater systems

Within the developed world there are numerous systems (some patented) which aim to dispose of greywater by treating it to acceptable standards and reusing it in some form of irrigation system. The systems described in this report are a selection chosen to describe some of the innovative means of treatment and disposal worldwide. It should be noted that most of these technical solutions presuppose that normal (full) water services are provided. In South Africa the use of greywater in certain areas warrants further consideration since this country is prone to water shortages, but some form of "on-site" treatment would be required to render this water safe for use. The cost implications, maintenance requirements and social acceptability of such systems would however have to be taken into account before deciding which treatment technology to adopt.

## B1. BioSand

The BioSand system (Watertiger, 2006)) is a mineral-enhanced sand filter and is reported as being able to treat greywater to a level for use on gardens or for toilet flushing. It has a maximum consumption of 10kW of power and does not require tanker de-sludging. The system can be used alone or as final polishing for other processes such as reed beds or aerated systems. It is designed to treat rainwater, greywater and solids-separated toilet waste of up to 1,000*l*/d. Under most conditions it can produce high quality effluent with levels of BOD & SS <10mg/l.

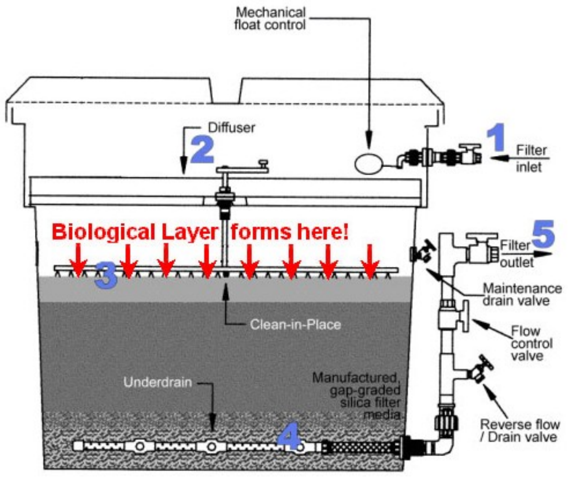


**Figure B1.1:Cross-section through BioSand filter**

**Figure B1.2: Example of BioSand filter installation**

Untreated water flows into the BioSand filter inlet and through the diffuser before flowing to the filter surface. The accumulation of organic matter, living and dead, forms a biolayer on the sand surface which develops with use, increasing filter effectiveness. Water then moves downward through the filter and is collected in the underdrain. Filtered water travels up through the standpipe to storage and/or disinfection.

# B2. Greywater Drywell

This is a passive (gravity drainage) greywater disposal system for situations when greywater use may not be an option. It consists of a self-cleaning filter and settling tank with all the relevant plumbing fittings plus a drywell kit, which consists of vent and fabric wrap for direct disposal of household greywater. Drywells (The Natural Home, 2006a) are designed to provide alternative water management solutions which reduce the need for costly labour-intensive concrete and pipe-in-trench leaching systems. Top loading of effluent (greywater) ensures maximum surge capacity for the drywell. Irrigation of an orchard is often the typical use of greywater from a system such as this – the drywell acts as "emergency overflow" leaching pit and the majority of the water is delivered directly to the trees in the orchard. Figure B2.1 shows a typical greywater drywell filter / settling tank and Figure B2.2 is an example of the self-cleaning filter.

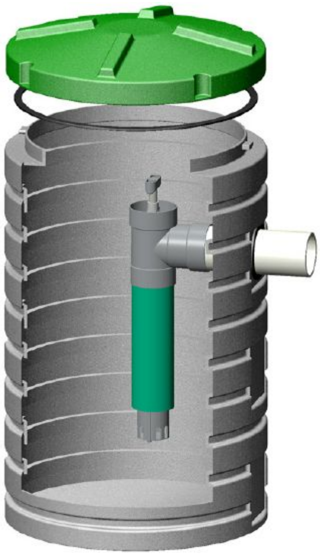

**Figure B2.1: Greywater Drywell filter / settling tank**

**Figure B2.2: Self-cleaning filter for Greywater Drywell**

The following instructions are given when purchasing this system and apply to greywater treatment in general:

- never store "treated" greywater in a large holding tank, cistern, lagoon or pond for future use.
- never allow greywater to drain on top of bare ground – the irrigation area needs to be below soil and/or mulch.
- never use unlabeled, unsealable or unvented containers for a filter basin – settling tanks need easy access.
- always vent the plumbing fixtures, filter basin, planter-bed, leach field and or leach pit to allow air into the system.
- always drain containers & planter-bed bases so as to allow oxygen to get into the soil.

## B3. Alternating Intermittent Recirculating Reactor (AIRR)

The AIRR system (US EPA, 2006) consists of a septic/dosing tank, a biological reactor with both secondary and tertiary sections, a cover structure, a recirculating tank and a discharge tank or pipe. The septic tank needs to regularly pumped, and visual inspections need to be carried out on the pipes with routine maintenance on the cover structure. This system works for both single family residences as well as for entire communities; it is energy efficient, has low construction costs and is able to be upgraded. The AIRR system is classified as a recirculating sand gravel filter (biological activity is controlled on the surface area of media in combination with high oxygenation) and delivers treated effluent that is suitable for recycling and re-use in non-potable applications (may be discharged underground into drainfields, or into salt water, streams and rivers, or can be used to irrigate golf courses, parks, forests or farm land).

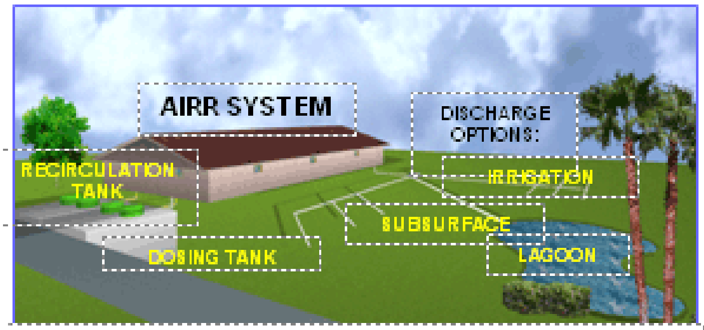


**Figure B3.1: Schematic of AIRR system**

**Figure B3.2: AIRR facility**

## B4. AquaCycle 900

This system cleans water from baths and showers with claims of potential savings of up to 90,000*l* of water per annum for a family of four. It is easy to install, is odourless and maintenance is also kept to a minimum, with low energy requirements (about 0.6kWh per day). The Aquacycle system (Freewater UK, 2006) makes use of the patented SmartClean system and operates as follows:

- Prefiltration – larger particles like hair and textile fragments are collected. A special spray pump automatically flushes the filter and sediments are washed away into the main wastewater drain.
- Two-fold biological treatment – in the main and secondary recycling chambers the dirt particles are decomposed by bio-cultures. The water is pumped to the next station at three-hour intervals.
- Sediment disposal – the organic sediments, which are produced during the recycling process, are regularly sucked out from the chambers and diverted into the wastewater drain.

- UV-Sterilisation – on the way to the storage chamber the recycled water flows through a UV-light lamp, which disinfects it. The high quality of the water now conforms to the E.U. Directive for Recreational Water and can be utilised for a variety of non-potable uses around the home.

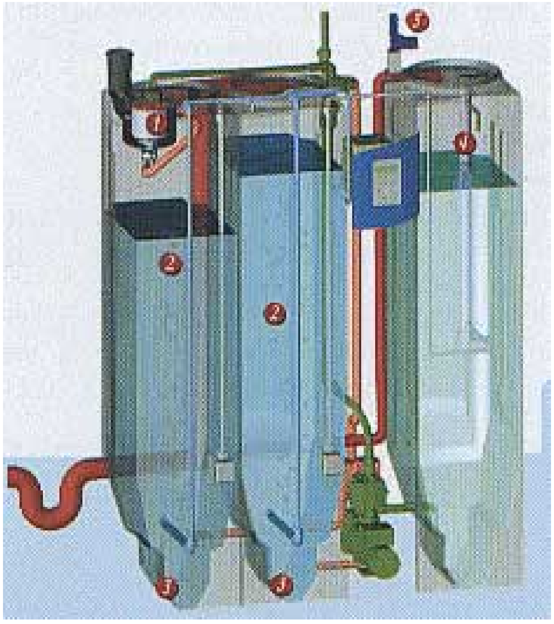

**Figure B4.1: AquaCycle 900**

## B5. Clivus® LPF20

The Clivus® LPF20 (The Natural Home, 2006b) is a filtration system that retains hair, lint and large particles in greywater produced by showers, sinks, and washing machines. The purpose of this filtration is to protect the pump and greywater injection and distribution pipes from matting and clogging. Inside the Clivus LPF20 are two stretch filters supported by a grate over a dosing chamber and pump. Greywater is directed by a three-way valve to one filter at a time. As water flows into the filter, larger particulates are trapped inside while the greywater seeps through the membrane and collects in the dosing chamber below. The filter continues to stretch to allow water to exit as the particulate load becomes greater. When the filter is too full to stretch further, the valve is turned to allow flow into the second filter. Whilst the second filter is in use, the first is dried out and can be carefully replaced with a new one. Once the dosing chamber has filled to the pre-set level, the pump engages automatically and moves the accumulated filtered greywater into delivery pipes which direct it into associated planter beds for final cleansing by plants and soil organisms. Plant roots take up the nutrients and absorb much of the greywater. Activity of soil organisms further breaks down the organic material left in the greywater; and it is then ready to recharge groundwater without harm to the fresh water

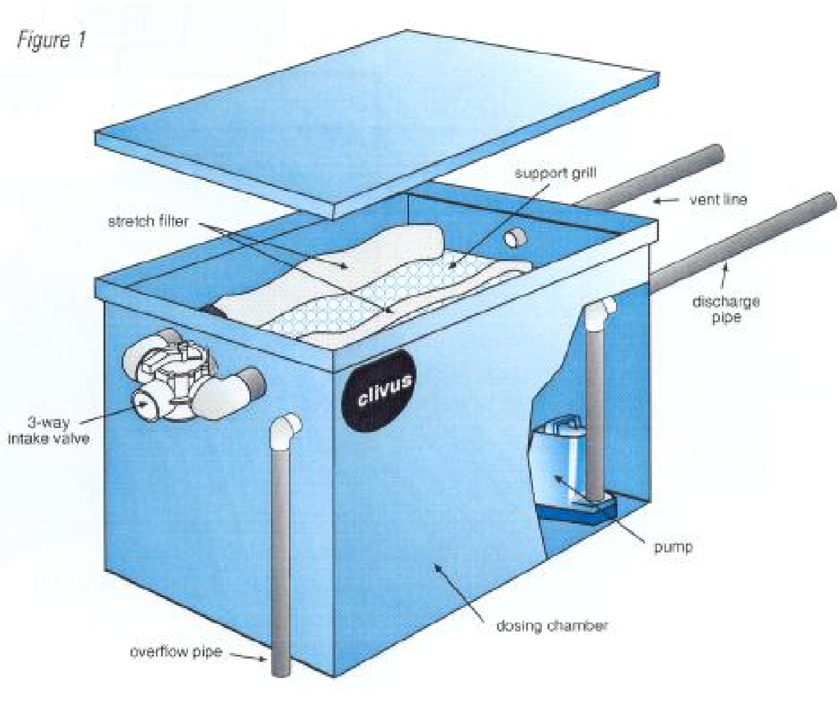


**Figure B5.1: Clivus® LPF20 system**

## B6. Ecomax

The Ecomax system (Ecomax, 2006) consists of a sedimentation / septic tank connected to a "dual disposal field" via sealed pipes and a manual diverter valve for rotation of flow between fields. The greywater from the sedimentation tank flows into pervious geotextile-encased pipework which is laid beneath lawns or garden beds and is surrounded by specially prepared nutrient-removing modified soil. Bauxite residue is also used in the filter bed, which has good absorptive properties for some minerals and metals and also works as a good bacterial filter. Below ground disposal ensures that the greywater is already at root access without losses to evaporation, and also provides better protection of public health. A typical Ecomax cell for greywater removal from a three bedroomed home would be 9m long and 4.4m wide.

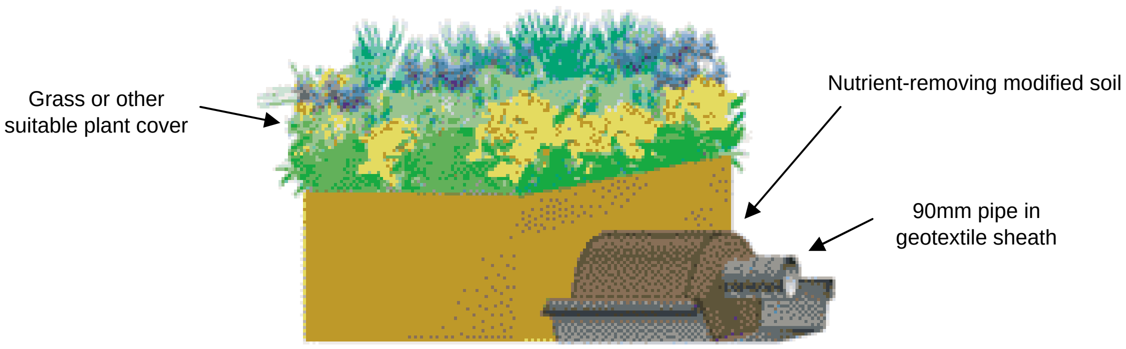


**Figure B6.1: Oblique section through Ecomax system**

# B7. Hanson gravity chamber

Hanson Associates (Greywater treatment, 2006) have created a chamber which is capable of loading approximately 100*l*/m$^2$ per day, receiving all the greywater from a three-bedroom house. The system uses half of a 150mm diameter PVC pipe which is placed in a trench on mesh plastic netting to prevent the walls from sinking into the soil. No pre-filtration is used.

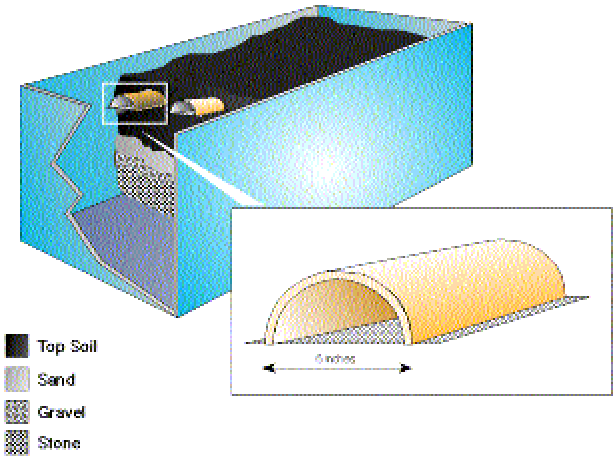


**Figure B7.1: Gravity leaching chamber**

# B8. ReWater® distribution cone greywater system

This system (Rewater, 2006) captures, filters and reuses the shower, bath, wash-basin, and laundry water from domestic residences and disposes of it in the ReWater's patented underground drip system, which is reported to be at least 30% and up to 60% more efficient than sprinklers. The system consists of a tank, pump, auto on/off switch, automatic filter, backflow and switching valves and is generally connected to the most regularly-used showers and washing machine in the home as it has been found that about 95% of the reusable water comes from these few sources.

When the pump turns on during the irrigation cycle, water is sent to the top of the filter canister and forced down through the sand filter media where hair, lint, and other debris is trapped in tiny spaces between the sand particles. Water then travels out to a series of irrigation valves for use in the garden. To keep the filter clean, when the controller has accumulated a certain (programmable) amount of run time, it begins a self-cleaning cycle after that day's irrigation has been completed by using fresh water, and diverting the backwash to waste. The fresh water is rapidly forced up into the sand filter media, causing sand particles to rise and separate from each other, releasing the trapped debris. Lighter than the sand, the debris rises to the top and flows out to the waste line. When the process is over, the valves return to their irrigation position.

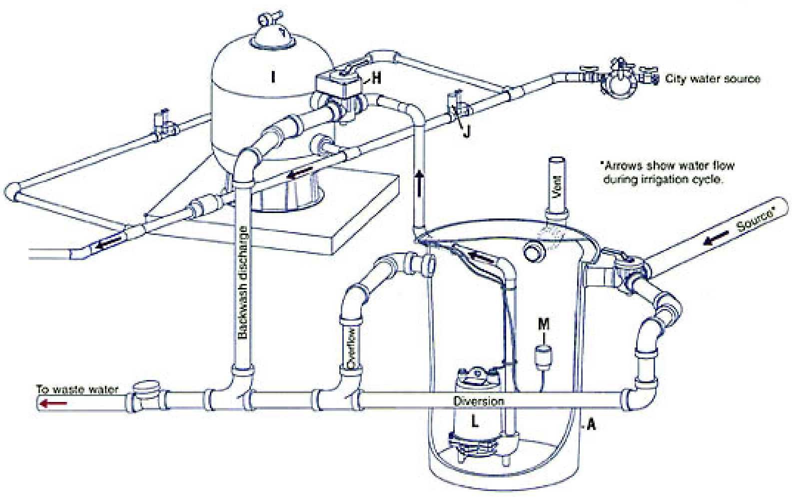


**Figure B8.1: ReWater® filter system**

## B9. Greywater irrigated greenhouses

These greenhouses (Greywater treatment, 2006) are constructed in such a manner that the fertilized growing beds provide efficient greywater treatment. The beds are automatically irrigated using household greywater. One such greenhouse in New Hampshire (USA) uses a fish pool as the final treatment after the soil beds, which stays clear by means of a biological treatment technique involving a waterfall and bio-filter plates on the pool-bottom. These greenhouses have been reported as providing a family of 4 – 6 people with more than enough vegetables throughout the winter season.

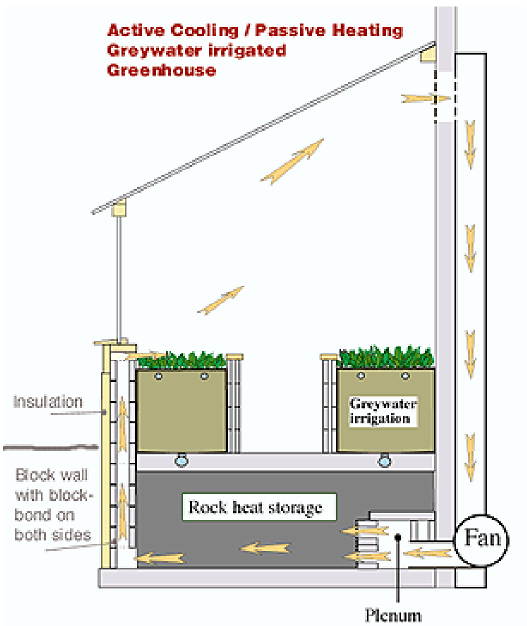


**Figure B9.1 Greywater irrigated greenhouse**

## B10. Outdoor planters

These are masonry soil boxes which effectively serve to build up the site's soil profile (Greywater treatment, 2006). They also act as retarding mechanisms within sandy soils to slow down the greywater so that sufficient treatment can be accomplished. Within dense settlements it is suggested that two adjacent neighbours build a large mound on their properties which acts as a property divider. In so doing they would also be able to plant hedges or evergreens on the leaching area.

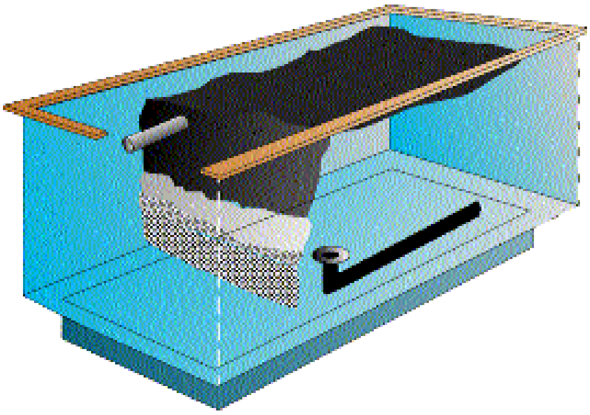

**Figure B10.1: Schematic of greywater planter box**

**Figure B10.2: Greywater planter in British Columbia**

Both aerobic and anaerobic pre-treatment of the greywater is possible before discharging it to the soil planters and can be used to improve the quality of the final effluent.

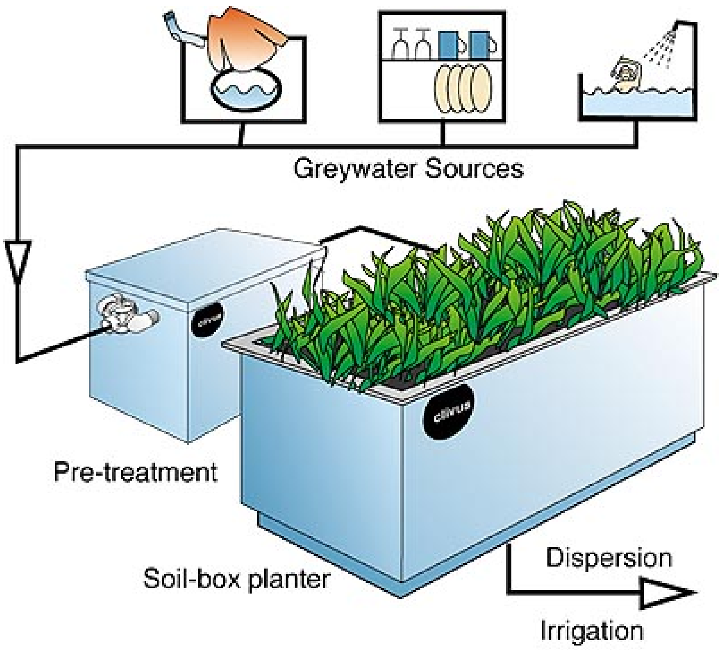


**Figure B10.3: Treatment system with planter box**

## B10.1 Aerobic pre-treatment

A stretch filter treatment technique removes large particles and fibres so as to protect the sequential infiltration pipes from clogging. The stretch filter allows the rest of the organic matter to travel through to the next stage of processing. Directly after this primary filtration the greywater is transferred into a biologically active, aerobic soil-zone environment where both macro- and micro-organisms thrive. This filter system is suitable for public facilities where the principal source of greywater is hand-washing and showers without any food waste to speak of (food wastes may accumulate in the filter causing it to become anaerobic and resulting in odours). See Figure B10.4 for a typical Clivus fabric filter configuration:

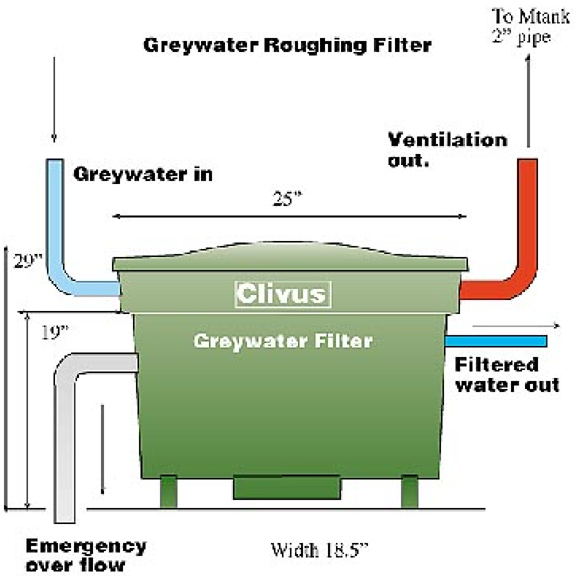


**Figure B10.4: Aerobic pre-treatment with Clivus fabric filter**

## B10.2 Anaerobic to aerobic pre-treatment

This system usually consists of a three-stage septic tank that caters for sludge and grease separation, resulting in effluent that is anaerobic. Following the septic tank is a sand filter which serves to stimulate aerobic conditions, after which the greywater is routed to the planter bed. This results in purified water of "near potable-quality". This is reported to be one of the most effective, simple-to-maintain on-site treatment techniques and is recommended where there are significant quantities of food waste in the greywater to be treated.

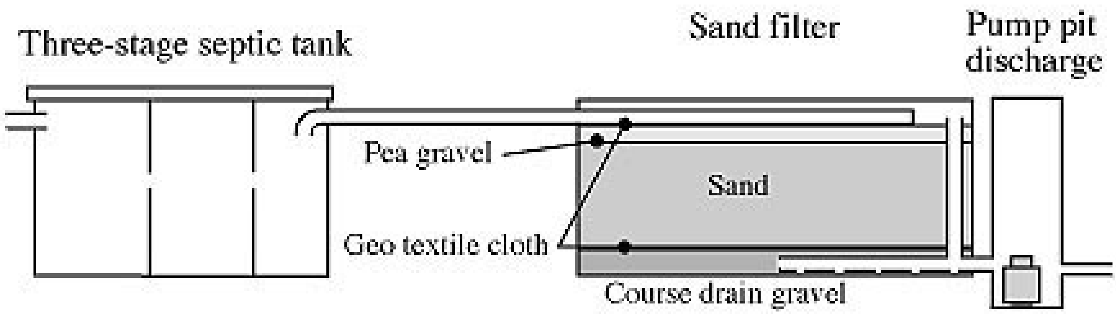


**Figure B10.5: Anaerobic to aerobic pre-treatment system**

## B11. The Greywater Recycling System (GRS)

This is a greywater diversion device that is a gravity-fed primary treatment, distribution and irrigation system (Greywater recycling systems, 2006) which reuses greywater for watering gardens. The system does not store the greywater in any form and is used for immediate disposal of the greywater. The GRS can recycle up to 2000*l* of greywater per day using irrigation areas 70m$^2$ in size. Since it operates on a gravity system the irrigation beds need to be lower than the greywater source points. The system consists of distribution pipes and connectors, outlet housings, an aerobic grease filter and "H" nozzle components.

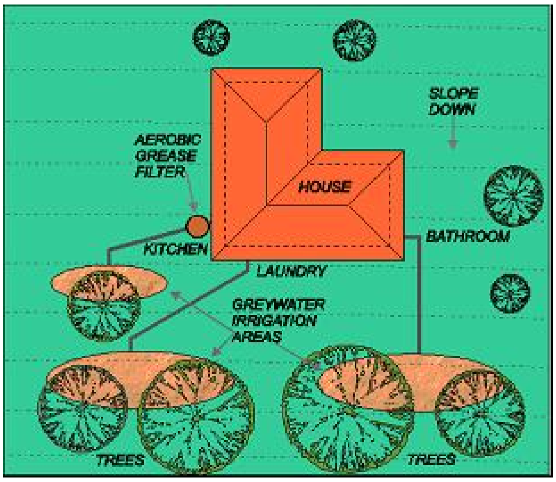


**Figure B11.1: Schematic of Greywater Recycling System (GRS)**

## B12. Water Rhapsody

Similar to the GRS above, this is a pipe network where greywater from the bathroom and washing machine is filtered before entering a pump system (Water Rhapsody, 2006). The greywater is then pumped down a hosepipe from where it is sprinkled onto the garden. One of the features of this system is that there is no storage of the greywater as the pump switches on as soon as there is any flow into the tank.

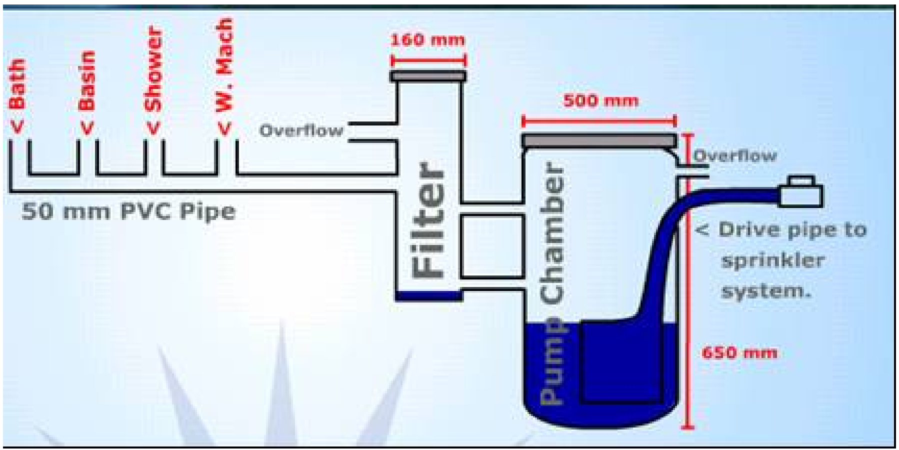


**Figure B12.1: Water Rhapsody**

## B13. Garden Res-Q

Another system similar to Water Rhapsody and GRS, the Garden Res-Q unit (Garden ResQ, 2006) uses greywater from a home bathroom to irrigate a small to medium-sized garden. The unit is connected directly to the outside drain-pipes of an existing bath or shower where the greywater is filtered of hair and lint, and then a low-pressure pump is activated to pump the water through a normal 20mm garden hose as soon as the sump starts filling with the greywater. Once the shower has been turned off or the bath emptied, the pump automatically switches off and ceases the irrigation process until the next bath or shower. A return to sewer mechanism / overflow has been included in the design of the system, and a small percentage of greywater is automatically diverted to sewer during each session, thereby assisting with solid waste removal and keeping rubber seals wet and lubricated.

**Figure B13.1: Garden Res-Q greywater system**

## B14. Tower gardens

The tower garden is a concept that was derived from a project occurring in Kenya (Crosby, 2004). Vegetables are grown in a column of soil surrounding a central stone-packed drain, in a bag usually constructed out of shade cloth. The type of shade cloth used to form the “skin” of this system is important. It was found that in South Africa, shade netting was ideal and could be used in conjunction with nylon string or fishing line to join up the ends to form the cylinder. Each day, greywater is poured on top of the stones so that the flow of water is controlled into the bag and vegetables are planted in holes cut in the sides of the bag.

The system is relatively easy to maintain with some basic irrigation skills. To account for the often-soapy greywater, pouring two buckets of clean water into the column each week clears the system. This system favours the growth of leafy vegetables such as spinach.

**Figure B14.1: Example of a modified tower garden in use in Limpopo province**

# B15. Wattworks Greywater Treatment System

This system (Wattworks, 2006) uses greywater generated from the household to flush one or two toilets in the home. It stores water from the shower or bathroom in a holding tank which discharges excess water to sewer every 24 hours so as to not to cause any offensive smells.

**Figure B15.1: Example of Wattworks installation**

# B16. Earthstar Greywater Systems

The Earthstar system (Realgoods, 2006) essentially consists of a 250*l* holding tank coupled to a greywater treatment system which is a simple sand filter with backwash cleaning. The irrigation cycle begins once the greywater reaches a certain level in the tank and a float switch activates a centrifugal pump. A simple 5-minute backwash cleaning process every 2 months is included in the design to keep the filter operating efficiently

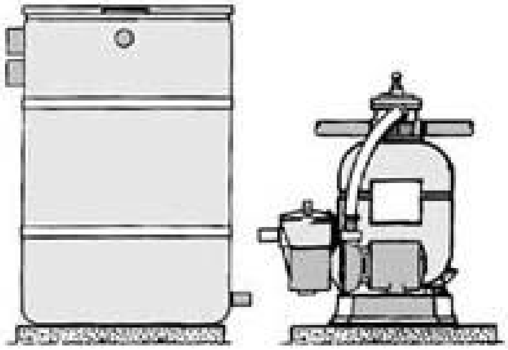

**Figure B16.1: Simple schematic of Earthstar greywater system**

## B17. Casa Juliana Kitchen Greywater System

This system (Casa Juliana, 2006) has been designed to treat kitchen greywater and consists of a distribution hub from a 25*l* cement bucket and a 15mm PVC pipe which distributes the greywater to six small infiltration chambers. The kitchen greywater first passes through an interceptor which traps grease and fats before it is used for irrigation purposes.

**Figure B17.1: Grease interceptor**

**Figure B17.2: Six pipes to distribute the greywater**

**Figure B17.3: Distribution hub**

**Figure B17.4: Detail of infiltration chamber at end of pipes**

## B18. Niimi Absorption Trench System

Greywater is led through a pipe to a collection tank where a distribution box feeds the absorption trenches (Rotaloo, 2006). The trenches are lined with 0.2mm thick heavy duty polyethylene and consist of inert mediums such as coarse gravel, shells, plastic etc. which are used for biological treatment of the greywater. The lengths of the trenches are designed on the volumes of water consumed by the household as well as the soil type in the area. These trench systems should not be used where the water table is less than 1.3m below surface level.

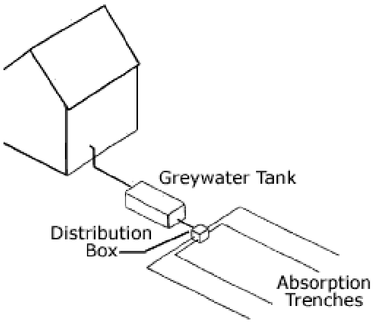


**Figure B18.1: Typical layout of Niimi system**

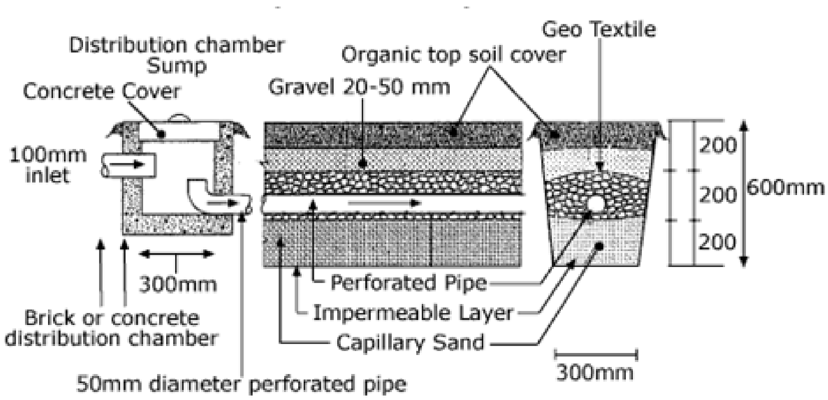


**Figure B18.2: Section through Niimi absorption trench system**

# Appendix C

## Health aspects of greywater use

**Jo Barnes**

# Health aspects of greywater use

## C1 Introduction

The urbanisation accompanying growing populations is increasing the demand for water supply in communities throughout the world, and the water resources for many cities are already proving inadequate. Accessing additional water sources is inherently costly and other water users (rural communities, industry and agriculture) may have competing water demands or water rights.

Water conservation, particularly through demand management, may delay the need for additional sources for a limited period. One approach that holds much promise in theory has been the reclamation of wastewater produced by communities themselves for non-potable uses such as landscaping, food and ornamental gardening, cooling, toilet flushing, etc.

Use of household greywater may be technically feasible, but a crucial consideration in decisions about implementation is risk. The use of domestic wastewater (greywater) to replace other water sources for irrigation is highly dependent on whether the health and environmental impacts entail risks that are acceptable or not. Contrary to common belief, greywater is not a 'safe' or harmless substance – it contains bacteria, viruses and other potential pathogens (organisms able to cause disease in humans or animals). Consequently, the potential reuse of greywater is as much a public health issue as it is a water conservation priority (Okun, 2000).

The species and total counts of the micro-organisms found in greywater vary widely according to *inter alia*, climatic conditions, season, available sanitation technology, sanitation habits of the people living in the communities and the disease incidences of the area (Palacios *et al*, 2001). This makes it difficult to categorise the microbiological quality of greywater from certain types of settlements.

## C2 Summary of health-impact guidelines (Australia and USA)

In light of the lack of any code of practice for the use of greywater in South Africa, it is useful to summarise the main health-impact guidelines in the regulations used by two of the world leaders in greywater use, namely Australia (State of Victoria, 2003) and the United States of America (Water Conservation Alliance of Southern Arizona, 2003). These restrictions highlight the health risks discussed below:

- Water that has come into contact with a toilet, urinal or a toilet fixture such as a bidet should never be used as greywater.
- Water that has been used to wash nappies or other clothing soiled by faeces and/or urine should not be used as greywater.
- Water from the kitchen sink or used in the kitchen to wash dishes or food should not be used (it is too highly contaminated with grease, bacteria, blood and chemicals).

- Greywater should not be allowed to leave the boundaries of the property on which it is generated and should under no circumstances be allowed to enter the stormwater system. Therefore, it is imperative that provision be made for the safe disposal of excess greywater into the sewerage system during rain periods or when too much greywater is produced for the garden to absorb. This provision should be "fail-safe", in other words even if the greywater system malfunctions or blocks, the greywater should not under any circumstances contaminate freshwater lines.
- Greywater should never be allowed to pond or pool where mosquitoes and other insect vectors of disease can breed. Such pools will also very quickly develop a foul smell.
- Greywater should never be applied to edible crops – especially not to vegetables eaten raw or lightly cooked, such as in salads. It should also be avoided for root crops such as carrots, since the pathogens accumulate in the topsoil.
- Greywater should be withheld from areas where children play, such as lawns. Children are the highest risk group with respect to contracting infections from greywater.
- Water used to wash animals such as domestic pets should not be used as this has too high a concentration of organisms able to cause disease.
- Warm greywater should be stored in a holding tank to cool down and should be used within 24 hours; otherwise the bacterial load will rise too high for safety. This tank should be classified as a septic tank and all the regulations for septic tanks should apply to such a system.
- Do not use greywater if anybody living on the premises is suffering from diarrhoea, ear or skin infections.
- Keep children and pets away from areas that are irrigated with greywater and under no circumstances allow them to drink this water.
- Preferably use only 'low risk' greywater – e.g. warm-up water from the hot taps, rinse water, bath or shower water.
- Take careful note of the slope of the soil to be watered to avoid greywater run-off into water courses, swimming pools or dams.
- Evidence indicates that the microbes in greywater have higher survival rates in topsoil. Always use subsurface irrigation or irrigation under a heavy mulch cover. Never hose, spray or mist with greywater.
- People living on the premises where gardens are irrigated with greywater should be encouraged to wash their hands without fail before eating or drinking.

## C3 Overall health impacts of poor water supply and sanitation

The health hazards of poor water supply and sanitation are manifold, but one of the major indicators used worldwide is the incidence of diarrhoea. According to the WHO Global Health Statistics (Harvard School of Public Health, 1996), an incidence rate of 77,344 cases of diarrhoea per 100,000 occurred worldwide in 1990, which caused 2.9 million deaths or a mortality rate of 56 per 100,000, mostly among children under the age of 5 years. These deaths represent approximately 15% of all child deaths under the age of 5 years in developing countries. A thorough review of water, sanitation and hygiene intervention studies found that the provision of water and sanitation services reduces diarrhoeal disease on average by between 25% and 33.3% (Esrey *et al*, 1991).

Attempts were made to try and obtain recent South African health clinic data on waterborne diseases or incidences of diarrhoea but it was only possible to get limited information at district level for typhoid and cholera cases (Section D10). While these numbers certainly give an indication of the impacts of poor water supply and sanitation on these communities (as evidenced by the typhoid outbreak in Delmas in 2005), the specific impacts from greywater disposal, particularly in densely-populated areas, could not be determined.

# C4 Common contaminants in greywater

Greywater contaminants vary from house to house and depend amongst other factors on the number of persons living in the house, their lifestyles and their ages. Households with babies or small children produce greywater with higher faecal counts, as do households with pet animals (especially if the pets are bathed or washed on the premises). Households with inhabitants suffering from acute diseases such as gastroenteritis, eye or ear infections, or waterborne hepatitis (jaundice) can produce greywater with considerable loads of bacteria or viruses during the course of the illness. Households with persons living with a chronic infectious condition (e.g. HIV/AIDS, tuberculosis) may also produce greywater with increased infection risks over the long term as these individuals have severely compromised immune systems and are likely to have secondary infectious conditions.

Even greywater from which water from the kitchen sink has been excluded contains appreciable amounts of soaps and detergents, fabric softener, shampoo, hair conditioner, toothpaste, medicines, disinfectants, food particles, pesticides, dyes, cosmetics (make-up), lint and other fibres. Human waste products such as saliva, sweat, body oils, hair, blood, and some urine and faecal matter are additional sources of contamination.

Examples of pathogens (microbial organisms able to cause disease) that could typically be present in greywater are listed in Table C1. The diseases caused by such pathogens are mainly gastroenteritic diseases, skin infections and eye and ear infections. Among the viral pathogens, hepatitis viruses (causing jaundice) also feature prominently. In endemic areas, diseases such as cholera and schistosomiasis (bilharzia) can also pose a serious risk. In Table C2 some of the major waterborne pathogens are listed according to their significance to health. Health significance can be judged from their persistence in water, their resistance to disinfection by chlorine and the relative dose needed to cause infection. Some examples of organisms causing diseases other than gastrointestinal ones that are associated with casual contact with water appear in Table C3.

It must be borne in mind that once a communicable infection has taken hold in a few individuals from a contaminated water source, it can spread by means of person to person contact or as airborne or foodborne infection (depending on the pathogen). After the initial contact, water does not have to be the only vector. If greywater is used on a wide scale by thousands of homes, incidents of accidental ingestion and contamination will inevitably occur, especially if supervision of the adherence to safety precautions is not conscientiously carried out (Mitakakis *et al*, 2004). Thus the potential for waterborne diseases will inevitably rise under such circumstances and public health authorities should be aware of this. One of the points in a well-planned greywater policy should be a decision on what frequency of contamination incidents and/or water-related diseases constitute a sufficient level to sound the alarm for the re-assessment of the continued use of greywater in that community.

**Table C1: Examples of pathogens associated with faecal contamination and poorly treated wastewater**

| Pathogen class | Examples | Disease |
|---|---|---|
| Bacteria | *Shigella* species | Baccillary dysentery |
| | *Salmonella* sp. | Salmonellosis (gastroenteritis) |
| | *Salmonella typhi* | Typhoid fever |
| | Enteropathogenic *E. coli* | Variety of gastroenteritic diseases |
| | *Yersinia* sp. | Yersiniosis (gastroenteritis) |
| | *Campylobacter jejuni* | Campylobacteriosis (gastroenteritis) |
| Viruses | Hepatitis A virus | Infectious hepatitis |
| | Norwalk viruses | Acute gastroenteritis |
| | Rotaviruses | Acute gastroenteritis |
| | Polioviruses | Poliomyelitis |
| | Coxsackie viruses | "Flu-like" symptoms |
| | Echoviruses | "Flu-like" symptoms |
| Protozoa | *Entamoeba histolytica* | Amoebiasis (amoebic dysentery) |
| | *Giardia lamblia* | Giardiasis (gastroenteritis) |
| | *Cryptosporidium* sp. | Cryptosporidiosis (gastroenteritis) |
| Helminths | *Ascaris* sp. | Ascariasis (roundworm) |
| | *Taenia* sp. | Taeniasis (tapeworm) |
| | *Necator americanus* | Ancylostomiasis (hookworm) |
| | *Trichuris trichuria* | Trichuriasis (whipworm) |

**Table C2: Orally transmitted waterborne pathogens and their significance in water extracted from WHO Guidelines for Drinking Water Quality, (1993)**

| Pathogen | Health significance | Persistence in water supplies[a] | Resistance to chlorine[b] | Relative infective dose[c] |
|---|---|---|---|---|
| **Bacteria** | | | | |
| *Campylobacter jejuni, C. coli* | High | Moderate | Low | Moderate |
| Pathogenic *E. coli* | High | Moderate | Low | High |
| *Salmonella typhi* | High | Moderate | Low | High |
| Other *Salmonellae* | High | Long | Low | High |
| *Shigella* spp. | High | Short | Low | Moderate |
| *Vibrio cholerae* | High | Short | Low | High |
| *Yersinia enterocolitica* | High | Long | Low | High |
| *Pseudomonas aeruginosa* | Moderate | May multiply | Moderate | High (?) |
| *Aeromonas* spp. | Moderate | May multiply | Low | High (?) |
| **Viruses** | | | | |
| Adenoviruses | High | ? | Moderate | Low |
| Enteroviruses | High | Long | Moderate | Low |
| Hepatitis A | High | ? | Moderate | Low |
| Enterically transmitted non-A, non-B hepatitis viruses, hepatitis E | High | ? | ? | Low |
| Norwalk virus | High | ? | ? | Low |
| Rotavirus | High | ? | ? | Moderate |
| Small round viruses | Moderate | ? | ? | Low (?) |
| **Protozoa** | | | | |
| *Entamoeba histolytica* | High | Moderate | High | Low |
| *Giardia intestinalis* | High | Moderate | High | Low |
| *Cryptosporidium parvum* | High | Long | High | Low |

[a]Period detected in water at 20ºC – Short: up to 7 days, Moderate: 7-30 days, Long: >30 days

[b]Water treated at conventional doses and contact times - moderate resistance means that organisms are not completely destroyed

[c]Dose required to cause infection in 50% of healthy adult volunteers. May be as little as 1 infective unit for some viruses.

**Table C3: Examples of organisms causing non-gastrointestinal illnesses associated with recreational or casual contact with water**

| Health problem | Examples of Causes |
|---|---|
| Skin diseases | *Pseudomonas aeruginosa*<br>Atypical mycobacteria<br>*Staphylococcus epidermidis* |
| Respiratory diseases | Viruses, especially adenovirus<br>Environmental mycobacteria, especially *Mycobacterium avium* complex (causing lung disease, particularly in immuno-compromised persons)<br>*Klebsiella pneumoniae* |
| Ear infections | *Pseudomonas aeruginosa*<br>*Staphylococcus aureus* |
| Liver or kidney diseases | *Leptospira* species<br>Various hepatitis viruses |
| Eye infections | *Pseudomonas aeruginosa*<br>*Acanthamoeba* species |

# C5 Risks to humans

A growing body of evidence indicates that the greatest risk of infection for enteric pathogens is borne by persons less than 19 years of age (Nwachuku & Gerba, 2004). Children are more likely to become ill from the consumption of contaminated water and from exposure via recreational activities. This may be because their immunological, neurological and digestive systems are still developing and/or because they are environmentally more exposed. Persons with compromised immune systems or those who suffer from other health conditions are also at increased risk. Old people, pregnant women, patients suffering from HIV/AIDS, tuberculosis, malnutrition and other chronic diseases also fall into this category. In South Africa this collection of people comprises a sizeable proportion of the population.

# C6 Risks to edible crops

Using greywater to irrigate edible crops, especially vegetables and fruits eaten raw or after minimal processing, is unsafe. Greywater emanating from non-sewered areas (and particularly densely populated informal settlements) is not suitable for the irrigation of edible crops except in times of such severe food shortage where the risk of disease becomes less than the risk attached to compromised food supplies (a very rare occurrence). There is also a large body of evidence showing bacterial transmission from greywater or other wastewater to food crops and livestock kept for slaughter (Petterson & Ashbolt, 2001; Fasciolo *et al*, 2002; Sadovski *et al*, 1978).

Petterson & Ashbolt (2001) found that clumping of viruses on lettuce and carrots irrigated with wastewater occurs with subpopulations of viruses showing high persistence also occurring under these circumstances. These factors may cause the risks associated with such contamination to be under-estimated.

Fasciolo *et al* (2002) carried out experiments in Mendoza, Argentina to assess the sanitary acceptability of crops irrigated with treated wastewater. Garlic irrigated with wastewater only reached sanitary acceptability 90 days after harvest once the roots and soil were removed. Onions cleaned immediately after harvest reached sanitary acceptability 55 days after harvest and none of the irrigated crops were fit to consume raw at harvest. In some greywater advisory documents (some of those that are written from an engineering perspective) the user is only advised to withhold irrigation with greywater for one week before harvesting root crops (e.g. Marshall, 1997). This is not considered to be scientifically justifiable advice.

Sadovski *et al* (1978) investigated the levels of microbial contamination of vegetables irrigated with wastewater by the drip method. They could show that irrigation carried out under plastic sheeting or buried under the soil surface significantly reduced crop contamination. Unfortunately they also found that microbial contamination persisted in the irrigation pipes for at least 8 days and in the soil for at least 18 days.

Abdul-Raouf *et al* (1993) investigated the ability of *Escherichia coli* O157:H7 (a serious pathogen which causes disease with a high mortality rate) to survive or grow on raw salad vegetables. This was done to study the fate of such organisms should the crops become accidentally contaminated before harvest and consumption. It was found that populations of viable *E. coli* O157:H7 declined on raw salad vegetables stored at 5°C, but increased on vegetables stored at 12°C and 21°C (conditions such as would occur in ordinary shelf storage).

## C7 Survival of pathogens in the environment

The ability of pathogenic organisms to survive in soil, in water and on surfaces has important implications for the production of safe food and for the health of humans and animals.

Maule (2000) investigated the survival of *E. coli* O157:H7 in various settings such as river water, different soil cores and stainless steel and plastic surfaces. Survival of the organisms was greatest in soil cores under rooted grass. Under these conditions a moderate decline occurred only after 130 days. The organism survived less readily in river water, where it fell to undetectable levels after 27 days. Air-dried deposits of the organism survived on stainless steel surfaces for periods in excess of 60 days. It was most stable at chill temperatures (4°C) and viability was only partially reduced at 18°C. The organism was also shown to survive for extended periods on plastic domestic food cutting boards at both chill and room temperatures. These data indicate the ability of some serious pathogens to persist in the environment beyond the expectations of some engineers and other advisors on greywater use projects!

Malkawi & Mohammad (2003) looked at the survival and accumulation of micro-organisms in soils with secondary treated wastewater as their source of pathogens. They irrigated soil samples with an amount of water equivalent to 100% of the Class A Pan evaporation reading, and some samples to 125% of the Class A Pan reading. The bacteriological analyses showed that the total coliform count was highest on the soil surfaces.

They stated that the results "strongly suggest the necessity to treat wastewater effluents to an extent to which no or very few residual bacterial contaminants will be detected". In practice these results could be obtained with contaminated greywater as well and therefore the recommendation should be borne in mind by proponents of unrestricted application of greywater in home gardens.

## C8 Note on outcome assessment in greywater reuse projects

One of the most frequently suggested ways of assessing the success of water and sanitation improvement schemes is to determine whether the prevalence of diarrhoea in the community has been reduced. Although instinctively persuasive, this is not a good outcome variable to use in such assessments in practice. After the initial contamination of water by waterborne pathogens, the environment very quickly becomes polluted by the movement of affected persons and animals, contamination carried around on the soles of feet and shoes, contaminated water wetting ever-increasing areas and the spread of person-to-person infection. An ever-widening circle of affected surfaces and people results, until the outbreak starts to wane, which can take some time.

In chronically polluted areas, there is a background level of endemic disease that takes a long time to dissipate; in keeping with the slow decreases in pathogen levels of pockets of affected surfaces, water pools, etc. The level of endemic diarrhoea in such a community (especially if it is an impoverished one) drops far more slowly than the outcome assessment that the intervention project usually allows for. If such levels are measured too soon after the intervention (within a few months or even sometimes a few years), no noticeable difference in diarrhoea prevalence will be recorded, leading to the erroneous conclusion that the intervention "did not work". The study by Kirchhoff *et al* (1985) serves as an example. A study of chlorinating household raw water in clay pots in rural Brazil was carried out while using diarrhoea incidence as the outcome variable. Diarrhoea incidence was recorded in households where water was treated and where it was left untreated. Although the treated drinking water was significantly less contaminated by pathogens, they did not find a reduction in diarrhoea incidence between those using treated vs. untreated water during the study period. In other words the treatment was successful but it was not reflected in the way they wanted to measure the outcome. They concluded that an intervention such as the one in their study may affect disease rates only when other factors related to faecal-oral transmission are ameliorated *at the same time*. These realities need to be recognised by funding organisations and project leaders in their planning of health impacts of water-related projects and their assessment of the outcomes of such projects.

## C9 Summary

Critics of overly restrictive policies for greywater reuse feel that rigid rules discourage home owners and especially the urban poor from utilising greywater as a resource. Unfortunately, making the use of greywater unrestricted (especially if there is no education about risks and no supervision) will increase the disease burden on those who can least afford it. According to the latest HIV survey by the Department of Health nearly 40% of women in South Africa between the ages of 25 and 29 years are HIV-positive. These women are in their peak childbearing years. They are also in the age and gender categories most likely to be involved in child care as well as cooking and cleaning, where most of the household greywater is generated. In impoverished areas they are also often involved in subsistence gardening, thereby coming into contact with polluted water (grey or otherwise). HIV infection damages the immune system and environmentally acquired infections can shorten the life expectancy of such persons. Greywater poses a much greater risk to those people than to the generally healthy, well-fed population of a First World country where much of our experience of greywater use originates.

In South Africa the advantages brought by extra food supplies generated using greywater in impoverished areas should be balanced against the risks of infection in vulnerable groups such as malnourished children and HIV positive persons. Achieving a balance in these special circumstances will be no easy task and the regulatory agencies should consult widely and debate wisely before they officially sanction the use of greywater. Key aspects of this would of necessity be the *education* that is crucial for the safe handling and use of greywater and the *supervision* of adherence to essential safety precautions (including personal hygiene practices).

There is an urgent need for research into the actual wastewater quality produced by low-income urban communities in South Africa and the health risks posed by such water. South Africa faces the conflicting demands of improving access to water for a large proportion of its inhabitants, while at the same time trying to improve the health of the population by reducing the risk of disease from dirty, polluted environments. This conflict needs to be very carefully weighed by the many stakeholders and affected public services before a decision on the widespread use of greywater in an unrestricted and unsupervised way is encouraged publicly. Okun (2000) stated that greywater use may be feasible, but “it imposes added public health risks that need to be accepted only as a last resort”. It should be a subject for careful consideration of actual risks and wide consultation of affected persons before a decision is made on when that point of last resort is.

# C10 Recent incidence of waterborne disease in South Africa

The following tables showing incidence of waterborne disease were sourced from the Epidemiology & Surveillance Directorate, National Dept. of Health (C = Cases, D = Deaths).

## C10.1 Cholera

| Province | 2001 | | 2002 | | 2003 | | 2004 | | 2005 | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | D | C | D | C | D | C | D | C | D | |
| Eastern Cape | 0 | 0 | 2335 | 45 | 3141 | 38 | 740 | 4 | 0 | 0 | 6216 |
| Gauteng | 0 | 0 | 24 | 2 | 4 | 0 | 1 | 0 | 0 | 0 | 29 |
| KwaZulu-Natal | 1831 | 16 | 15339 | 71 | 579 | 0 | 6 | 0 | 0 | 0 | 17755 |
| Mpumalanga | 0 | 0 | 4 | 1 | 176 | 7 | 1773 | 29 | 0 | 0 | 1953 |
| Limpopo | 0 | 0 | 465 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 465 |
| Western Cape | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Total | 1831 | 16 | 18167 | 121 | 3901 | 45 | 2520 | 33 | 0 | 0 | 26419 |

## C10.2 Typhoid

| Province | 2001 | | 2002 | | 2003 | | 2004 | | 2005 | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | D | C | D | C | D | C | D | C | D | |
| Eastern Cape | 33 | 1 | 16 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 53 |
| Gauteng | 4 | 0 | 12 | 0 | 0 | 0 | 3 | 0 | 40 | 0 | 59 |
| KwaZulu-Natal | 22 | 0 | 10 | 0 | 5 | 0 | 33 | 0 | 28 | 0 | 98 |
| Mpumalanga | 0 | 0 | 24 | 0 | 1 | 0 | 0 | 0 | 590 | 0 | 615 |
| Limpopo | 179 | 11 | 110 | 5 | 89 | 1 | 21 | 8 | 33 | 0 | 432 |
| Western Cape | 12 | 0 | 0 | 0 | 4 | 0 | 2 | 0 | 0 | 0 | 18 |
| Total | 250 | 12 | 172 | 5 | 101 | 1 | 60 | 8 | 691 | 0 | 1275 |

## C10.3 Typhoid Fever cases by district, 2000 – 2005:

### 1. Eastern Cape

| Magisterial district code | District | No. of cases |
|---|---|---|
| 3406 | Libode | 1 |
| 3408 | Ngqeleni | 6 |
| 3410 | Port St. Johns | 21 |
| 3412 | Cofimvaba | 1 |
| 3414 | Tsomo | 2 |
| 3415 | Umtata | 7 |
| 3416 | Willowvale | 7 |
| 3417 | Cala | 1 |
| 3418 | Lady Frere | 3 |
| 3703 | Cathcart | 2 |
| 3711 | Victoria East | 1 |
| 3713 | Peddie | 1 |
| 3801 | East London | 2 |
| 3803 | Mdantsane | 1 |
| 4301 | Port Elizabeth | 2 |
| 4402 | Graaff Reinet | 1 |
| Total | | 59 |

### 2. Gauteng

| Magisterial district code | District | No. of cases |
|---|---|---|
| 7301 | Germiston | 2 |
| 7302 | Alberton | 4 |
| 7303 | Boksburg | 10 |
| 7304 | Kempton Park | 18 |
| 7305 | Benoni | 6 |
| 7401 | Brakpan | 2 |
| 7602 | Cullinan | 1 |
| 7801 | Pretoria | 1 |
| 7900 | n/a | 11 |
| 7901 | Johannesburg | 2 |
| 7902 | Randburg | 7 |
| Total | | 62 |

## 3. Mpumalanga

| Magisterial district code | District | No. of cases |
|---|---|---|
| 6101 | Highveld Ridge | 2 |
| 6104 | Delmas | 590 |
| 6501 | Nelspruit | 1 |
| 6601 | Nsikazi | 1 |
| 6602 | Barbeton | 22 |
| 6603 | Witrivier | 1 |
| 6606 | Nkomazi | 4 |
| 6607 | Eerstehoek | 4 |
| Total | | 625 |

## 4. KwaZulu-Natal

| Magisterial district code | District | No. of cases |
|---|---|---|
| 4701 | Umbumbulu | 1 |
| 4702 | Umlazi | 1 |
| 4802 | Pinetown | 3 |
| 4803 | Inanda | 2 |
| 4804 | Chatsworth | 15 |
| 5001 | Mahlabatini | 1 |
| 5101 | Pietermaritzburg | 23 |
| 5201 | Camperdown | 1 |
| 5202 | Ixopo | 6 |
| 5203 | Umzintoti | 1 |
| 5301 | Port Shepstone | 3 |
| 5401 | Mount Currie | 14 |
| 5601 | Kliprivier | 11 |
| 5603 | Estcourt | 1 |
| 5701 | Newcastle | 31 |
| 5703 | Dannhauser | 2 |
| 5705 | Glencoe | 2 |
| 5904 | Eshowe | 5 |
| 5905 | Mtunzini | 1 |
| 6001 | Hlabisa | 2 |
| Total | | 126 |

## 5. Western Cape

| Magisterial district code | District | No. of cases |
|---|---|---|
| 0101 | Cape | 1 |
| 0102 | Wynberg | 1 |
| 0103 | Simon’s Town | 1 |
| 0106 | Mitchells Plain | 5 |
| 0202 | Kuilsrivier | 7 |
| 0301 | Caledon | 2 |
| 0302 | Hermanus | 2 |
| 0304 | Swellendam | 2 |
| 0601 | Worcester | 1 |
| 0701 | Malmesbury | 3 |
| Total | | 25 |

## 6. Limpopo

| Magisterial district code | District | No. of cases |
|---|---|---|
| 1010 | | 7 |
| 1030 | | 22 |
| 1040 | | 58 |
| 2020 | | 2 |
| 2030 | | 4 |
| 2050 | | 5 |
| 3020 | | 153 |
| 3030 | | 4 |
| 3040 | | 74 |
| 3050 | | 7 |
| 3060 | | 4 |
| 4030 | | 5 |
| 4040 | | 94 |
| 4050 | | 10 |
| 5020 | | 1 |
| 6010 | | 9 |
| 7405 | | 4 |
| 7603 | | 1 |
| Total | | 464 |

# Appendix D

## Case studies

# D1. Western Cape site surveys

The selection of sites in the Western Cape Province (WC) was a process that developed over time, culminating in a procedure for site selection that could be used for the remainder of the country. Similarly the survey methodology was also refined during the course of the WC study, including the survey questionnaire which was tested and finalised at the same time.

Eight sites were chosen for surveys in the Western Cape (Figure D1.1). Clanwilliam and Redhill were selected as the first sites to test the pilot questionnaire and familiarise the researchers with the problem of greywater management in non-sewered areas. Clanwilliam was chosen because the University of Cape Town (UCT) field station is located near the informal settlement of Khayelitsha, and it has been the focus of ongoing anthropology and archaeology research for a number of years. Redhill was selected based on the fact that it is an easily-accessible settlement relatively close to UCT.


**Figure D1.1: Locality map of Western Cape province showing selected sites for surveys**

In order to select further sites for the WC province, settlements were visited along a transect from Saldanha Bay and Vredenburg on the west coast of the WC, through to Kleinmond on the south coast. Field observations were taken at six sites along this transect with particular attention being given to the proximity of these sites to sensitive environments such as wetlands, rivers or natural vegetation. From this it was determined that Fairyland in Paarl and the informal settlement in Kleinmond were two sites where the potential health and environmental impacts of greywater could be high. Two further second round sites, one on the Cape Peninsula and one on the Cape Flats were also selected for sampling and surveys because of their potential impacts on wetlands (Masiphumelele) and on groundwater (Sweet Home Farm).

The two final sites chosen (Khayelitsha RR and Lingelethu, Malmesbury) were identified through the use of Census 2001 data, and after discussions with the relevant local authorities. Khayelitsha RR was chosen as an example of a dense settlement and Lingelethu as an example of an informal settlement with limited services on the edge of an RDP development.

## D1.1 Khayelitsha, Clanwilliam

### D1.1.1 Background

Clanwilliam was one of the earliest colonial settlements in South Africa and thus has a very long history of continuous habitation. The climate is typical of the Cape – winters that are cold and wet, and hot, dry summers (with temperatures reaching 40°C at times). The main economic activities are agriculture and tourism with the rooibos tea industry being the most important. Vineyards and citrus farms also provide seasonal employment to hundreds of unskilled workers, many of whom reside in Khayelitsha. Given the seasonal nature of agricultural work, the farm workers suffer periods of unemployment and poverty which compels them to seek work elsewhere. Population figures are thus heavily influenced by the season and there seems to be a general growth in the numbers of low-income Xhosa, Sotho and Tswana speaking migrant workers into the predominantly Afrikaans-speaking town (mainly coloured and white population).

As with the rest of the country, the system of social stratification and access to resources, including water, reflects the old hierarchies. The new arrivals to the town are also the ones most likely to have insufficient access to services. In August 2004 there was some conflict between Sotho speakers and Xhosa speakers in the migrant farm-labour community, which resulted in shacks being destroyed. This conflict highlighted the competition for work and other resources, including water. The increase in the population has been mainly due to migration, predominantly among the economically active age groups 15 – 34 and 34 – 65, with many of these in the low-income groups earning R2,400 or less per annum. The challenges of poverty have put tremendous pressures on the Cederberg Municipality’s resources as the numbers of disabled people and those living with HIV/AIDS have also increased.

Minimal water, sanitation and refuse collection services have been supplied to Khayelitsha and although the water supply is fairly reliable, sanitation and refuse collection services are less efficient. Four flush toilets have been made available in the settlement, but there is no drainage system for the greywater and the communal flush toilets do not function efficiently. Most residents have thus resorted to using the surrounding bush as their toilet. Greywater thrown out of buckets and basins is just left to flow down the slope into make-shift furrows, adding to the runoff from the standpipes. It then either evaporates in the sun or forms stagnant puddles, which cause odours and contribute to unsanitary living conditions in the settlement.

Prospects for the Khayelitsha community appear to lie with future access to RDP housing, but the informal settlements have grown at a much faster pace than the stock of RDP houses. It would seem therefore that although official planning focuses on providing waterborne sanitation, electricity and other basic services to as many people as possible, as per government policy, there may well be a need to develop alternative methods of providing water and sanitation to (upgraded) informal settlements which will incorporate a methodology for the strategic management of greywater.

### D1.1.2 Description of research

Groups of social anthropology students spent a day interviewing men and women in different households who were willing to answer questions on water use and greywater management. There was no structured sampling and the main aim was to get as many diverse viewpoints as possible. An average household water consumption of 65*l* per day (*l*/d) was estimated based on the replies to questions on water consumption.

**Figure D1.2: Greywater stream, Clanwilliam**

**Figure D1.3: Litter at Clanwilliam**

### D1.1.3 Social findings

There do not seem to be any significant water use practices that are influenced by cultural or religious beliefs. Socio-economic circumstances however show that income influences the amount of water used, types of detergents, frequency of laundry and amount of greywater generated. The low incomes, high unemployment levels and seasonal character of the work make the Khayelitsha, Clanwilliam community different from informal settlements in and around the city of Cape Town. The overall impact of the community on the environment is limited given the relatively small amounts of water used, greywater produced and dry climate that prevents buildup of stagnant water.

### D1.1.4 Water quality

No water quality data was captured during this early survey.

### D1.1.5 Concluding remarks

This was the first field trip undertaken and was therefore exploratory in nature, providing an opportunity for the research team to finalise the methodology, and pilot the survey questionnaire for further site visits.

## D1.2 Redhill

### D1.2.1 Background

The Redhill informal community in Simonstown dates back to the 1980s when people employed at the Kogelfontein road works and at the Cape of Good Hope Nature Reserve (Silvermine) set up a squatter settlement after failing to find accommodation in Simonstown. Plans to resettle them at Masiphumelele (Noordhoek) were rejected on the grounds that it was too far from their workplace. The original settlement was on Cape Farm 1404 – this was privately owned by a Mr. Kopfer who was compensated for the use of his land by the Provincial Administration of the Western Cape (PAWC). In 1995 there were 122 structures at Redhill – in the last ten years this figure has increased to over 200 structures, spread over three distinct camps.

The Redhill settlement is built on a slope surrounded by rocky National Park land covered in fynbos. The Redhill Road, a paved route between Simonstown and the small town of Scarborough, marks the upper boundary of the camp. Tall eucalyptus and Chilean pine trees shelter the settlement and provide firewood. Several steep rocky areas have prevented the construction of homes in certain vicinities and have created wooded natural patches dividing the settlement into camps. The lower camp consists of only a handful of houses and is significantly quieter than the rest of Redhill. The middle camp is the most populous area of the settlement with residents that are mostly Xhosa-speaking and come from the former Ciskei and Transkei regions of South Africa. The upper camp has about 25 houses and residents here are Afrikaans-speaking and are mostly “coloured.”

Redhill is relatively small and not as densely populated as most other informal settlements. It has what appears to be an effective political and administrative regime that prevents new settlers from putting up more shacks. Plans exist for the future development of formal township housing in Simonstown but this will in all likelihood exclude the unemployed and so although the Redhill informal settlement may not be allowed to expand, it nevertheless might continue to exist for much longer than planned in order to accommodate those who will not be able to afford formal housing.

Redhill has sandy, relatively infertile soils and receives large amounts of rainfall. These factors together appear to have an impact on Redhill water use and wastewater management practices. Present services in the settlement comprise pit latrines and communal tapstands from 5 water tanks, which are connected to a constant supply. Some of these services were initially financed by PAWC while RDP funding was later acquired by Simonstown to extend and improve the services (basic refuse removal services are also provided but are not very efficient). The residents of the settlement pay a flat rate to the municipality for water supply and refuse removal. The City of Cape Town (CoCT) has recently installed 10 urine diversion (UD) toilets at Redhill as part of a pilot study to test the efficiency of the new sanitation technology; however this will not impact on greywater management in the settlement as there is still no means of greywater disposal.

There has been little change in Redhill since it was established more than twenty years ago. Most important is the fact that the community has not been allowed to grow significantly. Damage to the environment, including water related pollution therefore appears very low if not insignificant due to the relatively low population density.

### D1.2.2 Description of research

Building on the pilot study conducted in Clanwilliam, the Redhill survey was more focused in its combining of social and environmental aspects of water use and greywater disposal. Samples of the greywater were taken and the women who were in charge of the laundry and kitchen duties were asked direct questions about the detergents and other chemicals that they used as well as details about how they used and re-used the water before discarding it as waste. From this it was ascertained that households used on average about 75*l*/d.

**Figure D1.4: Tapstand at Redhill**

**Figure D1.5: Clothes washing at Redhill**

### D1.2.3 Social findings

For all its well organized political lobbying, Redhill is a much-divided community, which is more likely to respond to household, rather than community-level interventions. Redhill residents share little and have shown no communal spirit in tackling problems like leaking water pipes for example.

When asked what they would like to see change in their lives both the Clanwilliam and Redhill residents prioritized ‘proper houses’ which have electricity and waterborne sanitation. These concerns are seen as the most pressing needs in resident’s lives. The functioning and malfunctioning of water supply is a daily frustration, however in both settlements the municipalities provide clean water on a daily basis. In the long run, greywater recycling may be essential for managing the drought-prone region's water supply and alleviate the mild concerns over wastewater on the ground, but this is not the main worry of the people in these settlements.

### D1.2.4 Water quality

Tests were conducted (on two separate sampling trips) on greywater generated from laundry washing for the purpose of establishing water quality and in an attempt to define the nature of greywater. Results showed a wide range of values with respect to Chemical Oxygen Demand (COD), Total Phosphorous (P), Sodium (Na), Total Kjeldahl Nitrogen (TKN), and Oil and Grease. Of concern were the high levels of these constituents that have the potential to impact on aquatic systems and downstream users should this water infiltrate into groundwater or flow into other water bodies. In addition, the level of faecal coliforms (greater than 1800 counts/100ml) is further cause for concern. High levels of faecal contamination are often associated with the washing of children's nappies but in this case, no nappies were observed in any of the containers where laundry water was sampled.

**Table D1.1: Redhill water quality indicators (15 June 2004)**

| Water quality indicator | Tapstand | Sample number | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1A | 3 | 4A | 4B | 5A | 5B |
| COD (mg/l) | 16.1 | 226 | 1161 | 2128 | 2041 | 1646 | 1613 |
| Total Kjeldahl Nitrogen (mg/l) | <1.0 | 7.1 | 18.4 | 27.5 | 28.2 | 22.1 | 18.1 |
| Total Phosphorous as P (mg/l) | <0.1 | 5.3 | 30 | 25 | 32 | 27 | 40 |
| Oil and Grease (mg/l) | <1 | 38 | 138 | 80 | 190 | 188 | 230 |
| Sodium as Na (mg/l) | 80 | 114 | 416 | 700 | 880 | 700 | 700 |
| E.Coli (per 100ml) | - | - | - | - | >1800 | - | >1800 |

**Table D1.2: Redhill water quality indicators (13 August 2004)**

| Water quality indicator | Sample number | | | |
|---|---|---|---|---|
| | 1A | 2A | 3A | 4A |
| COD (mg/l) | 121 | 2834 | 113 | 32.4 |
| Total Kjeldahl Nitrogen (mg/l) | 26.4 | 100 | 33.5 | 14.8 |
| Total Phosphorous as P (mg/l) | 5.1 | 14.7 | 8.3 | 5.9 |
| Oil and Grease (mg/l) | <1 | 684 | 16 | 20 |
| Sodium as Na (mg/l) | 169 | 170 | 184 | 96 |
| E.Coli (per 100ml) | >1800 | >1800 | >1800 | >1800 |

### D1.2.5 Concluding remarks

Redhill appears to be a very stable small community closely supervised by the municipal authorities and unlikely to grow. Its water management practices are wasteful and there does not appear to be any system for managing wastewater other than by letting it sink into the ground or evaporate. It can only be speculated what the long-term health and environmental consequences will be, but the current situation seems to be tolerable.

## D1.3 Fairyland

### D1.3.1 Background

Fairyland informal settlement is located in a peri-urban area adjacent to the town of Paarl and is administered by the Drakenstein municipality. The site is relatively small with 172 structures and an approximate population of 500 people (van Wyk, 2004). The site was supposed to be upgraded to an RDP status in 2005. Fairyland has been used as a temporary settlement for those awaiting RDP houses; however two residents interviewed during field visits claimed that they had lived in Fairyland for at least 5 years.

Water supply and sanitation services at the site are inadequate. Although communal toilets were installed by the municipality, all appeared to be dysfunctional. They were dirty, blocked and had reached the stage where residents were choosing to use the fields nearby as their toilets instead. As a temporary measure the Municipality intends increasing the number of toilets to 1 for every 4 households in the near future and will ensure that each household has their own lock and key to a designated toilet (van Wyk, 2004). Communal washbasins were also provided but these were vandalized and in a poor state. Most washing took place at a communal tapstand or in front of the houses after water had been collected from a tapstand nearby. Communal tapstands were surrounded by concrete bases with brick walls, which drained excess water to kerbside gutters aligning a grid-iron road system between the shacks.

### D1.3.2 Description of research

Three people were interviewed at Fairyland. There was no systematic approach to the selection of the interviewees. People who were found doing washing at the time were engaged in an interview and asked to answer questions about their generation and use of greywater. The selected water quality indicators (COD, TKN, Tot P, Oil and Grease, Na and pH), piloted during the Redhill study, were used in all four of the second round case studies. Each sample was sent to an independent laboratory for tests.

**Figure D1.6: Stormwater channel at Fairyland**

### D1.3.3 Social findings

It is estimated that household water use in Fairyland is approximately 75*l*/d. Informal discussions with at least 4 residents revealed that they were unhappy with the state of the toilets and were concerned that their children were often sick from living in these conditions. At least two mothers complained that their children frequently played in dirty water that accumulated along the kerbsides which had become blocked with litter.

### D1.3.4 Water quality

In contrast to the above statement, the site appears relatively well-managed with respect to greywater. Despite the fact that fine gravel surface soils predominate, there was little evidence of any standing greywater on surfaces either between huts or near tapstands.

Three samples of washing water and a sample of clean water from a tapstand was taken. These samples were taken to the laboratory for independent testing. The results are shown in Table D1.3.

**Table D1.3: Fairyland water quality indicators (16 September 2004)**

| Water quality indicator | Tapstand | Laundry A | Laundry B | Laundry C |
|---|---|---|---|---|
| COD (mg/l) | 8.0 | 4577 | 843 | 1526 |
| Total Kjeldahl Nitrogen (mg/l) | <1 | 58.9 | 93 | 27 |
| Total Phosphorous as P (mg/l) | <1 | 159 | 93 | 27 |
| Oil and Grease (mg/l) | 4 | 34 | 8 | 48 |
| Sodium as Na (mg/l) | 4.6 | 980 | 106 | 296 |
| E.Coli (per 100ml) | 0 | 0 | >1800 | >1800 |

In all cases, "Omo" washing powder was used for laundry. Of concern was the large volume of water that was flowing freely along the kerbside drainage channels. This water was channeled to a collection point intended for further treatment at the sewage works in Paarl. Observations on the 20 September 2004 showed that the grate at the collection point was blocked with litter allowing water to bypass the catchpit and enter an open stormwater canal feeding into the Berg River, which has a sensitive ecological system. Apart from possible direct impacts on aquatic systems and habitats, effluent from informal settlements and other activities could also contribute to eutrophication problems in the river.

Samples taken from the catchpit at Fairyland indicate relatively high levels of COD and Na, despite the dilution effects of large volumes of water flowing at this point. Samples taken in the stormwater drain eight metres prior to entry into the Berg River show high levels of COD, Na and E.Coli. While other sources of water are likely to contribute to the quality of water flowing into the Berg River, field observations revealed that the flowing water was generated from activities at Fairyland. Water quality indicators measured from samples taken at the catchpit in Fairyland and in the stormwater drain are shown in Table D1.4.

**Table D1.4: Water quality at the catchpit at Fairyland and in the stormwater channel close to the Berg River (16 September 2004)**

| Water quality indicator | Typical laundry water sample | Sample from catchpit | Stormwater channel next to sewage works |
|---|---|---|---|
| COD (mg/l) | 1526 | 843 | 56.2 |
| Total Kjeldahl Nitrogen (mg/l) | 27 | 93 | 20.8 |
| Total Phosphorous as P (mg/l) | 80.5 | 24.5 | 3.5 |
| Oil and Grease (mg/l) | 48 | 8 | 2 |
| Sodium as Na (mg/l) | 296 | 106 | 141 |
| E.Coli (per 100ml) | >1800 | >1800 | >1800 |

### D1.3.5 Concluding remarks

It is not possible to provide conclusive evidence of pollution from such a small sample other than to state the obvious. Eriksson *et al* (2002) report that most of the COD in greywater derives from household chemicals like dishwashing and laundry detergent, and similarly, detergents are likely to be the primary source of P and Na in this wastewater. The high concentrations of both P and Na in the greywater samples from Fairyland are a direct result of the large volumes of soap powder that are used. The obvious and most urgent, environmental concern is the spillage of sewage and greywater into the stormwater network, which ultimately finds its way into the Berg River.

## D1.4 Kleinmond

### D1.4.1 Background

The settlement is located on the periphery of the town of Kleinmond which is located along the southern Cape coast approximately 100km from central Cape Town. The site is in the transition zone of the Kogelberg Biosphere Reserve situated on the slopes of Voorberg Mountains and is within 1km of the Palmiet River estuary. There are approximately 346 structures on the site accommodating 1,600 people (van der Berg, 2004).

Services to the site include communal taps, washbasins and toilets, linked to a reticulation system. These services appeared to be functional but were in a poor condition (sewers were overflowing) and they were also situated some distance from the dwellings. This resulted in people collecting their water and taking it back to their homes for the purposes of washing and doing laundry, instead of using the communal facilities. Greywater is then discarded onto the ground in front of the dwellings after washing. In terms of the brief of this project, sites like these are effectively excluded from the scope of the study, however the situation warrants further research since the settlement is situated in a relatively sensitive area and is likely to generate reasonable volumes of greywater despite being sewered.

### D1.4.2 Description of research

The site was visited on two occasions, firstly to assess the applicability of the settlement with respect to the generation of greywater, and secondly to collect water samples and conduct interviews.

Samples and interviews were conducted on 20 September 2004. Three people were interviewed to establish the amount of water that each household was using and the manner in which greywater was being disposed. Three water samples were collected from laundry water, while a fourth sample was taken from a communal tapstand.

**Figure D1.7: Communal toilets and washing facility at Kleinmond**

### D1.4.3 Social findings

Interviews were held to determine the volumes of water consumed per household and their use of greywater. It was established that approximately 105*l*/d of water is used per household. All interviewees claimed that they tossed their greywater onto the ground outside their homes.

### D1.4.4 Water quality

Two samples of washing water and a sample from a tapstand were collected for further tests.

**Table D1.5: Kleinmond water quality indicators (20 September 2004)**

| Water quality indicator | Tapstand | Laundry A | Laundry B |
|---|---|---|---|
| COD (mg/l) | 4.0 | 3854 | 3172 |
| Total Kjeldahl Nitrogen (mg/l) | <1 | 63.4 | 156 |
| Total Phosphorous as P (mg/l) | <1 | 180 | 112 |
| Oil and Grease (mg/l) | 2 | 12 | 46 |
| Sodium as Na (mg/l) | 29.6 | 960 | 780 |
| E.Coli (per 100ml) | 0 | 0 | 0 |

As mentioned previously, the high COD appears to be linked to the large concentrations of soap powder used in the washing of laundry. In all three cases the interviewees used "Sunlight" soap powder for their laundry.

### D1.4.5 Concluding remarks

The greywater samples from Kleinmond were heavily polluted and are of particular concern given the site's proximity to environmentally sensitive areas. This site also demonstrates that while an area may be technically sewered, communal sanitation facilities do not necessarily provide an effective means of greywater disposal.

## D1.5 Sweet Home Farm

### D1.5.1 Background

The site is located in Philippi on the Cape Flats and has approximately 1,800 structures. The population growth rate is negative with the number of structures having decreased from 2,200 to 1,800 during the period 2003 to 2004. The decrease is attributed to the fact that people have been relocated to other areas due to flooding. The civic committee of Sweet Home Farm tries to prevent people from settling in the area as the settlement is low-lying and subject to flood inundation.

Observations from the first field visit (15 August 2004) showed many shacks were badly flooded following rains of up to 80mm in the first week of August. Floodwaters subsided slowly due to the high water table and saturated soils. Field kits were used to test the water for Tot P and Ammonia ($NH_3$). In the case of the former, >5 mg/l was measured and in the latter, >3 mg/l was measured. No other tests were conducted.

Water is provided to the settlement via 37 standpipes dispersed across the area. Communal toilets have been installed. All have locks to doors and are shared by 5 households. The toilets appear to be relatively well maintained and have been designed to operate as pour flush systems. This system reduces water demand in areas where there is limited supply, and also limits the volumes of sewage to the treatment works. The site is due to be upgraded in the future with the numbers of toilets increasing from 240 container toilets to 450 waterborne toilet systems. The number of standpipes will also be increased as well as the number of greywater collection containers (Gerber, 2004).

### D1.5.2 Description of research

The site was visited on two occasions; the first time to assess the applicability of the settlement with respect to the generation and disposal of greywater, and the second time to collect water samples and conduct interviews.

Samples and interviews were conducted on 16 September 2004. Three people were interviewed to establish the amount of water that each household generates and the manner in which greywater was being disposed. Three water samples were collected from laundry water while a fourth sample was taken from a communal tapstand.

**Figure D1.8: Shacks at Sweet Home Farm**

**Figure D1.9: Flooding at Sweet Home**

## D1.5.3 Social findings

Most of the residents experienced severe flooding during the first week in August. The team was taken to a number of houses that were flooded and samples were taken for P and $NH_3$ analysis.

Interviews during the second visit revealed that households used an estimated 70*l*/d. The system of establishing communal toilets in which 5 households were given ‘ownership’ and responsibility appeared to be working well.

## D1.5.4 Water quality

Three samples of household clothes-washing water and one of a nearby tapstand were collected for analysis and are presented in Table D1.6.

**Table D1.6: Sweet Home Farm water quality indicators (16 September 2004)**

| Water quality indicator | Tapstand | Laundry A | Laundry B | Laundry C |
|---|---|---|---|---|
| COD (mg/l) | 8.0 | 3709 | 11289 | 10483 |
| Total Kjeldahl Nitrogen (mg/l) | <1 | 50.8 | 279 | 186 |
| Total Phosphorous as P (mg/l) | <1 | 144 | 210 | 77.5 |
| Oil and Grease (mg/l) | <1 | 56 | 160 | 706 |
| Sodium as Na (mg/l) | 14 | 910 | 1700 | 770 |
| E.Coli (per 100ml) | 0 | 0 | NS | NS |

## D1.5.5 Concluding remarks

Conditions at Sweet Home Farm during flooding underscore the need for greywater management. Although limited water sampling tests were undertaken, the levels of P and $NH_3$ in the flooded homes are indicative of a potentially serious problem. The slow infiltration of floodwaters combined with heavily polluted greywater, has the potential to place residents’ health at great risk.

# D1.6 Masiphumelele

## D1.6.1 Background

This informal settlement is situated in Noordhoek in the Fish Hoek / Sun Valley area of the Cape Peninsula. Whilst the majority of houses in this settlement have been converted to RDP status, the periphery of the settlement continues to attract a shack-dwelling population. There are approximately 387 structures that have been erected adjacent to the Noordhoek wetland. It is estimated that 1,935 people live in these structures (Faure, 2004).

Attempts have been made by the Municipality to service the informal dwellings with tapstands and communal toilets. It was observed that women conducting their washing at tapstands discard their greywater either onto the soils or into the open stormwater drains alongside. Greywater and other polluted water is carried via these canals directly into the wetland.

## D1.6.2 Description of research

The site was visited on two occasions. The first visit was used to assess the generation of greywater and the proximity of the settlement to the Noordhoek wetland. Water samples were collected and interviews were conducted during the second visit.

Samples and interviews were conducted on 16 September 2004. Three people were interviewed to establish the amount of water that each household was using and the manner in which greywater was being disposed. Three water samples were collected from clothes-washing water while a fourth sample was taken from a communal tapstand.

**Figure D1.10: Stormwater channel to wetland, Masiphumelele**

## D1.6.3 Social findings

Following interviews, it was estimated that the amount of water used by households was about 100*l*/d.

### D1.6.4 Water quality

The close proximity of tapstands to stormwater canals, which ultimately feed the Noordhoek wetland, is a cause for concern. The wetland has no visible surface water as it is filled with *Phragmites Australis*, a common reed known to thrive in nutrient rich soils and in conditions where the water body is less than 1.5m depth. The high levels of COD, P and N, amongst others, contribute to the deterioration of these wetlands.

**Table D1.7: Masiphumelele water quality indicators (20 September 2004)**

| Water quality indicator | Tapstand | Laundry A | Laundry B | Laundry C |
|---|---|---|---|---|
| COD (mg/l) | 16.0 | 1935 | 11451 | 10161 |
| Total Kjeldahl Nitrogen (mg/l) | <1 | 31.2 | 210 | 150 |
| Total Phosphorous as P (mg/l) | <1 | 2.3 | 168 | 125 |
| Oil and Grease (mg/l) | 4 | 126 | 278 | 322 |
| Sodium as Na (mg/l) | 13.6 | 244 | 1210 | 948 |
| E.Coli (per 100ml) | 0 | >1800 | >1800 | >1800 |

### D1.6.5 Concluding remarks

A large number of people are living in close proximity to the wetland and contributing to the impacts thereon by depositing greywater and other sewage along the stormwater canals and directly into the wetland. The high levels of nutrients measured from laundry activities and the immediate release of this water into the stormwater canals is a major cause for concern.

## D1.7 Khayelitsha RR

### D1.7.1 Background

The township of Khayelitsha ('new home') contains the largest informal settlements within the Cape Metropolitan Area (CMA). The township covers an area of approximately 41km$^2$ and was initially intended to accommodate about 250,000 people (Minor *et al*, 2004). Population estimates vary widely from 350,000 to 900,000. There are virtually no elderly people in Khayelitsha – approximately 30% of residents are of school going age and the remaining 70% are of working age (Statistics South Africa, 2001).

Only 30% of the housing stock is regarded as formal (Minor *et al*, 2004). The majority of the residential areas are poorly serviced and lack adequate access to water and sanitation facilities.

There are few formal employment opportunities in Khayelitsha. Only 4% of residents work in the area, mostly in jobs provided by the municipality. According to Census 2001, 46.6% of households have an annual income of R9,600 or less, while 25% of all households have no formal income (Statistics South Africa, 2001).

### D1.7.2 Description of research

The research was conducted on the 11th and 13th December 2004 at a relatively new section of "invaded" land called Khayelitsha RR, with an estimated population of 800 people. The interviews and sample collection process started at a central location on Lansdowne Rd near the fire station. From there the group of researchers spread out into the interior of the densely-settled area across the railway line. The settlement is so densely built-up that there are no roads or even paths between the shacks in most sections. Fire engines and other service vehicles would not be able to get through in an emergency but a postman on a bicycle is able to deliver mail to the numbered shacks. These addresses were used to identify the households where interviews were obtained, although there were a few structures that had not been allocated numbers.

### D1.7.3 Social findings

Khayelitsha RR is a typical urban informal settlement occupied by low-income workers and migrants seeking work and a better life in the city. Household incomes ranged from no income to over R2,000 per month but a large number of people reported pensions and child support grants as their main source of income. Gifts from relatives were also mentioned as survival strategies.

Although the socio-economic profile of Khayelitsha is only slightly different to that of the other settlements, the size of the township as a whole, and its population density, makes the disposal of wastewater and solid waste difficult. The totally inadequate sanitation facilities in the RR section for example have resulted in many people using the remaining open land on and around the railway line as a toilet. Water standpipes are provided on the outside edges of the settlement only, and household water consumption seems to depend on the proximity of the shack to the tap. An average household water use of 55*l*/d was estimated.

**Figure D1.11: Tapstand at Khayelitsha RR**

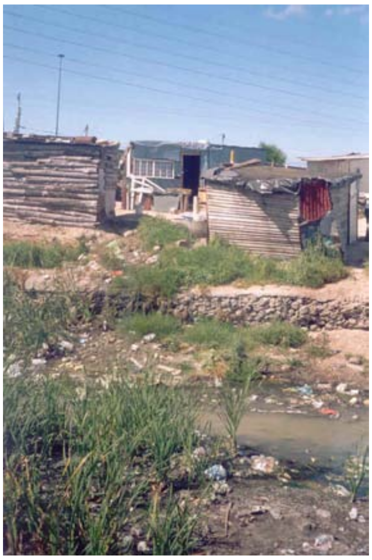

**Figure D1.12: Stormwater channel**

Much of the greywater was either thrown into the nearby stormwater canal or kerbside drains. Although most people were aware that it was wrong to dump wastewater into the canal, they nevertheless did so. A lot of the waste thus ends up in this canal as well as the downstream detention pond both of which overflow with polluted water and various solid matter. At the time of the visit a private firm sub-contracted by the Council was trying to clear the stream of plastic and other refuse but unless this clean-up exercise is regularly conducted it will not have much of a positive impact on the environment.

## D1.7.4 Water quality

Water samples taken from sites in Khayelitsha were tested for COD, Tot P, DO, $NH_3$, pH and E.Coli with most of the tests being conducted in the field. As recorded at other sites described in the report, the COD levels were high and were again shown to be higher in the case of dishwashing water than for laundry. Residents living close to open stormwater drains were observed tossing water into the drain thereby contributing to the contamination. Samples from the drain show high levels of P and $NH_3$, and the COD level is also extremely high. Of interest too is the relatively high pH of the water, which ranges from 9.4 to 10.2.

**Table D1.8: Khayelitsha RR water quality indicators (13 December 2004)**

| Water quality indicator | Laundry K1 | Laundry K2 | Laundry K3 | Laundry K4 | Dishes K5 | Stormwater drain |
|---|---|---|---|---|---|---|
| COD (mg/l) | - | - | 143 | 3586 | 7012 | 23904 |
| Total Phosphorous as P (mg/l) | 9 | 16 | 16 | 2.4 | 16 | 7 |
| Dissolved Oxygen (mg/l) | 3.6 | 3.6 | 3.6 | 3.7 | 3.8 | 3.5 |
| Ammonia N as $NH_3$ (mg/l) | 1.9 | 3 | 16 | 2.7 | >3 | >3 |
| pH | 10.2 | 9.9 | 10.4 | 9.4 | 9.8 | 10.2 |
| E.Coli (per 100ml) | >1800 | >1800 | >300 | >1800 | 0 | >1800 |

## D1.7.5 Concluding remarks

The link, if any, between the types of detergents and other cleaning materials used by consumers and the nature of the greywater produced has not yet been determined. This will require further investigation once the chemical content of the various branded washing materials that the residents referred to has been further investigated. For virtually all the survey areas, water consumption is limited to basic needs such as drinking, cooking, washing and bathing. There were a few very isolated examples of vegetable and flower growing, and where the water supply permitted, attempts by the children to splash about under a tap to keep cool. Other children even used ponds full of polluted water to play in. Some of the municipal authorities responsible for health mentioned the need for education to teach people how to care for their environment but only by raising the standard of communal facilities beyond their current low levels will such education campaigns become meaningful. There is little that individual households can do to clean up their environment, and the authorities need to be more directly involved.

# D1.8 Lingelethu, Malmesbury

## D1.8.1 Background

The town of Malmesbury is over 250 years old. It is now one of the main agro-industrial centres in the Western Cape and is home to over 27,000 people. Its main economic activity is agriculture of which grain production and processing are especially valuable. Vineyards and tourism are also well established.

## D1.8.2 Description of research

Malmesbury was one of the sites in the WC that was selected after examining the Census 2001 data and noting the relatively high potential for greywater generation in a non-sewered environment. As with other sites, water supply was made the most important criterion for further investigation of the Census data. After correlating with income levels and dwelling type and also race (population group), Malmesbury was identified as having a sufficient concentration of households with no sanitation (4,179) to warrant a survey.

As it turned out, the recent (since Census 2001) provision of RDP housing in the area has reduced the number of households without sanitation in Malmesbury. After consultation with the Housing Department at the Swartland Municipal offices therefore, the informal settlement of Lingelethu was identified as the most suitable site for the survey as it was still unserviced. This is about to change however – the project team was informed that plans for the provision of RDP housing to the residents of Lingelethu were advanced and that everyone in Malmesbury would have access to waterborne sanitation within a year's time.

Although the majority of the population in Malmesbury are "coloured", Lingelethu is made up of the more recent arrivals who are Xhosa and Sotho speakers. In this sense at least, the sample is not representative but it was a suitable study site otherwise, and it was decided to proceed with the survey.

**Figure D1.13: Water supply at Lingelethu**

**Figure D1.14: Washing at Lingelethu**

Interviews were conducted on 15th December 2004 by four main researchers and four research assistants with the local councilor acting as guide and mediator. The research assistants administered the questionnaire to the women who were doing their laundry or doing other domestic work. Samples of the greywater were collected and, using the finalised questionnaire, direct questions targeting socio-economic information and water use patterns were asked.

## D1.8.3 Social findings

Water consumption, and therefore greywater production in Lingelethu was much less than was recorded for the informal settlements in the CoCT. In fact all rural or small town informal settlement households surveyed in the province consumed less than 70*l*/d of water. This was due to a combination of factors including reliability of water supply, storage capacity of household as well as distance from tapstands.

The municipality provides plastic bags for solid waste disposal, water from communal tapstands and waterborne sanitation at communal toilets. The latter, however, were not functioning at the time of the visit and residents of Lingelethu used the neighbouring farmlands and open spaces to relieve themselves. This had created conflict with a neighbouring farmer who had dug a deep trench to separate the informal settlement from his land. Clearly when council planners build communal toilets they should also plan for continuous management including cleaning and repairs, otherwise they quickly become useless. The use of newspaper in place of toilet tissue for example is understandable for low-income populations but it leads to blockages and effectively renders standard toilets unusable unless there is proper maintenance. The same argument applies for greywater management devices, such as soak-aways – if these are not maintained and cleaned regularly by responsible personnel, they will not be effective.

## D1.8.4 Water quality

Four samples of household clothes-washing water and one of the water from the hose-pipe at the communal toilet block were collected for analysis. The results are presented in Table D1.9.

**Table D1.9: Lingelethu water quality indicators (15 December 2004)**

| Water quality indicator | Laundry L1 | Laundry L2 | Laundry L3 | Laundry L4 | Tapstand L5 |
|---|---|---|---|---|---|
| COD (mg/l) | 4014 | 11223 | 4096 | 5407 | <8 |
| Total Phosphorous as P (mg/l) | 8 | 16.6+ | 6.3 | 16.3 | 0 |
| Ammonia N as $NH_3$ (mg/l) | 2.88 | >3.6 | >3.6 | 2.28 | 0 |
| pH | 9.2 | 9.8 | 9.5 | 8.7 | 7.2 |
| E.Coli (per 100ml) | 0 | 0 | >1800 | 0 | 0 |

## D1.8.5 Concluding remarks

According to the Housing Department officials in the Malmesbury municipality, the informal settlement has been earmarked for upgrading, which will include the provision of waterborne sanitation. The town’s farms and industries will however continue to attract migrant workers and there will thus in all likelihood continue to be some informal, unserviced housing in the area. The lessons that can be drawn from this example of greywater management are limited because of the small population involved but can be summed up as follows:

- There is an adequate supply of water in the settlement and no need for the use of greywater for irrigation – it is therefore not considered as a resource for recycling but rather waste for discarding. It may help to green the yard around the shack and to keep the dust down, but the growing of vegetables or even flowers and shrubs with greywater for irrigation was not considered an option by those residents interviewed;
- As for most other services, it appears that most people in informal settlements look to the local government to provide adequate water and wastewater management systems.

## D1.9 Western Cape findings

The following maps show some of the overall findings from the case studies in the WC province, particularly in respect of the types of settlements surveyed, and selected water quality data:

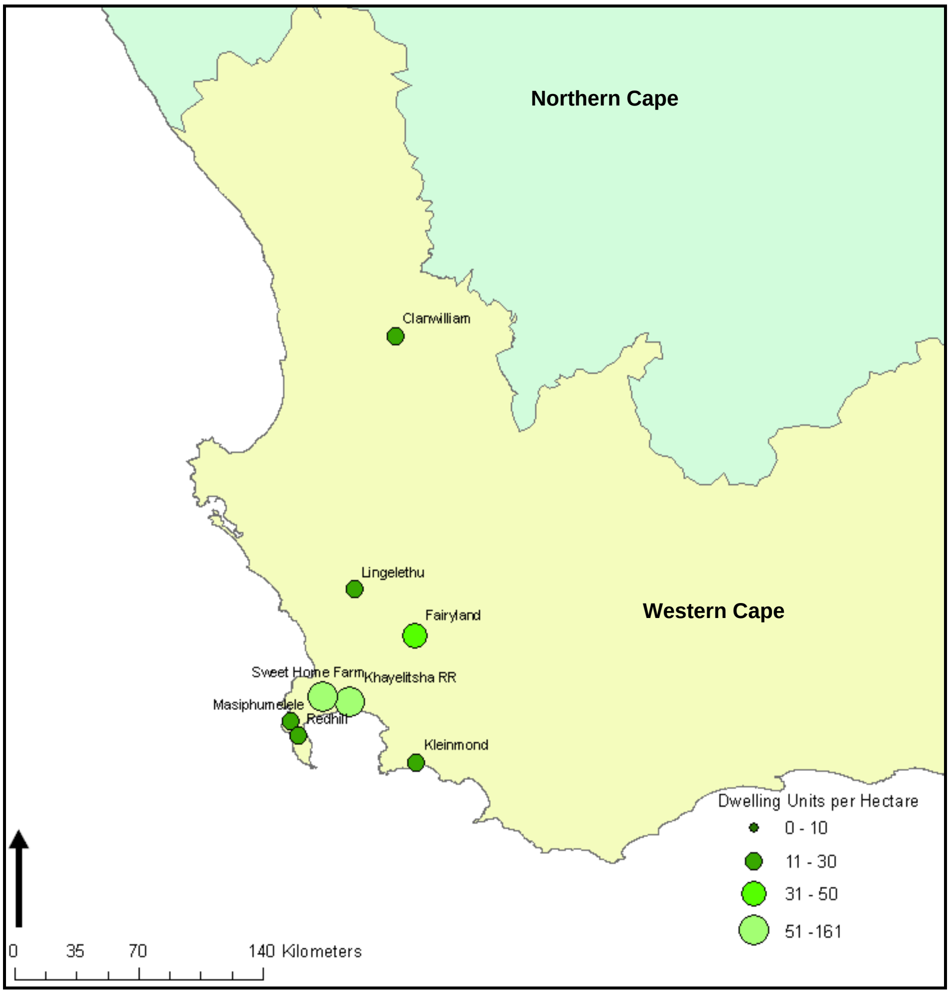


**Figure D1.15: Settlement density figures for Western Cape sites**

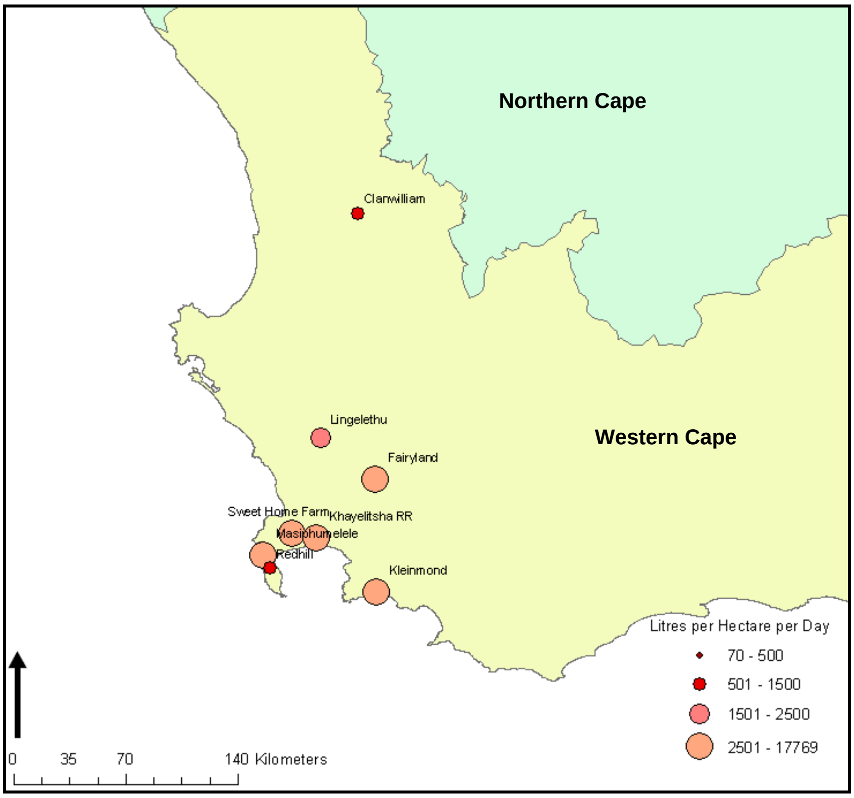


**Figure D1.16: Greywater generation figures for Western Cape sites**

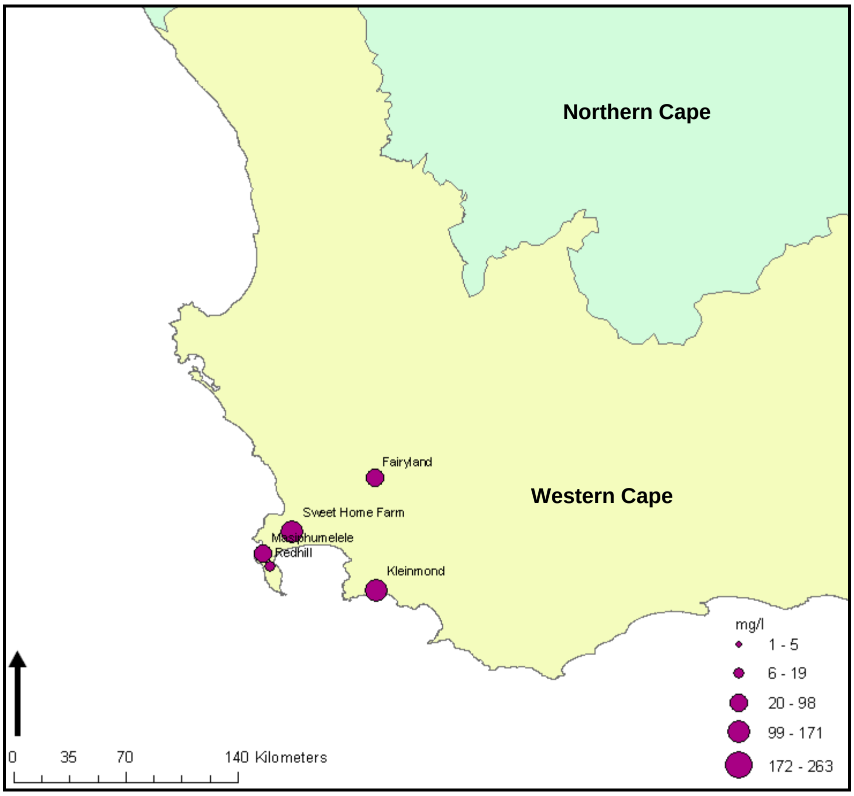


**Figure D1.17: Total Phosphorous figures for Western Cape sites**

# D2. Eastern Cape site surveys

The majority of South Africa's population resides in the better-watered eastern regions of the country, including the Eastern Cape province (EC) which is endowed with many springs and rivers. Although parts of the province are rich in water and frequently flooded in the rainy season, the Eastern Cape also experiences periodic droughts. In April 2005 when the site surveys were conducted, the countryside was still lush after good rains. Figure D2.1 shows the locations of the selected sites for surveys in the province.

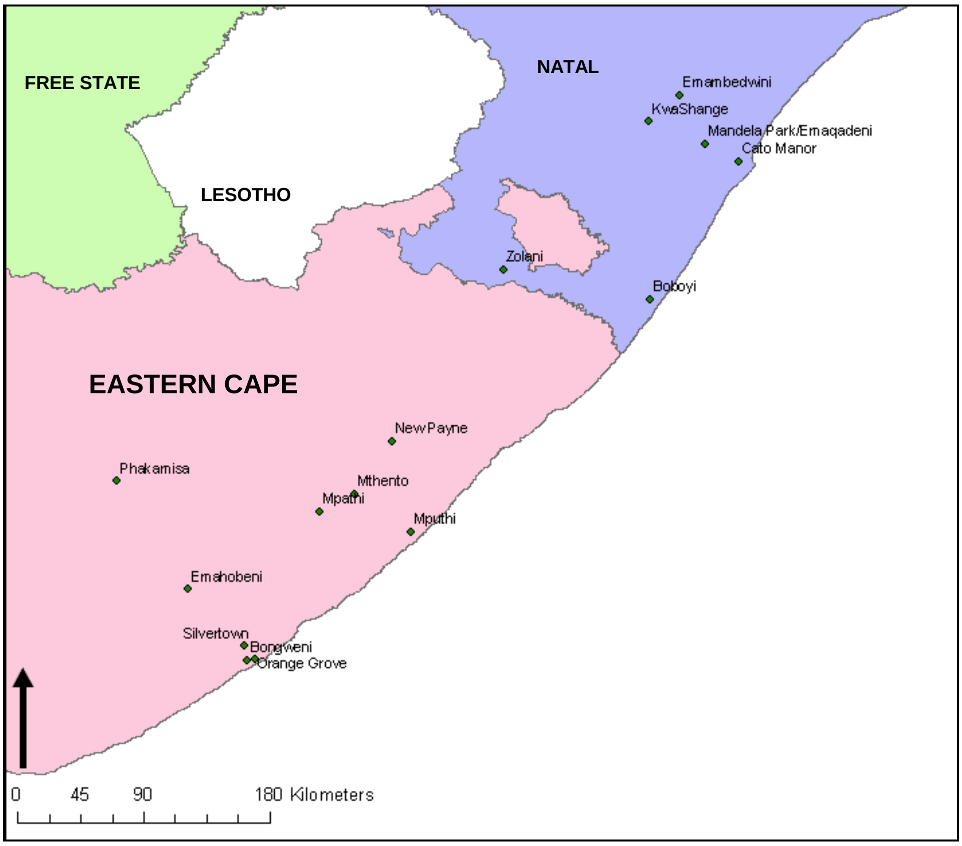


**Figure D2.1: Map of Eastern Cape province showing selected sites for surveys**

Whereas the major cities in the Nelson Mandela Metropolitan area (e.g. Port Elizabeth) and Buffalo City Municipal District (East London) provide their industrial / commercial properties and households with adequate supplies of high quality water, the rural areas of the EC are not well-serviced and are home to some of the poorest people in the country. When the Reconstruction and Development Programme (RDP) started in 1994, the EC had the largest backlog in the provision of basic services. The former inhabitants of the Ciskei and Transkei homelands in particular lacked, and many still lack, access to potable water and basic sanitation, and the RDP thus allocated a large percentage of its water service delivery funding to the EC.

The 1998 Poverty and Inequality Report stated that in rural areas, more than 80% of households had no access to piped water or waterborne sanitation (May, 1998). Although millions of people have since been provided with these services, the investment in water and sanitation may well be nullified by the lack of employment opportunities in the province, which has in turn resulted in the Eastern Cape becoming a net exporter of migrants to other provinces. The complex and sometimes unpredictable population dynamics involving seasonal, trans-provincial and trans-state migration also often result in previously well-serviced areas becoming overwhelmed by rapid population increases.

On-site surveys were conducted in nine different settlements in the Amatole and Oliver Tambo districts of the Eastern Cape.

## D2.1 Silvertown

### D2.1.1 Background

The area around Buffalo City, like much of the eastern part of South Africa, has undulating hills and rolling terrain. Due to the nature of the topography, many wetland systems are found in this area.

Rainfall occurs throughout the year, but predominantly in the spring to early summer months, namely August to November. Annual rainfall averages approximately 960mm in the East London area. During the month of March when the fieldwork was undertaken, the grass was green and the maize ready for harvesting

Silvertown is an informal spill-over of Mdantsane Township which is considered to be one of the larger townships in South Africa. Mdantsane as a whole is reported to accommodate 175,790 people (45,384 households) within a complex of urban and peri-urban components. Buffalo City surveys however indicate an actual population that is close to 350,000 people, or 25 to 30% of the city’s population. The township is located 20km from the East London CBD, situated along the N2 highway between East London and King William’s town. Over a quarter of the population is under the age of 15 years, reflecting a high level of dependency. In addition, HIV/AIDS, high unemployment and major security problems mean that Mdantsane faces many social challenges.

Silvertown has some old brick buildings and more new shacks. It may have been a farm at some point in the past. Like most other informal settlements it is home to many job-seekers from the rural areas who reside there in order to be closer to factories and construction sites. Plots have been demarcated and parceled out by local leaders and the occupants anticipate that their shacks will hopefully develop into fully serviced RDP-type formal housing in the near future. Although provided with water and close to main roads used by local taxis and delivery vans, Silvertown lacks most other services, including electricity. The lack of street lights in what is an extremely crime-prone area is of major concern to the residents.

### D2.1.2 Description of research

The research consisted of interviews with both men and women in their homes and at the water points.

**Figure D2.2: Surveys at Silvertown**

### D2.1.3 Social findings

In the sample of six households surveyed, the average number of people per household was just over three. The amounts of water used did not seem to depend on distance from the tap as much as on the reliability of supply. Most households were easily within 10m of a tapstand but it was reported that there are long queues in the mornings. The on-site surveys took place during the middle of the day however, and there were no queues observed at the taps. Greywater was simply tossed into the long grass around the houses and no signs of water-logging or runoff except at the tapstands, was observed.

### D2.1.4 Water quality

One sample each of washwater and tapwater were tested in the field for selected variables, as shown Table D2.1. The tests showed that the water from the tapstand was of acceptable chemical quality but that the greywater had high levels of P and $NH_3$.

**Table D2.1: Silvertown water quality indicators (2005)**

| Water quality indicator | Tapstand | Laundry |
|---|---|---|
| Conductivity (mS/m) | 43.6 | 188.6 |
| Ammonia N in $NH_3$ (mg/l) | 0 | 3+ |
| Total Phosphorous as P (mg/l) | 0 | 5+ |
| pH | 8.6 | 8 |

### D2.1.5 Concluding remarks

The Silvertown community has adequate access to water. It does not have a visible greywater drainage problem as most of it seeps away into long grass or evaporates, thus preventing the build-up of water. The problem of mosquitoes and skin rashes (perceived as a consequence of insect bites) were cited but it would be difficult to isolate greywater as the main cause.

## D2.2 Bongweni, Fort Grey

### D2.2.1 Background

The site is situated approximately 100km west of East London (Buffalo City). It is a rural area with a low population density of approximately 4 to 5du/ha. The built structures are mainly traditional huts. Water is obtained from two large 5,000*l* tanks in close proximity to the village. These tanks are filled each week by the local municipality, although residents reported that they frequently ran out of water. People from other villages also used this supply. Greywater does not appear to pose any problems because of the low population.

### D2.2.2 Description of research

Four interviews were conducted with women; all of whom were involved in washing laundry at the time of the visit. Water samples were taken from the communal water tank and from a container of laundry (rinse water).

**Figure D2.3: Water containers at Bongweni**

### D2.2.3 Social findings

The settlement of Fort Grey is semi-rural. The informal structures were similar to any found in urban squatter settlements but they were sparsely settled, surrounded by long grass, and the owners grew maize and kept livestock. There were no standpipes in the area but clean water was delivered by tanker and kept in drums at the entrance to the settlement. Unemployment and poverty were found to be high and the household size of over six was higher than previously visited urban settlements.

### D2.2.4 Water quality

One sample each of washwater and tapwater were tested in the field for selected variables, as shown in Table D2.2. There appears to be no problem with greywater being tossed on the ground or used for limited irrigation around the homes. Houses are situated on a relatively flat area. Greywater was used to water grass patches a few metres away from the homes and runoff appeared minimal. No rivers are in the near vicinity of this settlement.

**Table D2.2: Bongweni, Fort Grey water quality indicators (2005)**

| Water quality indicator | Tapstand | Wash Sample |
|---|---|---|
| pH | 7.2 | 7.8 |
| Total phosphorous as P (mg/l) | 0.0 | 3.5 |
| Conductivity (mS/m) | 520 | 916 |
| Ammonia (mg/l) | 0.1 | 3.0 |

### D2.2.5 Concluding remarks

Mosquitoes were the main water-related problem reported in Fort Grey but this could have been attributed to the fact that there had been a lot of rain and there were large pools of water around, suggesting a high water table or impervious rock. Pigs were also seen wallowing in the pools and this clearly provided breeding grounds for mosquitoes.

## D2.3 Orange Grove

### D2.3.1 Background

Orange Grove was suggested as a potential survey site by the planners in the Buffalo City Municipal offices. It is a rapidly expanding settlement located near the airport and close to a planned export promotion zone. The jobs that attracted people to the city have however not yet materialised for many. The site is densely settled and in appearance resembles many other South African informal settlements.

### D2.3.2 Description of research

The three research assistants interviewed the men and women who had come to the communal standpipe to fetch water and do their washing. The preferred water containers were 25*l* plastic jerry cans and 20*l* plastic buckets. Women were generally observed carried these containers on their heads while the men were seen ferrying several containers at a time in wheel barrows.

**Figure D2.4: Collecting water at Orange Grove**

### D2.3.3 Social findings

Residents expressed bitterness about the conditions in the settlement. Tapstands were difficult to access and were surrounded by muddy puddles. A lot of activity was observed around these tap stands. Pigs were also found around this muddy water. There were no concrete sills, pathways or means to drain the area. A further problem was the fact that the settlement was situated on a reasonably steep slope and this created added hardships in transporting water containers.

### D2.3.4 Water quality

One sample each of washwater and tapwater were tested in the field for selected variables, as shown in Table D2.3.

**Table D2.3: Orange Grove water quality indicators (2005)**

| Water quality indicator | Tapstand | Wash Sample |
|---|---|---|
| pH | 6.9 | 7.6 |
| Total Phosphorous as P (mg/l) | 0.5 | 5+ |
| Conductivity (mS/m) | 495 | 764 |
| Ammonia (mg/l) | 1.1 | 2.2 |

### D2.3.5 Concluding remarks

Areas around communal tapstands were very muddy and difficult to access and there were clearly insufficient communal tapstands available.

## D2.4 Phakamisa Park

### D2.4.1 Background

This site is situated 16km north-west of Queenstown. It is a rural area and is characterized by large plots with a settlement density estimated at about 8du/ha. The team visited the site on a Saturday morning and found many young children in the area. Housing structures were found to be a mixture of traditional and formal homes. There were also many old, run-down shack dwellings. Communal toilet facilities were provided in blocks (with two toilets each) but were clearly inadequate and most were dysfunctional; either broken or blocked. Some residents had built their own pit latrines in their yards. The settlement is relatively flat with spacious yards surrounding the houses.

### D2.4.2 Description of research

Five interviews were conducted and two water samples were taken from containers of laundry.

### D2.4.3 Social findings

Although generally poor, some of the people had initiated improvements to their houses such as the digging of private latrines, but the general feeling was that the local authorities should provide water and sanitation services to each household.

### D2.4.4 Water quality

Two samples of washwater were tested in the field for selected variables, as shown in Table D2.4.

**Table D2.4: Phakamisa Park water quality indicators (2005)**

| Water quality indicator | Wash sample 1 | Wash sample 2 |
|---|---|---|
| pH | 8.4 | 9.3 |
| Total Phosphorous as P (mg/l) | 2.3 | 1.5 |
| Conductivity (mS/m) | 681 | 346 |
| Ammonia (mg/l) | 3+ | 1.5 |

### D2.4.5 Concluding remarks

One interviewee was adamant that soap damages vegetable crops and she therefore avoids using greywater. In general, the interviewees were unhappy about conditions at the site. They complained that while the amount of tapwater made available was sufficient, there were too few communal standpipes and that the toilets were inadequate.

## D2.5 New Payne

### D2.5.1 Background

The area between Kei River and Umtata is characterised by undulating terrain with valley thicket occurring within the steep river valleys and grasslands on top of the ridges. Rainfall occurs predominantly in the summer months, typically from October to March. Annual rainfall averages approximately 650mm in the Umtata area with the wettest month of the year February, and the driest June. The grass was still long and green in this area during the survey period and the maize was still at the pollination stage.

### D2.5.2 Description of research

Three interviews were conducted with one woman (18 years old), a teenage boy (15 years old) and an older man (35 years old). One sample of laundry water was taken.

### D2.5.3 Social findings

Unemployment appears to be the most critical concern at New Payne although the settlement's proximity to Umtata means some people do have paid employment and there is some money in circulation locally. Most of the houses were made of bricks and were of a reasonable standard. The houses were quite well-spaced and some households had maize gardens on fenced plots. Many households had rain tanks on their properties for the storage of water which could be used to augment the potable water supply.

### D2.5.4 Water quality

One sample each of washwater and tapwater were tested in the field for selected variables, as shown in Table D2.5.

**Table D2.5: New Payne water quality indicators (2005)**

| Water quality indicator | Tapstand | Wash sample |
|---|---|---|
| pH | 8.2 | 7.7 |
| Total Phosphorous as P (mg/l) | 0.0 | 4.5 |
| Conductivity (mS/m) | 82 | 1128 |
| Ammonia (mg/l) | 0.0 | 2.6 |

### D2.5.5 Concluding remarks

The concept of rain harvesting was noteworthy; however, judging from a remark from one of the residents, it appears that people use hoses attached to the communal tapstands to top-up their rainwater containers, which are generally used merely as storage facilities.

## D2.6 Mputhi

### D2.6.1 Background

This is a rural area situated on very steep slopes overlooking the Idutywa River. The river is used for washing and bathing. Water is dammed up along the side of the river where it is collected for drinking purposes. Women were observed washing laundry further upstream and goats were seen sharing the same water source. The river appeared to be polluted.

The population density was estimated at 5 to 10du/ha. Houses were brick-built structures clustered on the crest of the hill overlooking the river.

### D2.6.2 Description of research

Two interviews were conducted. A water sample was taken at the watering hole on the Idutywa River, a sample of laundry water and a sample of wastewater that had ponded in a shallow depression alongside the river.

**Figure D2.5: Watering hole at Idutywa River**

### D2.6.3 Social findings

The young men herding livestock and tending the maize gardens in the residential area were the only signs of a rural economy. Most people appear to be dependent on wages, pensions or other grants as sources of money.

### D2.6.4 Water quality

One sample each of water from the river, laundry water and wastewater were tested in the field for selected variables, as shown in Table D2.6.

**Table D2.6: Mputhi water quality indicators (2005)**

| Water quality indicator | Water from river | Wash sample | Waste water sample |
|---|---|---|---|
| Ph | 8.4 | 8.2 | 9.6 |
| Total Phosphorous as P (mg/l) | 1.0 | 1.0 | 1.5 |
| Conductivity (mS/m) | 384 | 372 | 1194 |
| Ammonia, $NH_3$ (mg/l) | 0.2 | 2.0 | 0.2 |

### D2.6.5 Concluding remarks

The results of the analyses of the river water suggest that the river is polluted, with evidence of abnormally high P and $NH_3$ levels. This same water is being used for drinking purposes without any form of filtration or treatment and is thus cause for concern.

## D2.7 Mthento

### D2.7.1 Background

Situated 20km south of Umtata, this is a rural settlement with a sparse population density (3du/ha). There are no standpipes servicing the inhabitants. Water is collected from nearby gullies but at the time of the visit these were dry. The area is undulating with loamy soils. Greywater is unlikely to pose a problem in this area and could potentially provide an alternative source of irrigation water.

### D2.7.2 Description of research

Two interviews were conducted with older women.

### D2.7.3 Social findings

The economically active population appeared to be absent as a consequence of labour migration. The team only observed older women and young children in the settlement.

### D2.7.4 Water quality

No water samples were taken.

### D2.7.5 Concluding remarks

The priorities expressed by the two interviewees were those of toilets, water supply, and drainage systems during the summer rainfall period.

## D2.8 Mpathi

### D2.8.1 Background

Mpathi village is a few kilometers out of Idutywa and was selected as an example of a rural settlement with minimum services. The local population of this area is predominantly of the Xhosa-speaking Fingo ethnic group whose main farming activities include small-scale cultivation of maize and the raising of cattle, sheep and goats. The undulating country is sparsely settled and the population density for Mbashe Municipal District is estimated at 7du/ha. Idutywa, approximately 33km north of Butterworth, is the site of an old military post located in the valley of the Mputhi River, a tributary of the Mbashe River.

### D2.8.2 Description of research

The research in Mpathi consisted of interviews with villagers both in their homes and at the spring where the young men were watering their livestock and the young women were doing the laundry and collecting water for domestic use. As the lowest point in the valley was the site of the spring, the stream and the channel for the run-off from the houses and grazing areas, it was expected that the levels of pollution in the spring water would be high. Indeed one woman complained bitterly about a previous outbreak of cholera and demanded that the authorities should provide potable water to the village.

### D2.8.3 Social findings

Unlike the typical rural homesteads of scattered “rondavels”, Mpathi is laid out like a formal township. Although poorly serviced, the houses, livestock and stands of maize suggested that the people were not as poor as some that had been seen elsewhere in the province. Despite the apparent advantages of this however, the settlement was still lacking in basic services.

### D2.8.4 Water quality

No water samples were taken.

### D2.8.5 Concluding remarks

Interviewees were strongly of the view that greywater should be discarded and not used for irrigation. They claimed it caused diseases and was unhealthy. One interviewee wanted flushing toilet systems to remove the “dirty water”. The model of proper water supply and wastewater management that people have in mind appears to be that of the urban fully serviced house.

# D2.9 Emahobeni

## D2.9.1 Background

This settlement is situated 4km from Stutterheim. Houses were generally shacks, interspersed with some mud houses and a few RDP houses that have been built alongside the settlement. The settlement is best classified as a peri-urban area of low density (10du/ha). This is a well-established settlement in terms of age. Communal tapstands were supplied to the settlement, but interviewees claimed that the number of taps were inadequate. The soils are loamy with evidence of red oxides in clay. The topography is relatively steep.

## D2.9.2 Description of research

Three interviews were conducted and three water samples taken (two of laundry water, one tapstand).

**Figure D2.6: Flooded tapstand at Emahobeni**

## D2.9.3 Social findings

The RDP houses in Emahobeni are quite sparsely laid out. The communal taps and toilets were not well maintained and long grass was observed growing all around the pathways. The water taps had no soakaways and there were stagnant pools formed around them. The communal toilets had been so misused and filled with newspapers and other solid waste that they were no longer functional, which meant that people had resorted to digging their own pit latrines, using the bush or using the better facilities at the local bottle store. Yet again, the advantage of locating taps and toilets within individual yards, with the responsibility for their upkeep being given to an individual household, was demonstrated.

## D2.9.4 Water quality

Two samples of washwater and one of tapwater were tested in the field for selected variables, as shown in Table D2.7.

**Table D2.7: Emahobeni water quality indicators (2005)**

| Water quality indicator | Tapstand | Wash sample 1 | Wash sample 2 |
|---|---|---|---|
| pH | 8.2 | 7.6 | 8.1 |
| Total phosphorous as P (mg/l) | 0.0 | 1.2 | 4.5 |
| Conductivity (mS/m) | 84 | 314 | 448 |
| Ammonia (mg/l) | 0.0 | 3+ | 2.6 |

## D2.9.5 Concluding remarks

In all areas the DWAF-defined "adequate access to water" of 25*l*/c.d within 200m of private or communal tapstands / standpipes was provided for most people. The delivery of potable water has clearly been a priority of government. In rural settlements, however, women walked relatively long distances to water points, and the water was also likely to be of a poorer quality (e.g. from springs or open drums replenished by tankers). Mosquitoes and poor drainage were cited by two interviewees as problems. One interviewee suggested that simple drains should be constructed at the water points, and that this was a matter that should be addressed by the community committee.

In both the peri-urban and rural areas visited in the Eastern Cape Province, the amount of greywater generated appeared to be manageable, mainly owing to the fact that they were mostly sparsely settled areas where the runoff did not form stagnant pools or streams of effluent. This suggests that the current method of greywater management can probably remain unchanged in many places. If on the other hand greywater is perceived as an unutilised resource in a water-short country, then improved technologies for greywater recycling are worth promoting. In urban dense settlements, the residents and the local authorities appear to be convinced that the only option is to convey all wastewater into the sewerage system.

# D3. KwaZulu-Natal site surveys

The KwaZulu-Natal site surveys took place at the end of June 2005 and included rural and urban settlements in the areas around Kokstad, Port Shepstone, Lower Tugela, Pietermaritzburg, Stanger and Durban, that were chosen based on their proximity to watercourses and thus the potential environmental impacts that could result from greywater disposal. Figure D3.1 is a map of the province showing the positions of sites visited.

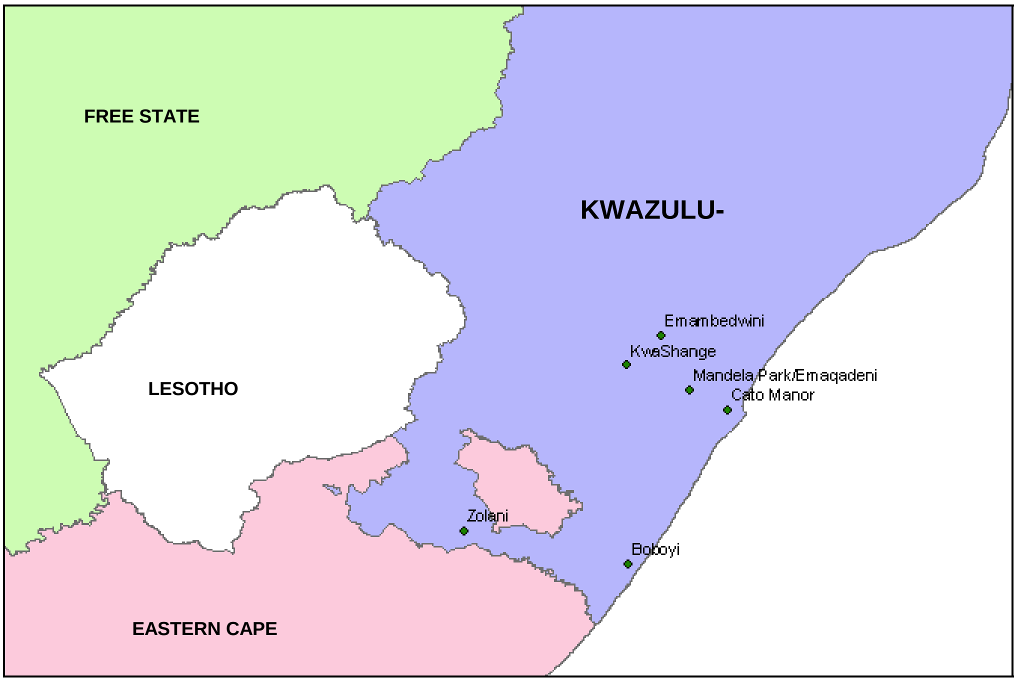


**Figure D3.1: Map of KwaZulu-Natal province showing selected sites for surveys**

## D3.1 Zolani, Kokstad

### D3.1.1 Background

The settlement is situated approximately 2.5km from the CBD of Kokstad and 1.2km from the outskirts of the formal town. It is located on a floodplain formed by the meandering of the Mzintlava River, formerly a part of the Bhongweni farm. The area is gently concave with a moderately steep slope within 70m of the river banks (see Figure D3.2) forming a gradient of 1:7. The highest point of the settlement is approximately 25m above the river bed. From the perspective of this study, the site provides an example where run-off of greywater could enter the river and also where residents use the stream for washing and bathing.

The area receives approximately 800mm rainfall per annum. Soils are dark, reddish and loamy, severely impacted by the movement of people and vehicles. Evidence of some gullying along the river banks suggests that run-off could be severe during rain storms.

### D3.1.2 Description of research

The site selection was informed by Census 2001 which recorded that the settlement of 'Horseshoe', also known as Zolani, had 1,134 black households without sanitation and water supply. The area was also recommended by an official of the Engineering Division of the Kokstad Municipality. In this study, the settlement is referred to as Zolani, Kokstad.

### D3.1.3 Social findings

The researchers estimated the population at Zolani to be between 2,500 and 3,000. There is a high density of people living in an area of approximately 50ha. Since Census 2001, some progress has been made by the municipality to implement services. Standpipes, with concrete slabs surrounding these tapstands and stormwater channels, have subsequently been established in the settlement. The construction of RDP housing began in 2005. Pit latrines were mostly to be found in the yards of individual households but there were other communal latrines situated in the settlement. Many residents complained however that they were not permitted to use these pit latrines and they were therefore forced to use the bushes or the river.

Unemployment appears to one of the most important concerns. Residents reported very low levels of income (less than R400 per month appeared to be the norm) while three of the people interviewed reported living off social grants. The majority of the interviewees claimed that water, housing and toilets were highest on their list of priorities required to meet their immediate needs. Residents did not wish to reuse greywater, claiming that greywater was dirty and could cause disease. One interviewee claimed that the tapstand was close to his residence and there was therefore no need to conserve water by reusing it.

**Figure D3.2: Shacks situated on moderate slopes on banks of Mzintlava River**

**Figure D3.3: Children washing clothes in Mzintlava River**

Washing at tapstands is forbidden by the municipality. Apparently spot checks are conducted and if people are caught by officials doing their laundry, clothing items are confiscated. Interviewees were not certain why this policy was necessary. It is possible that it has been put in place to prevent queues forming at tapstands and thereby improve general access to water. The researchers found a number of women washing laundry a few metres from tapstands in close proximity to unlined stormwater drains (culverts), and greywater was being disposed into these culverts.

There was very little evidence of any attempt to grow vegetables or plants in the yards. In part, this could be explained by the fact that residents felt unsettled and insecure now that the process of constructing RDP housing had began. This insecurity caused them to question the wisdom of investing time and effort into the growing of vegetables or plants in an area likely to be used for formal housing in the near future.

### D3.1.4 Water quality

Six samples of washwater, river water and tapwater were tested in the field for the selected variables (Table D3.1).

**Table D3.1: Kokstad water quality indicators (2005)**

| Water quality indicator | Tapstand | Laundry: 1st wash using Sunlight powder | Laundry: 1st rinse. Slight odour | Laundry: 1st wash from Sunlight powder | Dish water using Sunlight | Mzintlava River |
|---|---|---|---|---|---|---|
| Total Phosphorous as P (mg/l) | 0 | 3.5 | 0.7 | 4.2 | 5+ | 0 |
| pH | 7.8 | 7.9 | 9.4 | 8.3 | 9.8 | 8.3 |
| Conductivity (mS/m) | 0.1 | 87 | 33 | 116 | 559 | 15.4 |
| Ammonia N as $NH_3$ (mg/l) | 0 | 3.5 | 3+ | 1.7 | 0.2 | 0.9 |
| Dissolved Oxygen (mg/l) | 0.9 | 1.2 | 1.2 | 2.4 | 0.1 | 1.4 |

### D3.1.5 Concluding remarks

Although the settlement was undergoing considerable changes with the construction of RDP housing in a section of the site, Zolani nevertheless presented a good example of a situation in which residents no longer rely on water from the nearby stream. Tapstands in the near vicinity of their houses meant they no longer needed to reuse dirty water. All interviewees expressed a preference for tossing dirty water onto the ground, as they were mistrustful of reusing it, citing that it could cause disease.

## D3.2 Boboyi, Port Shepstone

### D3.2.1 Background

The steep hilly topography of Boboyi consists of conglomerates, greywacke and shales formed during the Cambrian Period about 570 million years ago. Surface soils have subsequently been modified considerably through urban and agricultural activity, resulting in loams and clays with relatively poor soil infiltration, especially on flat or gentle slopes. The site was chosen because of its proximity to a network of rivers discharging into the Mzimkulu River, a large perennial river with its outflow immediately north of Port Shepstone. The settlement lies approximately 7.5km west of Port Shepstone CBD.

Prior to agricultural activity and urban encroachment, the vegetation is likely to have consisted of coastal forests and thornveld. Remnants of this vegetation can be observed in the steep valleys near the crest of hills. Boboyi is described as a built-up area on SA Topographic map 3030CB Port Shepstone; however the hilly terrain has ensured a sparsely-developed area especially on slopes of 1:3 or steeper.

Homesteads in Boboyi were generally old brick structures, well-maintained, and situated on reasonably large stands of 800m$^2$ or more. Most residents used their gardens to grow vegetables and plants. Water is available either in the yard or from nearby tapstands.

## D3.2.2 Description of research

The site was chosen because of its physical and topographical characteristics – a hilly topography in close proximity to a number of small rivers draining into the Mzimkulu River.

Potential interviewees were selected because they were present in their yards or around the homesteads and in most cases interviewees were washing laundry at the time. Water samples were taken from containers in which laundry was being washed. One sample contained nappies that had been left to soak for over 5 hours (Sample no. KN0205). Samples were also taken from two tapstands and from nearby rivers.

**Figure D3.4: Topography of Boboyi**

**Figure D3.5: Sampling river below the settlement**

## D3.2.3 Social findings

It is difficult to estimate the population of Boboyi. The settlement has low density housing and is estimated to have less than 5du/ha.

Boboyi is a peri-urban area. In general, interviewees find work and income from employment in nearby Port Shepstone. Growing food in the area surrounding their houses merely supplements the household food supply and no households appeared to be subsisting entirely from the produce.

On average, the interviewees were found to have lived in the area for 5 years or more. It is expected therefore that people have formed habits to deal with greywater and opinions about the use of greywater. Households collect up to 150*l* of water per day with the average being closer to 100*l*. The daily chore of collecting water on average took about 15 minutes. Daily storage amounts to approximately 100*l* per household. Most households were well organized with buckets and barrels in which to store water.

In general the interviewees preferred to use washing powder for laundry rather than the green “Sunlight” soap bar. They claimed that the powder was a little more expensive but was more effective. Unlike other settlements visited in this study, there were a fair amount of other cleaning agents used for cleaning floors and basins – “Chibochi”, “Dettol” and “Handy Andy” were identified.

There was overwhelming agreement that greywater tossed onto the ground attracted flies and mosquitoes. As a result, some residents said that they poured the water onto a defined spot in the yard. In one case, the residents chose a spot to the side of the house to avoid wastewater running off into the neighbour’s yard down the slope. Interestingly, some residents were happy for the water to run downhill into the rivers. They claimed that they no longer needed the river as a water source. Another resident suggested that greywater should be piped directly to the river!

### D3.2.4 Water quality

Five samples of washwater, river water and tapwater were tested in the field for the selected variables (Table D3.2).

**Table D3.2: Boboyi water quality indicators (2005)**

| Water quality indicator | Laundry KN0205 | Laundry KN0208 | Laundry KN0204 | Tapstand KN0203 | River KN0206 |
|---|---|---|---|---|---|
| DO (mg/l) | 0 | 0.4 | 1.4 | 0.7 | 0.5 |
| Conductivity (mS/m) | 167.8 | 132 | 83.2 | 19.2 | 48.9 |
| Total Phosphorous as P (mg/l) | 2.5 | 2.8 | 3.2 | 0 | 1.4 |
| Ammonia N as $NH_3$ (mg/l) | 3 | 3 | 3 | 0 | 0 |
| pH | 9.3 | 9.2 | 9.9 | 9 | 7.6 |

### D3.2.5 Concluding remarks

Despite the proximity of the houses to nearby rivers (average distance ranges between 20 and 70m) and steep slopes, the water quality in the rivers appeared to be relatively good, based on the sample (KN0206) results. This is surprising since many of the interviewees claimed that they were happy to use the rivers to dispose of their wastewater. Owing to the fact that interviewees had resided for a relatively long period at Boboyi, it was disappointing to find that residents had not found creative solutions to deal with greywater. The dominant perception was that greywater is dirty, creates a health risk and needs to be thrown as far away as possible.

# D3.3 KwaShange, Pietermaritzburg

## D3.3.1 Background

KwaShange is situated 20km south west of Pietermaritzburg CBD. It is a low-density rural settlement with traditional, brick-built structures in a peri-urban area. The settlement is a small village with less than 3du/ha. Most houses are traditional and are situated within 100m – 500m of a water body. KwaShange lies on a ridge approximately 250m from the Nembes River. This river feeds the Msunduze River, which then enters the Henley Dam approximately 2km downstream. Streams were flowing at the time of the visit. A sample was taken from one of these rivers close to the settlement. A further sample was taken from the stream at the bottom of the valley. The geology of the area consists of shales, mudstone and shallow soils typical of the KZN midlands.

## D3.3.2 Description of research

The site was chosen because of its physical and topographical characteristics – it is located in a small catchment with headwaters fed by numerous streams in close proximity to the homesteads.

The researchers visited the site on a Sunday morning and anticipated that it would be easy to find people to interview. A total of 14 interviews were conducted at various homesteads. Interviewees were found in the near vicinity of there homesteads and yards. Washing and general cleaning activities were observed in only a few households. Water samples were taken from a variety of containers, some with laundry at the first stages of washing; some with rinse water; and one sample from stored greywater.

## D3.3.3 Social findings

Houses in this area were mainly found to be brick structures. In most cases houses had 3 to 4 rooms, with other family units adjoining or alongside the main house. Most of the interviewees received water either from a tap in the house or from a tapstand close to their homes.

**Figure D3.6: Overlooking the Msunduze River**

**Figure D3.7: Laundry washing in a yard with a water tap in garden**

Homesteads all have pit latrines. It was reported that inhabitants did use river water for drinking purposes, but they had been warned by a Councillor that it was unsafe to do so. Rivers lower down the valley were used for washing clothes or large washing loads.

From the interviews conducted it appeared that people enjoy living in this area and have stable social relations with their neighbours. The average income per household falls into the range of R801 – R1,600; at least 6 of the interviewees said that their household income was partly sustained by pensioners contributing to the household expenses.

### D3.3.4 Water quality

Six samples of washwater, river water and tapwater were tested in the field for the selected variables and samples were also collected for analysis in a laboratory (Table D3.3).

**Table D3.3: KwaShange water quality indicators (2005)**

| Water quality indicator | Laundry KN0301 | Rinse water KN0302 | River KN0303 | Laundry KN0305 | Dishes KN0304 | Stored water KN0308 |
|---|---|---|---|---|---|---|
| Total Phosphorous as P (mg/l) | 6.2 | 5.8 | 5.2 | 406 | 12.3 | 11.2 |
| Total Kjeldahl N | 33.1 | 37.3 | <0.10 | 152 | 105 | 108 |
| pH | 9.6 | 9.2 | 7.6 | 9.4 | 9.7 | 7.4 |
| Conductivity (mS/m) | 57.1 | 27.8 | 13.2 | 58 | 72.3 | 78.9 |
| Ammonia N as $NH_3$ (mg/l) | <0.15 | 10.3 | <0.15 | 44.7 | <0.15 | 7.4 |
| Dissolved Oxygen (mg/l) | 0 | 0 | 0.3 | 0.1 | 0.6 | 0 |
| Oil & Grease | 332 | 584 | <1 | 1528 | 2416 | 224 |
| Boron (as B) | <0.10 | - | - | - | - | <0.10 |

### D3.3.5 Concluding remarks

Since water is easily available to most people living in this settlement, there was an obvious reluctance to use greywater because it was perceived to be dirty. Most interviewees claimed that they tossed dirty water away and were reluctant to try and reuse it. Greywater is however sometimes used for washing floors, to dampen and control dust in the yards, for making bricks, and feeding cattle.

## D3.4 Emambedwini, Wartburg

### D3.4.1 Background

Emambedwini is situated approximately 12km east of Wartburg. It is a rural area with relatively low-density brick and traditional homesteads forming a ribbon development alongside the many tributaries that flow into the Mkabela and Mqeku Rivers. The settlement density is estimated at approximately 4du/ha. Most houses are within 100m to 500m of some form of surface water. Streams were flowing at the time of the visit, but appeared to be polluted towards the bottom of the valley with cattle either feeding or walking through areas where surface flow was temporarily contained. The geology of the area consists of shale, mudstone and shallow soils typical of the KZN midlands.

### D3.4.2 Description of research

Once again the site was chosen because of its physical and topographical characteristics, with homesteads that are located along the hills and in valleys adjacent to watercourses. Pit latrines were found at each homestead where interviews took place. Most homes had a water source in the home and/or yard.

The researchers visited the site on a Monday morning. A total of 14 interviews were conducted at various homesteads. Most interviewees were found washing laundry and other items at the time of the visit. Water samples were taken from the river and a spring (used for drinking purposes), and from containers, some with laundry and others with kitchen utensils.

**Figure D3.8: Dispersed settlement overlooking the Mkabela River Valley**

**Figure D3.9: Small dam polluted by sediment and dirty water**

### D3.4.3 Social findings

Homesteads in this area were mostly brick structures with some traditional buildings. In most cases houses had 3 to 4 rooms, with other family units adjoining or alongside the main house. Water was obtained from a tap in the house or from a tapstand within 200 to 500m of their homes. Some interviewees claimed they drew water from nearby streams. Vegetables and maize were being grown in the yards or fields attached to the properties.

Interviewees reported low levels of income (average range R401-R800) and education, with most people only having been educated to senior primary school level.

### D3.4.4 Water quality

Five samples of washwater, river water and tapwater were tested in the field for the selected variables and samples were also collected for analysis in a laboratory (Table D3.4).

**Table D3.4: Wartburg water quality indicators (2005)**

| Water quality indicator | River KN401 | Laundry soaking KN405 | Kitchen KN406 | Laundry KN407 | Spring used for drinking KN409 |
|---|---|---|---|---|---|
| Total Phosphorous as P (mg/l) | 5.2 | 769 | 12.5 | 8.5 | 5.7 |
| Total Kjeldahl N | <0.10 | 40 | 43.9 | 79 | 12.1 |
| pH | 8.9 | 10.3 | 9.3 | 10.2 | 6.2 |
| Conductivity (mS/m) | 11.5 | 1260 | 264 | 177 | 28.8 |
| Ammonia N as $NH_3$ (mg/l) | <0.15 | 4.4 | <0.15 | 20.8 | 0.22 |
| Dissolved Oxygen (mg/l) | 0.9 | 0.5 | 0.6 | 0.6 | 0 |
| Oil & Grease | <1 | 3640 | 736 | 1056 | 48 |

### D3.4.5 Concluding remarks

All interviewees were reluctant to use greywater as it was perceived to be dirty, to cause diseases and to encourage mosquitoes and flies. The poor state of rivers and roads were the main problems facing the people in this settlement. Rivers are used for washing large items such as blankets, carpets and mats and there appears to be little respect for the resultant pollution of the river or for the impacts on neighbours further downstream.

Of interest are the results for water sample KN405 (soaking laundry) in Table D3.4; they not only indicate high levels of P, but also unusually high levels of Oil and Grease. This is likely to have occurred from the practice (observed on various occasions) of leaving the detergent bar in the basin of soaking laundry for prolonged periods, thereby resulting in larger quantities of chemicals in the laundry solution. In addition to this, many residents reported using a tar-based household disinfectant ("Madubula") around their shacks as a sanitizer and as an insect repellant, which could also explain the elevated Oil & Grease levels measured ("Madubula" is a creosotic material rich in phenolic and cresylic compounds).

## D3.5 Mandela Park & Emaqadeni, Botha's Hill

### D3.5.1 Background

Emaqadeni is an old peri-urban settlement situated 3km west of Botha's Hill, Durban. It has a low population density estimated at 5du/ha. Properties surrounding the homesteads are large, ranging between 800 and 1,500m$^2$. Most homes had taps either in the house or in the yard.

Mandela Park was chosen because of its close proximity to the Valley Trust, a well known NGO operating in the area that provides educational and medical services. It was assumed that the Valley Trust would have had some input into the redevelopment of the RDP-type settlement and may have intervened in the implementation of the dry sanitation systems and urine diversion toilets that had recently been installed. No water samples were taken at this settlement.

### D3.5.2 Description of research

Ten interviews were conducted at Emaqadeni. It was noticeable that there were not too many people around at the time when the interviews were being conducted and the researchers did not easily find potential interviewees.

**Figure D3.10: Mandela Park: controlled water supply**

**Figure D3.11: Mandela Park: Urine diversion toilets**

### D3.5.3 Social findings

Emaqadeni: those people that reported on incomes indicated a higher than usual household income (above R1,600). At least two homes were headed by young children.

Mandela Park: Registration for housing in the area began in 1994. In 2004 Jali Construction company began building RDP houses. The drum / tank system of dispensing water to every home was installed in May 2005. The plan is to have 200*l* drums filled daily at a specific time. The water is considered safe, but the problem of an unlocked lid to the container is now seen as a risk factor. Residents feared that the water could be contaminated by their neighbours. The drums also get very hot in the summer. All greywater is thrown into a channel where it seeps away. One of the interviewees had no knowledge of the Valley Trust even though the boundary of the Trust was within 150m of the interviewee’s home. It was also claimed that the new dry sanitation systems did not work.

### D3.5.4 Water quality

Six samples of washwater, river water and tapwater were tested in the field for the selected variables and samples were also collected for analysis in a laboratory (Table D3.5).

**Table D3.5: Emaqadeni, Botha's Hill water quality indicators (2005)**

| Water quality indicator | Bath water KN501 | River KZN503 | Laundry: KN505 | Tapstand KN506 | Ponded water KN507 | Stored water KN508 |
|---|---|---|---|---|---|---|
| Total Phosphorous as P (mg/l) | 2.8 | 0.90 | 511 | 1.1 | 21.6 | 0.70 |
| Total Kjeldahl N | 26.3 | 1.7 | 5.0 | 0.70 | 11.3 | 1.0 |
| pH | 9.2 | 8.4 | 9.2 | 7.4 | 9.1 | 7.8 |
| Conductivity (mS/m) | 32.8 | 45.2 | 82.3 | 21.3 | 91.3 | 93.5 |
| Ammonia N as $NH_3$ (mg/l) | 10.5 | <0.15 | 5.3 | <0.15 | 8.7 | 1.2 |
| Dissolved Oxygen (mg/l) | 1.2 | 0.2 | 0.4 | 0 | 0 | 0.1 |
| Oil & Grease | 312 | 4 | 152 | <1 | 216 | <1 |

### D3.5.5 Concluding remarks

There was nothing surprising about the water quality found at this site. Once again greywater was treated as dirty water that should not be touched.

## D3.6 Cato Manor, Durban

### D3.6.1 Background

This site is severely degraded and represents some of the worst conditions seen at any of the settlements visited in this study. The site lies 8km west of the Durban CBD lying at approximately 150m above mean sea level. Gently sloping hills of shale and sandstone drain water from a small catchment towards Durban Bay. The site was chosen because of its close proximity to centre of Durban CBD. Run off from Cato Manor flows into the Mkhumbane River, drains into the Umbilo Canal and ultimately into the Durban harbour.

**Figure D3.12: An informal dwelling at Cato Manor**

**Figure D3.13: Polluted stream east of Cato Manor**

The settlement is a dense, informal establishment. Water is collected from communal tapstands. In general residents have to queue for over 20 minutes to get water. At the time of the field work, RDP houses were being erected close to the settlement.

### D3.6.2 Description of research

A total of 20 interviews were conducted. Interviewees were selected because they were cleaning items in close proximity to their homes. Water samples were taken from rivers on either side of the ridge straddling the houses. Samples were also taken of a ‘first wash’ laundry container.

### D3.6.3 Social findings

The Cato Manor population is poor with low levels of education ranging from Std 2 to Matric, with the average being Std 5 (Grade 7). Most interviewees were unemployed or held very informal jobs.

### D3.6.4 Water quality

Six samples of washwater, river water and tapwater were tested in the field for the selected variables and samples were also collected for analysis in a laboratory (Table D3.6).

**Table D3.6: Cato Manor water quality indicators (2005)**

| Water quality indicator | Polluted River KN601 | Ponded KN603 | Laundry KN604 | River KN605 | River KN606 | Tapstand KN607 |
|---|---|---|---|---|---|---|
| Total Phosphorous as P (mg/l) | 37.2 | 20.4 | 14.4 | 6.9 | 24.6 | 0 |
| Total Kjeldahl N (mg/l) | 189 | 55 | 488 | 42 | 53.2 | - |
| pH | 9.2 | 8.2 | 8.8 | 7.9 | 7.8 | 7.4 |
| Conductivity (mS/m) | 45.4 | 52.8 | 54.3 | 54.3 | 84.3 | 12.7 |
| Ammonia N as $NH_3$ (mg/l) | 61.6 | 33.3 | 7.6 | 19.5 | 25.3 | 0 |
| Dissolved Oxygen (mg/l) | 0.3 | 0 | 0.6 | 0 | 0 | 0.2 |
| Oil & Grease (mg/l) | 3348 | 36 | 108 | <1 | 84 | - |

### D3.6.5 Concluding remarks

High levels of phosphorous were found in the river east of Cato Manor (37mg/l) with associated high levels of Oil and Grease (3348mg/l), and nitrogen (189mg/l). The rivers surrounding this settlement generally appeared to be in a very poor condition.

## D3.7 Eastern Cape and KwaZulu-Natal findings

The following maps give an indication of the types of settlements that were visited in both the Eastern Cape and KwaZulu-Natal as well as an overview of the water quality results obtained:

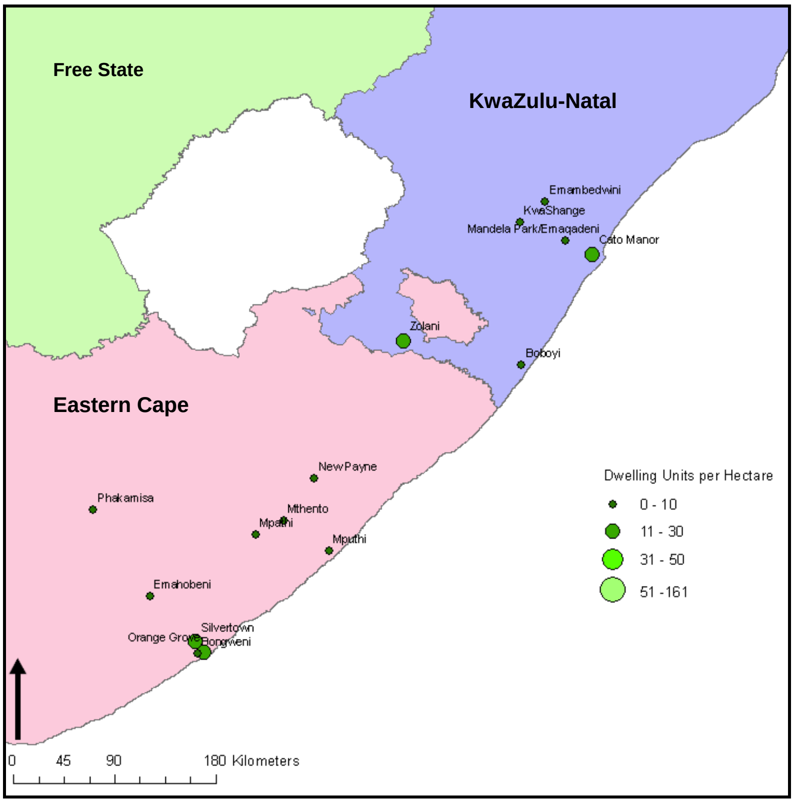


**Figure D3.14: Settlement density figures for Eastern Cape and KZN sites**

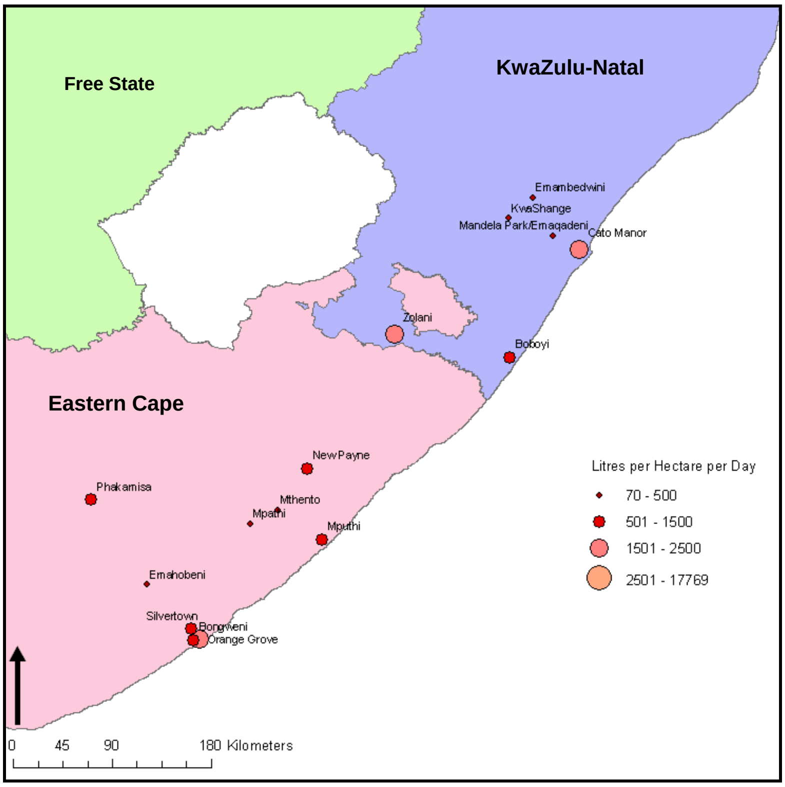


**Figure D3.15: Greywater generation figures for Eastern Cape and KZN sites**

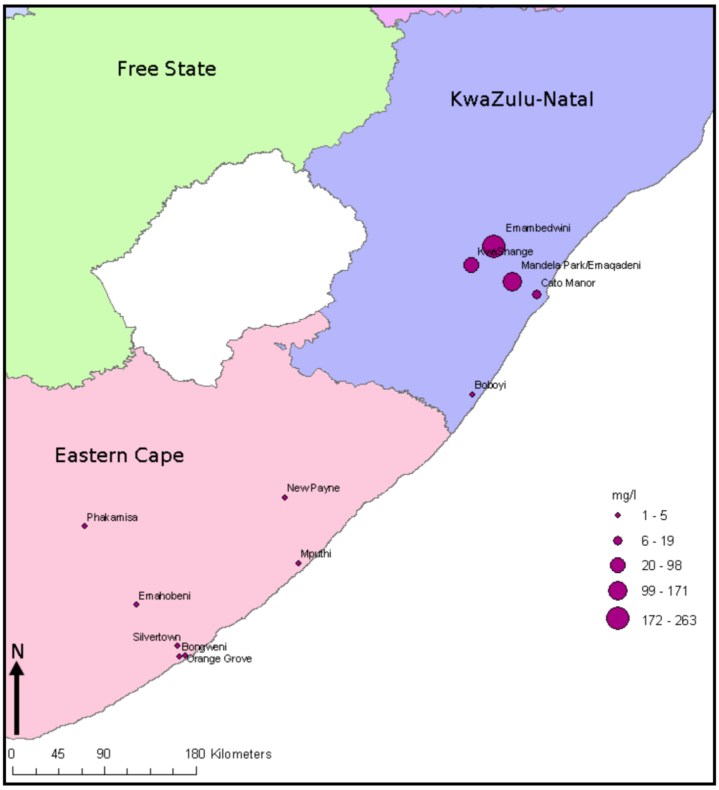


**Figure D3.16: Total Phosphorous figures for Eastern Cape and KZN sites**

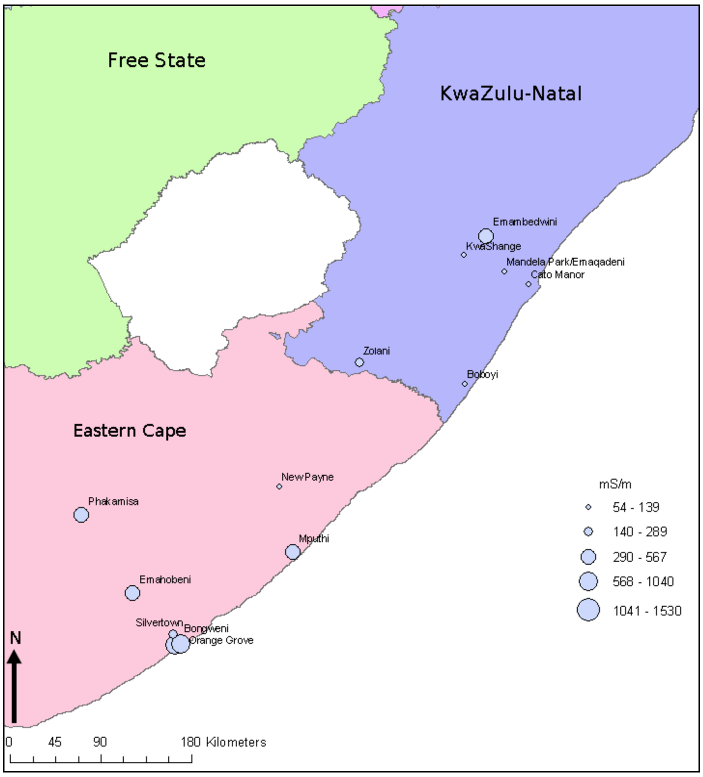


**Figure D3.17: Electrical conductivity figures for Eastern Cape and KZN sites**

# D4. Limpopo site surveys

The Limpopo province was visited during January 2005 during the same period that the surveys were conducted in Mpumalanga. Most of the settlements visited (about 80%) were rural with the remainder being townships and communal authority areas. The surveys focused on the areas around Groblersdal (Leeufontein), Sekhukune (Jane Furse), Polokwane and Potgietersrus (Mahwelereng) as shown in Figure D4.1. It was found that water supply is often from underground sources and is generally well managed although people spend quite a lot of their time fetching water.

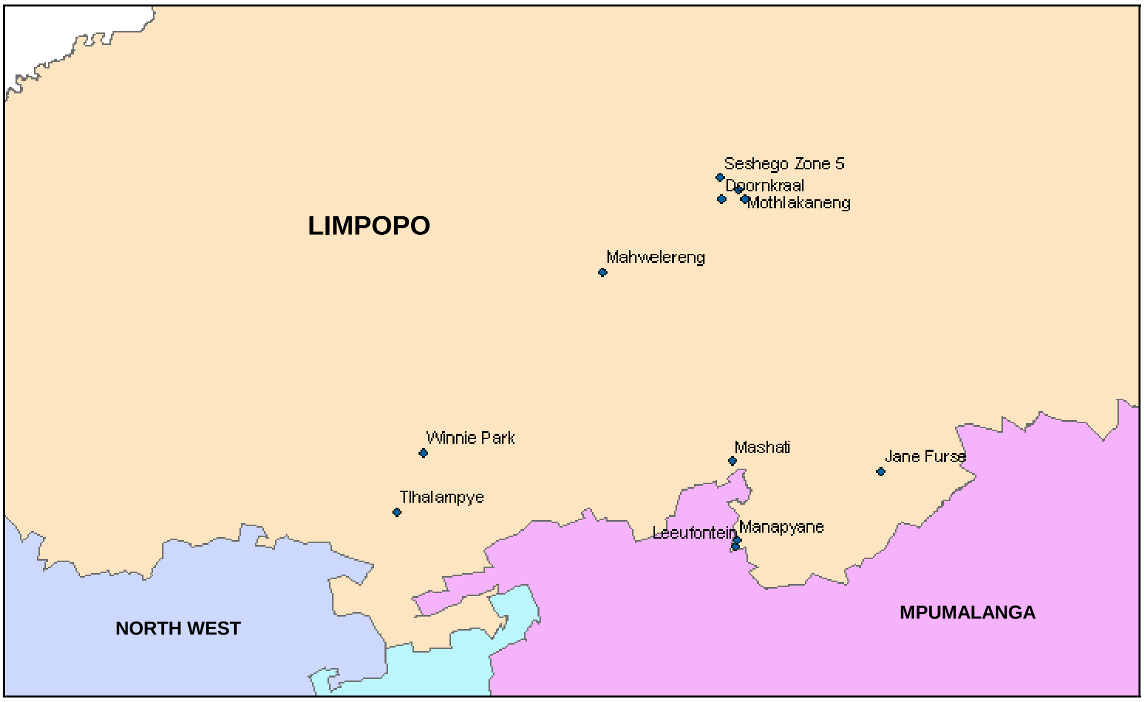


**Figure D4.1: Map of Limpopo province showing selected sites for surveys**

## D4.1 Leeufontein / Manapyane, Groblersdal

### D4.1.1 Background

According to Census 2001, Groblersdal and the settlements in its near vicinity had over 3,000 households which were non-sewered. However, this did not appear to be the case during the 2005 survey. The researchers were eventually guided by commuters, who were waiting at taxi ranks near the city centre, to two small settlements 12km north east of Groblersdal. Leeufontein is a recent housing project with RDP-type housing, while Manapyane is a small village approximately 1km from Leeufontein. Figure D4.2 shows the new housing development at Leeufontein with reasonably spacious yards. In the hot, dry climate of this region, most residents had planted trees and shrubs in their yards to create shaded areas, but greywater was not being used to water these plants. Both settlements used pit latrines and accessed their water from nearby communal tapstands.

### D4.1.2 Description of research

A similar approach was adopted to previous surveys: interviewees were selected because they were involved in washing laundry or dish-washing in their homes or yards at time of the visit. Four interviews were conducted: two at Leeufontein and two at Manapyane.

**Figure D4.2:New housing development at Leeufontein**

**Figure D4.3: Children around the tapstand**

### D4.1.3 Social findings

The average household in Manapyane is nearly double the size of that in Leeufontein. The settlement density at Leeufontein is approximately 5du/ha, while at Manapyane it is closer to 3du/ha. The number of people per household at Leeufontein is 4 compared to 8 at Manapyane. At Manapyane the yards were being used to grow some vegetables, fruit trees and shade trees. Interviewees were however reluctant to use greywater on their crops.

### D4.1.4 Water quality

One sample each of washwater and tapwater from Leeufontein, and one sample of washwater from Manapyane were tested in the field for selected variables, as shown in Table D4.1.

**Table D4.1: Leeufontein & Manapyane water quality indicators (2005)**

| Water quality indicator | Laundry L1 | Laundry M1 | Tapstand: Leeufontein |
|---|---|---|---|
| Conductivity mS/m | 770 | 112 | 73.6 |
| Ammonia N in NH3 (mg/l) | Too dirty | 3 | 0 |
| Total Phosphorous as P (mg/l) | Too dirty | 5 | 0 |
| pH | 10.9 | 9.3 | 8.7 |
| E. Coli (per 100ml) | - | - | - |

### D4.1.5 Concluding remarks

Residents are conscious of water scarcity and the difficulty of having to fetch water from some distance, especially at Manapyane, however they were still reluctant to use greywater.

## D4.2 Jane Furse, Sekhukhune

### D4.2.1 Background

The decision to visit Jane Furse was guided by Census 2001 data, which suggested that over 3,500 households in and around the town were without any form of sanitation. On arrival however, it was difficult to identify these areas. Most areas had had some development and non-sewered areas were difficult to find. Unfortunately, the research team arrived late in the day and municipal officials were not available for consultation. As an alternative, the researchers visited two large, well-established homes near the centre of the town. These homes were supplied with pit latrines. Water supply was available in the yards and reticulated to these houses.

### D4.2.2 Description of research

The researchers relied on by-standers to help identify non-sewered areas in the town. Only one water sample was taken and two interviews were conducted.

### D4.2.3 Social findings

The two selected interviewees represented a high socio-economic sector within the town and are clearly in the minority. The homes were well-established places with well-managed gardens, indicative of households with a reasonable income.

### D4.2.4 Water quality

One sample of dishwater was tested in the field for selected variables, as shown in Table D4.2.

**Table D4.2: Jane Furse water quality indicators (2005)**

| Water quality indicator | Dishwater sample |
|---|---|
| pH | 10.3 |
| Total Phosphorous as P (mg/l) | 1.6 |
| Conductivity (mS/m) | 389 |
| Ammonia (mg/l) | 2.9 |

### D4.2.5 Concluding remarks

The two residents interviewed were aware of water shortages and scarcity and were already using greywater on their plants and grass, but they felt that it had to be managed properly. One interviewee suggested that people should be supplied with large containers for greywater, which could be emptied by the municipality each week.

# D4.3 Doornkraal, Polokwane

## D4.3.1 Background

Doornkraal is a relatively new housing development situated 10km west of Polokwane. It is an area with limited infrastructure located on an old farm, and as such it forms an isolated settlement. Houses are constructed of corrugated iron on plots of approximately $100m^2$. It is estimated that the total population is 500, with an average density of 15du/ha. It is a non-sewered area and there are no communal taps with water being obtained from a well-point. Most residents reported that they needed to walk more than 500m to access this water. This resulted in residents doing their washing at the well point. The potential for greywater to enter the groundwater at this point is very high as can be seen from the results of the water sample tested at this site.

## D4.3.2 Description of research

The researchers were guided to the site by a police officer from Polokwane who appeared to be knowledgeable about settlements surrounding the city. Four interviews were held, while water samples were taken of greywater generated from washing, and one sample taken of the underground water supply.

**Figure D4.4: Doornkraal dwelling**

**Figure D4.5: An unprotected well point**

## D4.3.3 Social findings

Doornkraal is a relatively recent settlement, which was not captured in the 2001 Census. Interviewees reported on their daily struggle of fetching and carrying water from the well point. For most this meant a walk of over 500m, consuming at least two hours of time each day. Given the scarcity of fresh water, the interviewees showed great reluctance to reuse the water and suggested that any water left in containers became contaminated with all kinds of human waste.

### D4.3.4 Water quality

One sample each of washwater and underground water were tested in the field for selected variables, as shown in Table D4.3.

**Table D4.3: Doornkraal water quality indicators (2005)**

| Water quality indicator | Laundry D1 | Underground water source D2 |
|---|---|---|
| Conductivity (mS/m) | 489 | 105.5 |
| Total Phosphorous as P (mg/l) | 5+ | 2.5 |
| Ammonia N as $NH_3$ (mg/l) | 3+ | 2 |
| pH | 9.7 | 7.7 |

The high levels of P and $NH_3$ in the underground water supply is a cause for concern. It is possible that this water is being contaminated by washing water that is tossed onto the ground near to the well point pipeline.

### D4.3.5 Concluding remarks

The difficulty of accessing water influences the quality of greywater. Greywater is treated with extreme caution resulting from the high concentration of chemicals and that residents showed no interest in trying to use this water for other purposes.

## D4.4 Mothlakaneng, Polokwane

### D4.4.1 Background

Mothlakeneng is situated 18km west of Polokwane. It is a high-density area with limited infrastructure. Houses consist of a mixture of corrugated iron shacks on small plots no more than $40m^2$ while others are brick-built structures on larger plots of $80m^2$. It is estimated that the total population is 1,500 with an average density of 25du/ha. It is a non-sewered area serviced with a limited number of communal taps. There was no protection around these taps and consequently the area surrounding the taps was sodden and muddy.

**Figure D4.6: Collecting water from a communal tapstand**

The soil type is clay, rich in iron and other minerals. Residents were observed cleaning their shoes in laundry water because of dust and dirt.

### D4.4.2 Description of research

Four interviews were conducted, while water samples were taken of dishwashing, laundry and tap water.

### D4.4.3 Social findings

Nothing significant to report.

### D4.4.4 Water quality

One sample each of dishwater and laundry water, as well as one sample of tapwater was tested in the field for selected variables, as shown in Table D4.4. Traces of P and $NH_3$ suggest that the tapwater could be contaminated.

**Table D4.4: Mothlakaneng water quality indicators (2005)**

| Water quality indicator | Tapwater M1 | Dishwashing M2 | Laundry M3 |
|---|---|---|---|
| Conductivity mS/m | 99.3 | 189.3 | 202 |
| Total Phosphorous as P (mg/l) | 3 | 5+ | 5+ |
| Ammonia N as $NH_3$ (mg/l) | 0.6 | 3+ | 1.8 |
| pH | 7.8 | 8.9 | 9.9 |

### D4.4.5 Concluding remarks

The amount of effort required to collect water influences the water quality after use and also the perception of the users. Interviewees were very reluctant to use greywater. The levels of P and $NH_3$ are a cause for concern and should be investigated further.

## D4.5 Seshego Zone 5, Polokwane

### D4.5.1 Background

Seshego is a well-established informal settlement situated 15km south-west of Polokwane. The infrastructure is limited but there appears to be good management of the settlement judging by the open spaces between the rows of housing, trees found in open spaces and the well-managed informal roads between the houses. Houses are constructed of corrugated iron on plots of approximately $80m^2$. It is estimated that the total population is no more than 350 with an average settlement density of 10du/ha. It is a non-sewered area and water is supplied at communal taps. Most residents reported that they fetched water from between 200 and 500m from their homes.

The site lies on sandy to clay soils on a gentle gradient within 500 to 800m of a river. Observations of the stream (about 2m wide) revealed that it was gently flowing, clear water, but pools of algae had collected in areas of low flow. It is unlikely however that greywater tossed on the ground at the settlement would have any impact on this stream.

### D4.5.2 Description of research

Three interviews were conducted. Three water samples were taken: two of laundry and one from a communal tap.

### D4.5.3 Social findings

Nothing to report.

### D4.5.4 Water quality

Two samples of washwater and one of tapwater were tested in the field for selected variables, as shown in Table D4.5.

**Table D4.5: Seshego Zone 5 water quality indicators (2005)**

| Water quality indicator | Tapwater S1 | Laundry S2 | Laundry S3 |
|---|---|---|---|
| Conductivity mS/m | 105.5 | 143 | 123.5 |
| Total Phosphorous as P (mg/l) | 1.5 | 5+ | 1.8 |
| Ammonia N as $NH_3$ (mg/l) | 0 | 3 | 0 |
| pH | 8.5 | 8.4 | 8.4 |

### D4.5.5 Concluding remarks

A similar pattern in water quality was detected here relative to the other settlements that were visited surrounding Polokwane. The drinking water had high levels of P and higher than expected levels of Electrical Conductivity (indicating high Total Dissolved Salts). Interviewees were unanimous in treating greywater with caution, although two respondents were using this water on ornamental plants.

## D4.6 New Pietersburg, Polokwane

### D4.6.1 Background

New Pietersburg is an informal settlement on the periphery of Polokwane, approximately 4km west of the centre of town (close to the industrial sector) and has very limited services other than communal water supply points.

The settlement is relatively densely populated with plenty of makeshift shelters towards the outskirts. It is estimated that 800 to 1,000 people inhabit the settlement with a settlement density of over 18du/ha.

The settlement lies on gentle gradient leading down to the river which is approximately 800m from the nearest house. The soils are sandy-clay. It is unlikely that greywater would have any direct impact on the river.

### D4.6.2 Description of research

The researchers visited the site late on a Sunday afternoon. Some washing was taking place but most inhabitants were either watching a local soccer match being played on a green belt between the settlement and the river, or were fetching water. The researchers interviewed three people doing washing at the time. A greywater sample was taken from a laundry container and high levels of P and Electrical Conductivity were noted. It was interesting to note that tapwater samples taken from three separate tapstands also revealed similar high values for P and EC, indicating some form of pollution of the water source.

**Figure D4.7: A well-manicured garden in a degraded squatter settlement**

### D4.6.3 Social findings

Residents were not happy with the conditions in the settlement. One interviewee complained of the unsanitary conditions and general dirt that characterized the settlement. They felt that it was unsafe and their health was at risk. All interviewees felt that greywater should be thrown away because it was unsafe. One inhabitant had a very neat garden and used greywater on occasion on her plants (Figure B4.7). Also of interest was the residents' desire to learn more about greywater as illustrated by comments such as, "Give us more education", or "Teach us how to handle it".

### D4.6.4 Water quality

Three samples of tapwater and one of laundry water were tested in the field for selected variables, as shown in Table D4.6.

**Table D4.6: New Pietersburg water quality indicators (2005)**

| Water quality indicator | Tapwater NP1 | Tapwater NP2 | Tapwater NP3 | Laundry NP4 |
|---|---|---|---|---|
| Conductivity mS/m | 102.5 | 110.8 | 110 | 153 |
| Total Phosphorous as P (mg/l) | 3.8 | 3.8 | 3.8 | 5+ |
| Ammonia N as $NH_3$ (mg/l) | 0 | 0 | 0 | 3+ |
| pH | 7.9 | 7.8 | 7.8 | 8.9 |

### D4.6.5 Concluding remarks

It is difficult to properly assess the quality of the greywater owing to the fact that there are high levels of both Phosphorous and Electrical Conductivity in the water supply. The water supply to this settlement in particular, requires further testing and investigation.

## D4.7 Mahwelereng, Potgietersrus

### D4.7.1 Background

The Potgietersrus area was selected because Census 2001 data indicated that over 3,000 inhabitants in the municipal district were without sewerage facilities. The researchers were unable to establish how much work had been done in the interim to address the situation; nevertheless it proved relatively easy to find areas which were non-sewered. Mahwelereng is situated less than 4km from the centre of town. It is a well established formal settlement on the periphery of Potgietersrus.

### D4.7.2 Description of research

The researchers collected information in the usual manner. Four interviews were conducted and three water samples were taken: two from laundry washing and one from a tapstand.

**Figure D4.8: Disposing of greywater down a pit latrine**

### D4.7.3 Social findings

The community appeared to be well organized. Interviewees indicated that community structures were in place and there was a sense of community interest and pride in the area. Homes and yards were neat and orderly. In general, people had settled here for lengthy periods and in the case of 3 interviewees, for over 8 years. All these respondents were conscious of water scarcity and the need to save water. Some used greywater on ornamental plants and even on vegetables. People were observed disposing of excessively dirty greywater down the pit latrines and also using the cleaner greywater to clean the toilet seat.

### D4.7.4 Water quality

One sample of tapwater and two samples of washwater were tested in the field for selected variables, as shown in Table D4.7.

**Table D4.7: Mahwelereng water quality indicators (2005)**

| Water quality indicator | Tap water MH3 | Laundry MH1 | Laundry MH2 |
|---|---|---|---|
| Conductivity mS/m | 65.9 | 89.9 | 124 |
| Total Phosphorous as P (mg/l) | 0.5 | 5+ | 5+ |
| Ammonia N as $NH_3$ (mg/l) | 0 | 0.5 | 2.5 |
| pH | 7.8 | 9 | 9.3 |

### D4.7.5 Concluding remarks

Nothing unusual was noted at this site other than the effort on the part of the individuals to use greywater where possible to their best advantage. In one case, it was being used to grow vegetables but only if the water was sufficiently diluted. The researchers were impressed with the experience of the interviewees with respect to the use of greywater.

## D4.8 Mashati, Potgietersrus

### D4.8.1 Background

The village of Mashati is best described as a peri-urban area although it is situated approximately 18km from the town of Potgietersrus. Houses are placed on large plots of 800$m^2$ or more in a typical grid-iron pattern. The streets between the houses are wide and give a sense of space. There are mature trees throughout the settlement and the river, situated about 1km to the north of the centre of the settlement, also adds to the tranquility of this place. Some of the interviewees had lived in Mashati for over 30 years. Many were involved in tending their plots of maize, vegetables and plants. The soil was found to be loamy clay and rich in oxides, judging by its red colour.

### D4.8.2 Description of research

Four interviews were conducted. Two water samples were taken and analysed in the field and also one sample from a borehole in the yard of one of the interviewees.

**Figure D4.9: A traditional house in the background with maize in the foreground**

### D4.8.3 Social findings

The social circumstances are more typical of a rural area in which households are headed by an elderly person, usually a grandmother, and in which the immediate children are working elsewhere while the grandchildren are being looked after by the elders. Food is produced from the available land in the yards.

The population of Mashati is estimated at 350 people, while density is low at about 3du/ha. There is ample space to dispose of greywater or to use it for other purposes.

### D4.8.4 Water quality

Two samples of laundry water and one sample of the borehole water that was being used for drinking purposes were tested in the field for selected variables, as shown in Table D4.8.

**Table D4.8: Mashati water quality indicators (2005)**

| Water quality indicator | Borehole MT1 | Laundry MT2 | Laundry MT3 |
|---|---|---|---|
| Conductivity mS/m | 104.6 | 248 | 330 |
| Total Phosphorous as P (mg/l) | 0.3 | 5+ | 2 |
| Ammonia N as $NH_3$ (mg/l) | 0 | 3+ | 1 |
| pH | 7.7 | 10.6 | 10.3 |

### D4.8.5 Concluding remarks

The interviewees indicated that they were not in favour of using greywater for irrigation purposes. They have found that it kills their crops (maize was identified as one crop that wilts and dies with soapy water).

# D4.9 Winnie Park, Nylstroom

## D4.9.1 Background

Winnie Park is a settlement that was developed over the last 2 years as a site-and-service plan. It is situated 12km south west of Nylstroom. The inhabitants have been supplied with housing materials and most houses are simple in their construction, mostly decked with corrugated iron. Yards are fenced off. The soil is sandy with very little vegetation (trees) offering much shade or protection from the sun. Each house has a pit latrine and a communal tap within 200m of the dwelling. Concrete slabs have been placed around these taps and the run-off is observed to be significant. The area is generally flat with no waterbodies in the nearby vicinity.

## D4.9.2 Description of research

The researchers arrived late in the day to seek interviews, but still managed to find a number of people busy washing and cleaning in their yards at about 16h00. Four people were interviewed. A sample of laundry washing water was tested as well as sample from a tapstand.

**Figure D4.10: An example of care taken in keeping yards tidy**

## D4.9.3 Social findings

There is little to report on this aspect of the visit other than it was noted that the inhabitants took pride in their homes as is evident in Figure B4.10. In general, yards were well-kept and a number of residents were seen sweeping the yards. Residents had also made an effort to grow plants in their yards. In two cases, the interviewees reported that they had dug holes in their yards to dispose of their greywater.

## D4.9.4 Water quality

One sample each of washwater and tapwater were tested in the field for selected variables, as shown in Table D4.9.

**Table D4.9: Winnie Park water quality indicators (2005)**

| Water quality indicator | Tap stand WP2 | Laundry WP1 |
|---|---|---|
| Conductivity mS/m | 42 | 234 |
| Total Phosphorous as P (mg/l) | 0 | 5+ |
| Ammonia N as $NH_3$ (mg/l) | 0 | 3+ |
| pH | 8.3 | 10.1 |

The water quality from the one communal tap that was sampled appears to be of excellent quality.

### D4.9.5 Concluding remarks

The availability of communal tapstands placed strategically around the settlement has meant that people spend less than 30 minutes per day collecting water. This availability also means that people are putting clean water on their gardens and do not see much point in using dirty water on their plants. Nevertheless, the interviewees were well aware of the value of water and did feel that conservation was important.

## D4.10 Tlhalampye, Bela Bela

### D4.10.1 Background

The site is situated 8km north east of Bela Bela. It is an adjunct to the much older former township of Warmbaths. It is an informal settlement with site-and-service infrastructure providing pit latrines and communal water taps. The layout of the settlement was found to be poor, with shacks scattered about rather than following the usual grid pattern. The scarcity of taps provided work for some in that water was being transported to homes by donkey cart. The surface soils are sandy and flat. There were no visible waterbodies in the nearby vicinity.

**Figure D4.11: Transport of water on donkey cart**

**Figure D4.12: Well-managed yard where greywater is used to water the garden**

### D4.10.2 Description of research

The researchers arrived in the early morning with the intention of interviewing people doing their first washing chores of the day. Water samples were taken from dishwater and from laundry washing. Four people were interviewed using the standard structured questionnaire.

### D4.10.3 Social findings

The population of this section of the township, called Tlhalampye is approximately 300, with a settlement density of about 4du/ha. The sandy soil meant that people were not troubled by greywater and were able to toss it on the ground without attracting flies or mosquitoes because it infiltrated quickly.

Most people appeared to be unemployed and in at least one case, the interviewees were living in very severe and squalid conditions (overcrowded and dirty). By contrast, one of the interviewees presented a neat yard with well-established flowers and shrubs and claimed to regularly water the plants with greywater.

### D4.10.4 Water quality

One sample each of tapwater, dishwater and laundry water were tested in the field for selected variables, as shown in Table D4.10.

**Table D4.10: Tlhalampye water quality indicators (2005)**

| Water quality indicator | Tapstand T1 | Laundry T2 | Dishwater T3 |
|---|---|---|---|
| Conductivity mS/m | 56 | 845 | 770 |
| Total Phosphorous as P (mg/l) | 0 | 5+ | 3.5 |
| Ammonia N as $NH_3$ (mg/l) | 0 | 3+ | 2.2 |
| pH | 7.8 | 10.7 | 7.9 |

### D4.10.5 Concluding remarks

The water supply appears to be of a high quality. Greywater does not appear to be a problem given the space available to dispose of it and the sandy soil conditions.

# D5. Mpumalanga site surveys

The Mpumalanga site surveys were undertaken together with the visits to Limpopo province during January 2005 and included two semi-rural settlements in the areas around Witbank (Masakane) and Middelburg (Doornkop). Figure D5.1 is a map of the province showing the positions of sites visited.

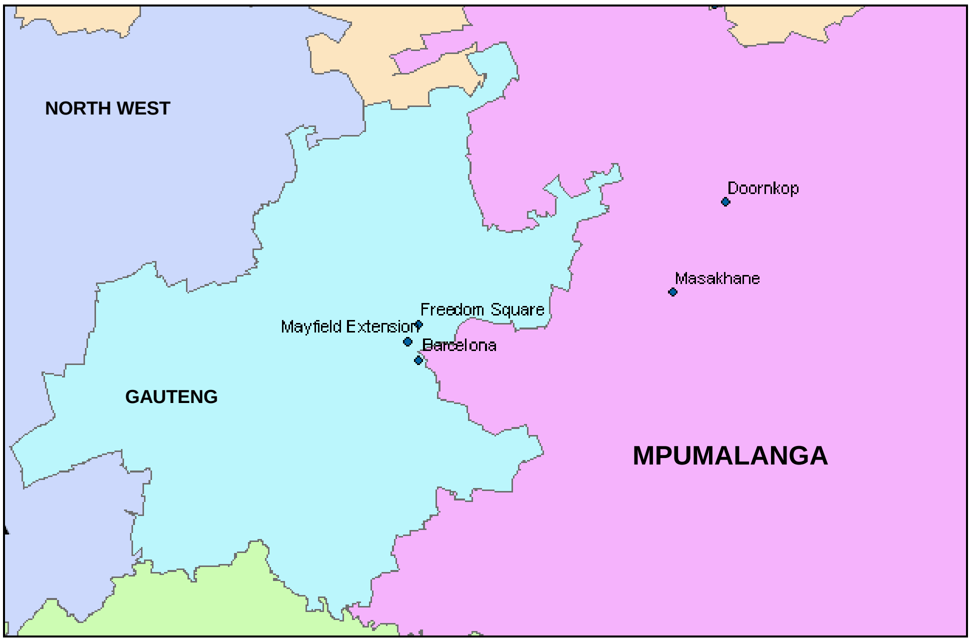


**Figure D5.1: Map of Mpumalanga province showing selected sites for surveys**

## D5.1 Masakhane, Witbank

### D5.1.1 Background

The researchers were directed to Masakhane after discussions with municipal officials at Witbank (Water Services Division). The research team was informed that this was the only site in the near vicinity of Witbank that did not have waterborne sanitation. Masakhane is a peri-urban settlement situated 8km west of Witbank. Most houses are shacks built from corrugated iron and wood, but there are also brick structures. Designs varied a great deal. There was very little evidence of attempts to grow produce from gardens. Properties were generally 400 to 500m$^2$ with the actual house taking up about 50% of this area. Thus, there was ample space that could be used to grow produce. It is estimated that the settlement density was 15du/ha.

### D5.1.2 Description of research

Initially the rainy weather conditions made it difficult to find people with whom to conduct interviews. Eight interviews were eventually conducted. Water sampling and testing was confined to field test assessments only.

**Figure D5.2: Drawing water from an unprotected spring**

**Figure D5.3: Greywater stored to feed pigs**

### D5.1.3 Social findings

Interviews indicated that household income was in the order of R401-R800 per month. Water is not supplied to homes. Most people fetch their water from an unprotected well point or from a local spaza shop whose owner pumps water from a borehole into a 5000*l* tank for everybody's use without any charge.

On average, residents reported spending between 1 and 2 hours fetching and carrying water every day. There was no desire to reuse water other than in one case where water was stored to feed to pigs.

### D5.1.4 Water quality

Five samples of dishwater, laundry water and stored greywater were tested in the field for selected variables, as shown in Table D5.1. No samples were tested of the tapwater in Masakhane.

**Table D5.1: Masakhane water quality indicators (2005)**

| Water quality indicator | Laundry M1 | Laundry M2 | Dish washing, M6 | Stored greywater used to feed pigs, M4 | Dishes M5 |
|---|---|---|---|---|---|
| Conductivity mS/m | 176.3 | 153.7 | 143.6 | 1346 | 310 |
| Total Phosphorous as P (mg/l) | 5+ | 4 | 5+ | Too discoloured | 4 |
| Ammonia N as $NH_3$ (mg/l) | 3 | 2 | 3+ | Too discoloured | 3+ |
| pH | 9.8 | 9.9 | 6.5 | 7.5 | 3.3 |

### D5.1.5 Concluding remarks

Seven out of eight interviewees were in favour of water being re-used and recycled, but only after it was properly managed. Some suggested that storage containers are required to manage the situation properly. This preparedness to recycle was unusually high compared to other sites. The shortage of water and difficulty of access may however influence this preparedness.

## D5.2 Doornkop, Middelburg

### D5.2.1 Background

The researchers initially visited the Middleburg town municipality, but were unable to arrange an interview with the manager from Water Services. Later, a meeting was held with the Town Clerk who is enthusiastic about the municipality's role in peri-urban renewal programmes, which are promoting densification and improvements in service provision. Unfortunately these plans have yet to reach fruition and the researchers were unable to visit any sites under construction. The researchers were also informed that there were no non-sewered areas on the periphery of Middelburg. It was advised that the nearest site to Middelburg was Doornkop. This was verified the next morning during site visits to two informal settlements to the south of the city. These settlements were all sewered.

Doornkop is situated 18km north of Middelburg. It is a rural settlement that falls under a tribal authority. Homesteads are larger brick structures on plots of approximately 800 to 1,200m$^2$ and the settlement density is estimated at approximately 6du/ha. In many cases, produce is grown on the property and includes vegetables, maize and fruit trees. Communal land adjacent to the settlement is used for grazing cattle. Water is obtained from an underground supply. It is pumped into two large 5,000*l* tanks. On average people spent between 15 to 30 minutes per day fetching water over a 50 to 100m distance. Four water samples were taken and tested in the field.

**Figure D5.4: Large open areas in properties with communal land in background**

**Figure D5.5: Interview held with residents among the fruit trees**

### D5.2.2 Description of research

As explained earlier the researchers were advised to visit Doornkop by the Town Clerk of Middelburg Municipality. Once again, interviewees were selected because they were washing laundry at the time of the visit. Four interviews were held.

### D5.2.3 Social findings

The interviewees appeared to have made this rural settlement a lifestyle choice. Most interviewees did not have work other than finding various means of subsisting under these circumstances. Education levels were relatively high. No-one offered an estimate of household income. Residents appeared largely content with their situation despite the efforts required to fetch water daily.

### D5.2.4 Water quality

Four samples of tapwater and washwater were tested in the field for selected variables, as shown in Table D5.2.

**Table D5.2: Doornkop water quality indicators (2005)**

| Water quality indicator | Tapstand | Laundry D1 | Laundry D2 | Laundry D3 |
|---|---|---|---|---|
| Conductivity mS/m | | 53 | 94.5 | 229 |
| Total Phosphorous as P (mg/l) | | 5+ | 5+ | 5+ |
| Ammonia N as $NH_3$ (mg/l) | | 3+ | 2.8 | 3+ |
| pH | 8.8 | 9.3 | 9.7 | 9.8 |

### D5.2.5 Concluding remarks

Interviewees were conscious of water shortages and scarcity. They indicated a willingness to conserve water. However, the overwhelming impression was that greywater was dirty, even toxic, and could not be used.

# D6. Gauteng site surveys

The Gauteng site surveys took place at the beginning of July 2005 and were focused on the East Rand area, as shown in Figure D6.1.

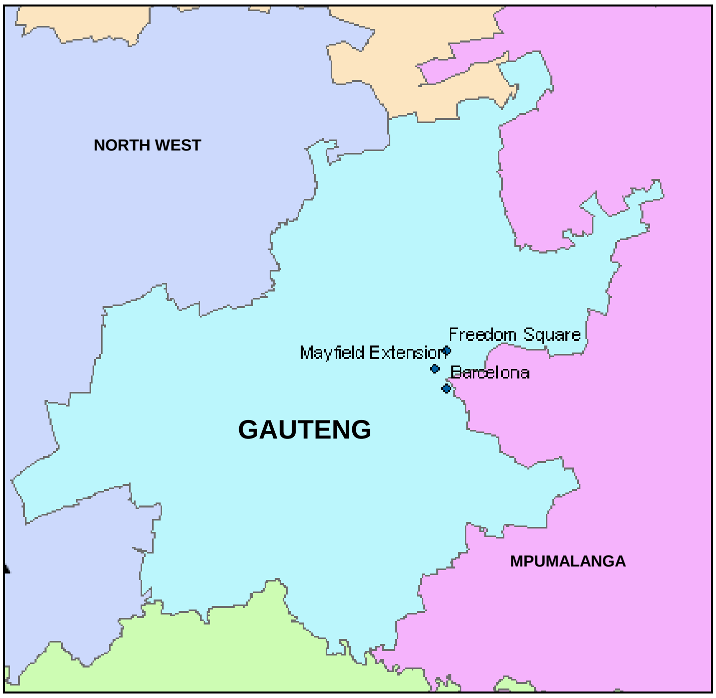


**Figure D6.1: Map of Gauteng province showing selected sites for surveys**

Gauteng province is the most urbanized of the provinces in South Africa, and the East Rand area i.e. Ekurhuleni Metropolitan Municipal Council (EMMC) in which the surveys were conducted, is a major mining and industrial area. Although the whole of the EMMC area was once grassland through which a few rivers flowed, today the various urban and industrial developments have so transformed the landscape that most of it can no longer be described as natural (according to land use patterns recorded in 2000, only 43 percent of the land in EMMC is still natural). The non-sewered areas visited were all informal settlements whose inhabitants either work or seek work in the nearby industrial centres of Benoni and Boksburg.

Mining has had the greatest impact on the environment, including the water quality in and the flow patterns of rivers and streams in this area. The most important surface water systems in the part of the East Rand that was surveyed are the Blesbokspruit and Grootvlei rivers. These rivers flow through the Benoni / Daveyton area south through Springs and the outskirts of Nigel to the Vaal River. The Blesbokspruit is particularly important for its RAMSAR site status, as is the Marievale Nature Reserve. Both of them are threatened by discharges of excess minewater from Grootvlei and other mining areas, as well as agricultural inflows from the smallholdings and sewage effluent from Daveyton and informal surrounds.

Freedom Square informal settlement is situated in the catchment area of the Kaalspruit / Olifantspruit, which flows north into Midrand joining a tributary from the Clayville industrial area. There are many other informal settlements apart from Freedom Square in this area, some of which are situated along river banks and they are all seen as causes of high microbial contamination in the rivers. However, as already noted for Daveyton, the water pollution from the squatter settlements is part of a larger urban problem. Other contributors to this pollution include mining and other industries, municipal sewage reticulation and sewage treatment works as well as agricultural runoff (Dept of Environmental Affairs & Tourism, 2003).

There are many in-stream dams located on the watercourses and tributaries which were mainly created for agricultural or mine water storage. Indeed, the towns of Benoni, Boksburg and Springs are all famous for their dams, golf courses and boat clubs that use the water. There are also a number of endoreic pans (collecting water but having no primary outflow, for example Bullfrog Pan) in the EMMC, pans which occur within more urbanised areas, e.g. Homestead Lake and Rynfield Dam and those that were dammed for mining purposes, e.g. Leeuwpan, Jan Smuts, and Rolfes Pan in Jetpark.

Although many of the wetland habitats in the EMMC have been degraded and some lost altogether, they represent one of the most important ecosystems in the area due to their substantial hydrological, biological or ecological role in the natural functioning of the catchments in the Metro. Many of the watercourses and pans form part of these wetlands, most notably is the man-made Blesbokspruit wetland system, which is one of the larger wetland systems in the highveld and part of which (near to Springs) is the designated RAMSAR site (1996).

## D6.1 Mayfield Extension

### D6.1.1 Background

Mayfield Extension informal settlement is laid out on a grid pattern approximating what could be considered the normal RDP township pattern, with most of the houses consisting of informal dwellings constructed with metal sheets. It is less densely settled than some informal settlements with about 254 dwellings (approximate population of 1,016 people) on about 8ha of land (i.e. 32du/ha), and is situated near Daveyton on the East Rand. Mayfield gives the impression of potentially developing into a permanent settlement once it has been upgraded as there are neatly laid-out stands with ample space within and between the yards for the location of the experimental dry sanitation toilets that are currently being piloted in the area. Not all parts of the settlement have these toilets however, so most people are still using unventilated plain pit latrines and there are communal standpipes for water supply.

Annual rainfall in the area amounts to approximately 600mm and the settlement is situated within the 50-year flood plain of the nearest river, which is about 200m from the closest shack. The depth to the water table was reported as about 1.2m during the wet season.

### D6.1.2 Description of research

Between Friday 2 July 2005 and Monday 4 July 2005 a team consisting of a key researcher and two student research assistants worked on the East Rand (Gauteng) conducting research on greywater management in the area. It was decided to focus on settlements where on-going trials were being conducted on three different models of dry sanitation toilets. Some time was spent during the first day at the Benoni offices of the Ekurhuleni Metropolitan Municipal Council (EMMC) and discussions were held with members of their Water Department. Interviews were then conducted in the Mayfield Extension informal settlement; a reporter from the WRC's Water Wheel accompanied the team to take pictures of the fieldwork and file a report for the magazine

Preliminary assessments of settlement characteristics were made possible by way of faxed questionnaires that were sent to municipal officials before the visit and these were discussed with staff members at the Boksburg offices of the EMMC on 2 July 2005.

**Figure D6.2: Garden in Mayfield Extension**

### D6.1.3 Social findings

There was evidence of some gardening in Mayfield with attempts to maintain tiny patches of green lawns, flower and vegetable gardens, fruit trees and hedges with varying degrees of success. At the time of the visit the region was in the middle of the dry winter season and much of the vegetation was dead, but around some of the houses gardens seemed to be relatively well maintained. Greywater was used more for keeping down the dust than for irrigation but where it had been used to irrigate gardens; grey detergent residues were visible on the surface suggesting a build up of salts and oils. The amount of greywater generated by most Mayfield households was relatively low – lower than it would have been had the water supply been more reliable. Rivers of run-off were therefore not observed in this area due to the lower population density and the dry taps in many parts of the settlement. Adding to the problem of controlling dust in the settlement, the residents also complained about the lack of a proper drainage system and reported that during the summer rains the water table rises and floods the pit latrines. It appears that the area has large areas of dolomite, which causes the problems with drainage.

Although people were aware of the concept of recycling, the use of greywater was a totally new concept and the responses to the questions about its usability were hesitant. More information will be required before their perceptions can be taken as a serious measure of their opinions. Indeed the researchers were asked several times if they thought the water was usable. In the event that the use of greywater around the household was to be promoted by the local authorities, they would need to provide detailed information on the safest ways of using greywater. At present there are trial and error use patterns evident but by and large greywater is not considered to be a major resource.

### D6.1.4 Water quality

One sample each of tapwater and washwater were collected for analysis in a laboratory (Table D6.1).

**Table D6.1: Mayfield Extension water quality indicators (2 July 2005)**

| Water quality indicator | First wash GP0101 | Tap water GP0102 |
|---|---|---|
| Total Phosphorous as P (mg/l) | 240 | <0.10 |
| Total Kjeldahl N | 43 | <1.0 |
| pH | 9.8 | 8.2 |
| Conductivity (mS/m) | 653 | 272 |
| Ammonia N as $NH_3$ (mg/l) | 21.8 | <0.15 |
| Dissolved Oxygen (mg/l) | 0.6 | 0.3 |
| Oil & Grease | 1484 | 36 |

## D6.2 Freedom Square

### D6.2.1 Background

Freedom Square informal settlement is a very densely populated urban settlement near Tembisa on the East Rand with about 1,050 dwellings (approximate population of 4200 people) on about 6.5ha of land. This settlement appears chaotic compared to Mayfield Extension, and completely unplanned with dwellings so closely built next to one another that the new experimental toilets had to be built on the periphery of the settlement owing to the lack of space between the houses. According to one of the consultants employed on the dry sanitation project, Freedom Square with 162du/ha (and not Mayfield with only 32) is considered to be typical of the informal settlements in the EMMC area. It is very likely however that this whole settlement will be relocated at some point in the future, even though the current site is convenient for working people wishing to stay near their employment centres. The high-tension electricity pylons that pass over the houses are enough of a health hazard to warrant relocation, but in any case the people’s sense of insecurity is reflected in the lack of order in building. Security and crime issues were cited by many as the most important issues that they would like the local authority / government to address, e.g. the new toilets located on the edge of the settlement were considered out of bounds after dark because thieves and rapists lay in ambush there.

Annual rainfall in the area amounts to approximately 500mm and the settlement is situated about 800m from the nearest surface water body. The depth to the water table was reported as about 1.5m during the wet season.

## D6.2.2 Description of research

Freedom Square was highly recommended by the EMMC officials as a settlement where interesting things were happening with regard to service delivery and where the community was integrally involved in the selection, testing and possibly modification of the three models of waterless toilets being piloted by the Council. Freedom Square is also considered to be a typical Gauteng informal settlement in terms of the density of the population and general lack of facilities.

As with the other sites visited, water samples were collected and interviews were conducted of (mainly) women who were doing their laundry at the communal tap, and others who expressed interest. The local committee leader was also interviewed and he provided an overview of the political processes around sanitation as well as certain environmental issues in the settlement.

**Figure D6.3: Greywater disposal down stormwater manhole**

**Figure D6.4: Stormwater drain at Freedom Square**

## D6.2.3 Social findings

Owing to the high density of houses in Freedom Square, there were no noted attempts at gardening. However, as usually happens when a large number of people are disposing of their wastewater on the ground, streams of water have formed, which in this case could end up in other people's shacks. It was agreed amongst the residents therefore that all greywater should be carried from the homes and deposited in the stream that takes runoff from the standpipes to the stormwater drain near the main road. Many women did their washing at the standpipes and thus dumped their laundry water into the overflow from the taps. Smaller amounts of greywater from the kitchens were probably just thrown onto the sand near the houses but some children were also observed carrying buckets of greywater to the stormwater drain as agreed. In one case it was noted that a woman whose house was situated near a stormwater manhole was using the manhole to dispose of large amounts of laundry water. Some plastic bags and other solid waste also ended up in the manhole owing to the fact that the main refuse dump was on the outskirts of the settlement, near the toilets.

## D6.3 Barcelona

### D6.3.1 Background

Radical elements belonging to the ANC and PAC are said to have been behind the 1993 land invasions that resulted in the creation of Barcelona, a squatter camp near Daveyton. Plots were apparently sold to people and promises made regarding the delivery of services after the elections. PAC officials were also associated with squatter settlements in other parts of the EMMC area which they justified ideologically as repossession of lost ancestral lands. A newspaper report suggested that "…an ANC self-defence unit member was selling stands for R45, while (a PAC activist was) selling stands for R80. The funds were not being handed over to any organisation, and both enriched themselves in the process." (Donaldson, A., 2001). Be that as it may, the informal settlement of Barcelona (probably named after the Barcelona Olympics of 1992) is seen as a spill-over of Daveyton township. As the backyard shacks became overcrowded and new migrants arrived continuously from the rural areas, Daveyton township was extended in several directions. The Etwatwa extension has formal housing but the great majority of the "surplus" population ended up in the squatter settlements.

Barcelona is situated on a large plain which turns into a swamp in the wet season. It is, like Mayfield Extension, also laid out on a grid pattern reflecting both an orderly distribution of plots (i.e. local organization either by the rogue politicians or by grassroots campaigns) and anticipation of legalization and the provision by local government of RDP houses. However, Barcelona unlike Mayfield does not have the old eucalyptus trees that the mining companies planted in order to draw down the water table and still has the natural vegetation of local grassland. As the settlement grows, even the low lying areas that people have avoided thus far when putting up their houses may be invaded thereby affecting both surface and underground water.

According to the Ekurhuleni State of the Environment Report (Department of Environmental Affairs and Tourism, 2003), the squatter settlements around Daveyton township require special attention as they may be contributing to the deterioration of wetlands on the Blesbokspruit which is a tributary of the Vaal. It was reported that generally however, it is the mining, manufacturing and commercial industries that are the main reason for the mushrooming of formal and informal residential settlements in this area are collectively to blame for:

- Elimination/transformation and fragmentation of natural habitats to create urban landscapes.
- The fact that the Rocky Highveld and Moist Cool Highveld grasslands have been fragmented by the conversion of natural habitats into man-made structures.

- The filling in of pans in the EMM for urban development, and the isolation of wetlands and surface waterbodies. These pressures have all lead to losses of ecosystem function and biodiversity. Fences and walls on the edges or across pans also prevent natural migration of adult and juvenile Giant Bullfrog species between foraging areas and suitable breeding sites.
- Poor services in impoverished settlements which have lead to sewage pollution (no proper sanitation), litter and solid waste pollution (no / poor waste collection services) and deteriorating water quality in surface water bodies. The informal settlements in the Daveyton area are therefore contributing to the deterioration of the RAMSAR site on the Blesbokspruit.

## D6.3.2 Description of research

Barcelona differs from the other two sites in not having the dry sanitation testing project and also by being located on a previously undeveloped, thus natural landscape. Interviews were conducted with men and women found using water for laundry, to water their gardens or fetching water at the standpipes. The opinions of those who were just sitting outside their houses were also sought. As with the other sites samples of the greywater were also collected.

**Figure D6.5: Vegetables growing in Barcelona**

## D6.3.3 Social findings

It is very difficult to plot the movements of residents of informal settlements, especially as that was not the aim of this project. It was noticeable however that some of the owners of houses also had residential addresses elsewhere in the Johannesburg area, either to be near schools or work. It would seem therefore that some of the people that invest in a stand may not necessarily be homeless. It also means that the population fluctuates though probably not enough to register major differences in water use patterns.

As in Mayfield, there were visible signs of attempts to keep small patches of lawn (which were mainly brown on account of the dry winter conditions) as well as hedges, flower and vegetable gardens and the odd peach tree. Clearly the township model of maintaining one's yard is well known but it is too difficult to fully attain when using communal water points and when water supplies are irregular. Thus, although there are always a few determined households that invest time and effort in creating a garden and improving their landscape, most wait for proper housing before making the effort. The more secure the claim on the land and the more stable the household the greater the likelihood of gardening. Bachelor shacks in other words are neglected whereas family ones tend to have better kept surroundings. The use of greywater to irrigate lawns or flowers is not considered normal behaviour. Not only is the water dirty, it is argued, but the people in formal housing do not use it. Tossing it out onto the dusty ground is therefore considered the normal use for greywater.

## D6.4 Concluding remarks from Gauteng surveys

Most of the people interviewed were hearing about greywater for the first time but were vaguely familiar with the concept of recycling as an environmental intervention. The research assistants even had some difficulty translating the greywater recycling concept although residents seemed to be aware of the concept of water reuse as illustrated by the practice of putting a bucket of water to multiple uses before discarding it as dirty. In Mayfield, the people said the water table is shallow and when it rains even the pit latrines become waterlogged. Clearly then, tossing greywater on the ground will only add to the pools of stagnant water. Barcelona was also situated in an area of flooding, especially the low-lying outskirts of the settlement. Freedom Square on the other hand was at the end of a main road and all its runoff ended in the stormwater drains. In all these sites therefore, greywater was neither a resource nor a major inconvenience at the time of the research. More important issues for the residents were the reliability of the water supply, toilet facilities, and especially in Freedom Square, the lack of security, particularly at night.

Various problems were encountered with the communal facilities and particularly the experimental toilets. In the EMMC as in most other councils, planners and consultants assume that every informal settlement constitutes a community. First and foremost a community is not a given but is constructed around a common interest or goal. When people from different parts of the country simply congregate in a particular area in the hope of finding employment this does not generally constitute enough of a sense of community for them to be mobilized into campaigning for the provision of water and sanitation services and for a healthy environment for them to live in.

It has been observed that water standpipes and communal toilets are sometimes vandalized for no apparent reason. In contrast to this, people in other areas have taken the initiative to repair broken pipes and taps themselves, dig drainage ditches and dump their greywater and solid-waste in dedicated disposal areas. In general however, the majority of South Africans associate post-apartheid urban life with RDP houses as the minimum standard. Each homeowner therefore expects to have his/her own water supply point and toilet, and so preliminary evaluations of the EMMC dry sanitation pilot reported that:

- "In most cases it was found that members of households where the toilet was installed were the ONLY users (emphasis added) of systems…"

- "…we found in Mayfield that instead of four households sharing a toilet as planned, this was not easily implemented because each plot was usually fenced off and some had razor wire all round. So if the owners of the house are away then the toilet was also out of bounds." For whatever reasons some neighbours could be involved in a dispute and "stop talking to each other" during which time they would, of course, not be in a position to share access to the toilet.

The EMMC consultants also confirmed the project team's observations that when there was no clearly-defined responsibility for the cleaning and maintenance of the communal facilities everyone tended to stop cleaning them with the result that they either became unusable or the private property of whoever took the initiative to clean and lock up the toilets. Thus, for toilets more than for water points, privacy, decency and a sense of propriety demand that each house has its own facility unless a much greater level of discussion than currently occurs between developers and residents is implemented prior to the introduction of communal services.

After preliminary contacts were made with EMMC officials, the non-sewered areas selected satisfied the demographic requirements and also provided an opportunity to observe the ongoing experiment (testing) of dry sanitation systems and how these would affect the way people use their water and manage their wastewater.

The following maps show the results obtained during the site surveys in Limpopo, Mpumalanga and Gauteng:

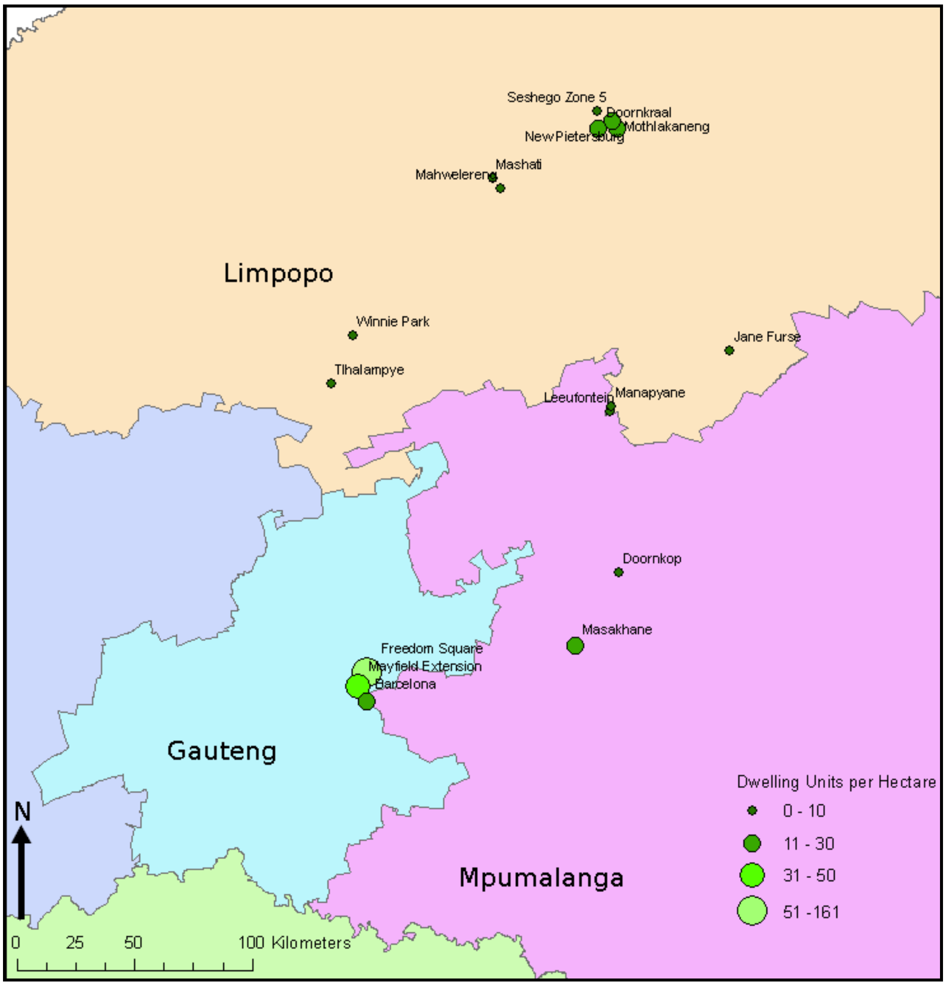


**Figure D6.6: Settlement density figures for Limpopo, Mpumalanga and Gauteng**

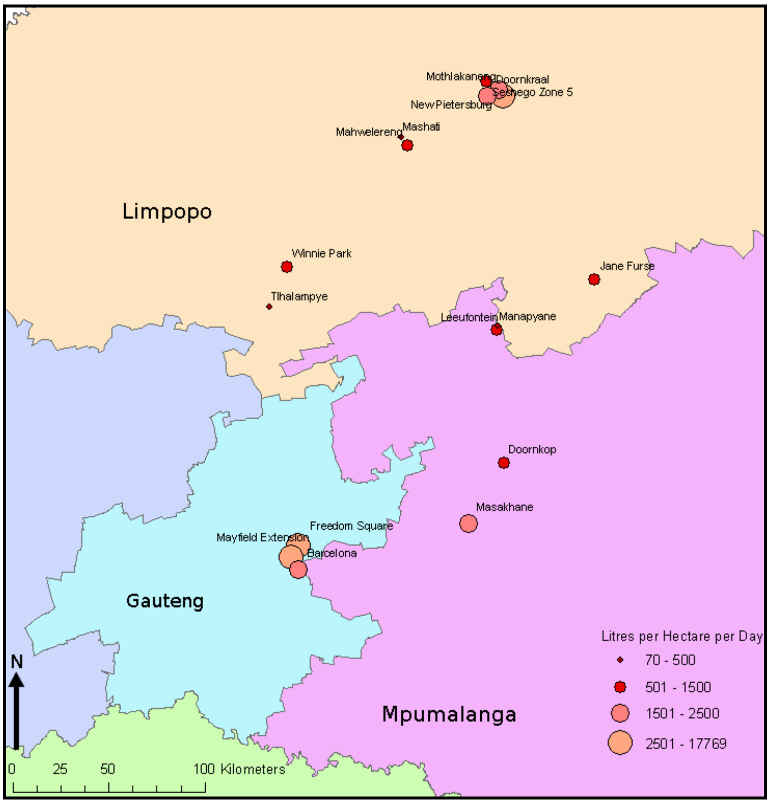


**Figure D6.7: Greywater generation figures for Limpopo, Mpumalanga and Gauteng**

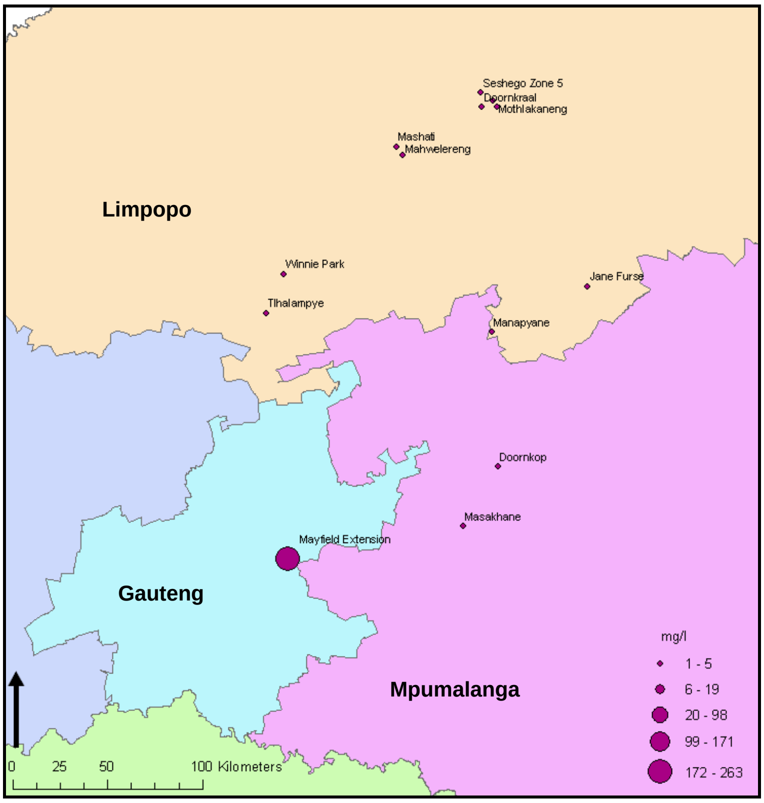


**Figure D6.8: Total Phosphorous figures for Limpopo, Mpumalanga and Gauteng**

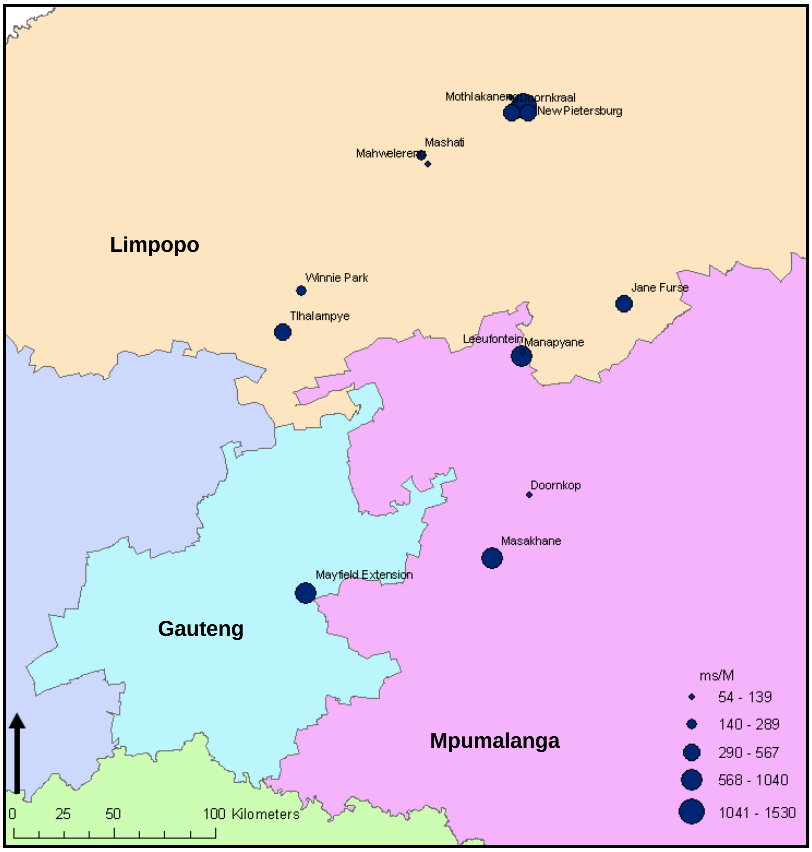


**Figure D6.9: Electrical Conductivity figures for Limpopo, Mpumalanga and Gauteng**