THE OPERATION AND MAINTENANCE OF SETTLED SEWERAGE (SS) SYSTEMS IN SOUTH AFRICA

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FINAL REPORT

to the

WATER RESEARCH COMMISSION

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EXECUTIVE SUMMARY

1. BACKGROUND AND MOTIVATION FOR THE PROJECT

1.1 Aim and justification of the project

During interactions by the CSIR with communities lacking sanitation it is apparent that raw sewage conveyance (ie: waterborne) systems are the first choice of most of these communities. There are not, however, adequate funds available to provide this system to all those in need of sanitation facilities. Interest in alternative technologies is therefore increasing, in particular alternatives that provide for flush toilets but have lower cost implications. One such alternative technology is settled sewerage systems.

CSIR has been researching settled sewerage systems since 1989, and has established that systems exist in Zambia, Australia and the USA. As a product of this early research, design guidelines for settled sewerage system have been available from the CSIR for a few years, and numerous requests are still received for this document. Seminars on the technology, held in 1993 and 1994 were well attended, and good interest in the settled sewerage technology was evident.

The purpose of this project was to determine the performance, operation and maintenance requirements of the systems currently in operation, under South African conditions, with the object of preparing guidelines for the Civil Engineering aspects of the technology.

The aim of this project was, therefore

To determine the operation and maintenance requirements of settled sewerage systems in South Africa.

1.2 Description of settled sewerage systems

A settled sewerage (SS) system is a system or network of pipes designed to convey the liquid portion of sewage to a central treatment and/or disposal point. The solids in the sewage are settled out in a septic tank upstream of the pipe network. The elements of a settled sewerage system are

- a pedestal and a flushing mechanism
- an on-site storage/settlement unit
- solids-free sewers
- a mechanism for removing sludge from the on-site containers

- a treatment and/or disposal facility.

Only the on-site storage/settlement units and the sewers are addressed in this report.

2. RESULTS

2.1 Status of technology usage

Settled sewerage systems have been in use for over thirty years and are now used in seven countries throughout the world. There are currently at least 21 schemes, serving over 16 000 erven, in South Africa.

The technology has been used successfully with high-, middle- and low-income communities, but users accept the system more readily where communities have been involved in the choice of the system.

2.2 System inspections

The problems experienced with South African settled sewerage systems relate to poor construction, failure of some septic tanks to act as anaerobic digesters, and blocking of outlet tee-pieces due to problems with the initial tee-piece design (now corrected). In general the systems function as theoretically predicted. Most blockages have occurred at the inlet and outlet tee-pieces of the septic tanks. A change in the design of the latter fittings has addressed this problem. Blockages in the Marselle system have been addressed by replacing corroded cast-iron Y-junctions with uPVC fittings, and remedying poor construction.

Very limited information was available from the local authorities responsible for the Zambian schemes visited. Problems related mainly to blockages arising from the coupling of raw sewage outfalls to the solids-free outfalls, failure to desludge septic tanks, lack of maintenance over 40 years of system operation, failure to deal with problems as they arose, institutional collapse and a poor understanding of the technology.

2.3 Advantages of settled sewerage systems

The advantages of settled sewerage systems include savings on capital, operation and maintenance costs, simpler design and easier construction, and simpler treatment requirements.

Generally the initial capital costs of the technology are lower than for raw sewage conveyance systems with savings of between 8,7% and 43% on South African schemes. Savings on the water supply system, water consumption, and wastewater treatment should be included in the cost comparison. Operation and maintenance requirements of the technology, both in South Africa and internationally, are generally less intensive and less costly than that of raw sewage conveyance systems.

Disadvantages relate primarily to access to the septic tanks and the cost of emptying the septic tanks and lack of understanding of the system among operators.

2.4 Health and hygiene

Settled sewerage technology meets the requirements of sanitation systems in terms of health and hygiene, offers the same level of service as a raw sewage conveyance system and meets the requirements of the National Policy on Sanitation (Draft White Paper, June 1996).

3. RESEARCH OUTPUTS

3.1 The expected outputs

The expected outputs for the project were

(i) A review of current literature on operation and maintenance of settled sewerage systems

(ii) Guidelines for local water and sanitation committees which would:
- explain the settled sewerage process
- explain the circumstances under which to choose the technology
- set out operational and maintenance procedures to ensure the satisfactory performance of the technology
- identify resources required to carry out operation and maintenance.

(iii) Guidelines for engineers, which would enable them to design SS systems in a manner which makes them suitable for operation and maintenance by communities themselves. These guidelines would include
- operation and maintenance requirements for trouble-free, effective, operation of the system
- design for maintenance
- most suitable flush volumes
- the probability of a slime layer forming on the pipe wall, and the circumstances under which this layer detaches from the pipe
- selection process for choosing SS technology

- mass balance of a typical septic tank in a SS system
- analysis of samples from a typical SS system septic tank
- processes taking place in settled sewerage systems.

(iv) A report outlining the findings arising from the visits to existing installations.

3.2 Final project outputs

This report forms the first report in a set of three documents prepared for Water Research Commission Project K5/708: Guidelines for the operation and maintenance of settled sewerage systems by communities in South Africa. The full set of documents comprises :

(i) The operation and maintenance of settled sewerage (SS) systems in South Africa : *Research report*

The research findings are set out in this document, which includes the information abstracted from the literature review (section (i) of the proposed outputs) and the reports on the field inspections carried out under the project (section (iv) of the proposed outputs).

(ii) Settled Sewerage Systems in South Africa : *A community leader's guide*

This booklet addresses section (ii) of the proposed project outputs.

The booklet comprises sixteen pages and is entitled "Settled sewerage systems in South Africa: A community leader's guide". The booklet provides information on all the aspects listed in section 3.1 (ii) above, with the exception of the circumstances under which to choose the technology.

The issue of technology choice was addressed by presenting a comparison between settled sewerage and raw sewage conveyance systems, since settled sewerage technology is suited to situations where water is to be used for flushing, and the criteria for choosing SS technology over another option are costs and community acceptance.

(iii) Operation and maintenance of settled sewerage systems in South Africa : *Guidelines for engineers*

The first two items listed in section 3.1 (iii) were addressed in great depth. While less information was available on the third and fourth items, sufficient was available to allow for firm recommendations. The choice of settled sewerage systems was addressed by including a section on the advantages of the technology. The last three items of section 3.1(iii) above were not addressed at all during the study since no existing work on these issues could be located.

4. EVALUATION OF THE SUCCESS IN MEETING THE PROJECT OBJECTIVES

4.1 Project outputs

Although the three aspects which would have provided information for the treatment of settled sewerage were not addressed by this project, the aim of the project has been met, since a thorough understanding of the requirements of the technology and the typical problems that can be encountered in operating settled sewerage systems has been gained. The three documents forming the project output are therefore considered to provide sufficient guidance for the design, operation and maintenance to ensure successful functioning of the settled sewerage technology.

There was insufficient information on certain of the aspects which were to have been addressed. These aspects, in particular aspects relating to flush volumes, biochemical processes and mass balance in the septic tank, are important in the understanding of the treatment requirements of settled sewerage systems, but do not affect the design of the sewerage system for operation and maintenance by the community. These aspects also require in-depth research in their own right since very little has been done in these fields.

The lack of information on the last three aspects listed in section 3.1.(iii) above are believed not to affect the usefulness and accuracy of the documents produced.

4.2 Contribution to the state-of-the-art

The research conducted under projet K5/708 contributes to the knowledge on these systems by differentiating between theoretically "probable" maintenance actions required, and the actual experience of operators in the field. In particular, the incidence of blockages are shown to be a function of incorrect design or construction, lack of fat-traps, and a lack of understanding of the system. A barrier to the choice of the technology, namely the perception of increased incidence of blockages in small diameter sewers, has therefore been effectively removed.

The guidelines produced under this contract are a further contribution to the settled sewerage technology, since information on operating and maintaining the technology is now available both to designers responsible for installing the technology and to communities responsible for the effective operation of the system.

4.3 Benefit to the user

The research outputs provide the local authority and design engineer not only with a source document from which to draw on the experience of other settled sewerage system operators, but also with a set of guidelines on which to base design and operation and maintenance decision-making.

The manual for communities (output ii) provides the local authority with a simple and comprehensive tool for user education, as well as providing local water and sanitation committees with information on which to base their decisions with respect to choice of system.

5. RECOMMENDATIONS

5.1 Settled sewerage systems

The following recommendations are made in respect of selection, design, operation, maintenance and use of settled sewerage systems in South Africa : that

- the primary consideration in the choice of a settled sewerage system should be the affordability of the system to the residents;
- consideration be given to providing systems that require minimal operation and maintenance by the local authority. For example, by dividing large communities into zones, with separate low technology treatment facilities for each zone, members of the community can, (with limited training) operate and maintain their own system. This approach will ensure sustainability under conditions of economic collapse;
- raw sewage conveyance system standards be adopted, with additional provision for the corrosive atmosphere due to the settled sewage, in systems that combine settled and raw sewage conveyance;
- the community be involved in the decision-making and planning stages;
- design criteria to minimize operation and maintenance be adopted;
- an operation and maintenance manual be prepared for each project;
- education and training specifically related to health, hygiene and the technology be conducted for all settled sewerage schemes, both for the community and the local authority;
- a user manual be prepared for both domestic and industrial / commercial users.

5.2 Recommendations for further study

Further research is required into the following aspects:

- the sizing and design of septic tanks

- an evaluation of the effect of varying flush volumes, anal cleansing materials and tank configuration on biological processes in the tank
- costs of operation and maintenance, including the economics of tank emptying related to septic tank size
- disposal of sludge through the sewerage network rather than using tankers
- use of local contractors and manually operated equipment of simple design for desludging of septic tanks
- evaluation of the cost effectiveness of education and training
- preparation of a example operation and maintenance manual
- testing of the operation and maintenance guidelines for community leaders
- development of construction guidelines, quality control techniques and maintenance methods
- the solids conveying capacity of low volume flushes
- the use of sections flowing under pressure

5.3 Recommendations for information/technology transfer

Recommendations with respect to technology transfer and information dissemination include :

- distribution of copies of the Community Leader's Guide to local authorities currently using the SS system, free of charge, with a request that they supply information on the usefulness of the document as an educational and decision-making tool
- distribution of the operation and maintenance guidelines to all local authorities which participated in the project, with a request that they comment on the usefulness of the document
- presentation of workshops, in regional centres, on settled sewerage technology. The workshops would cover choice, design, construction, and operation and maintenance of the technology.

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%	Percentage
BOD	Biochemical oxygen demand.
CED	Common effluent drain.
COD	Chemical oxygen demand.
CSIR	Council for Scientific and Industrial Research
EPA	See USEPA
HDPE	High density polyethylene
km	kilometre
ℓ/s	litre per second
m	metre
m/s	metre per second
m^2	Square metre
m^3	Cubic metre
mill	million
mm	millimetre
R	Rand
RSC	Raw sewage conveyance system
SA	South Africa
SDGS	Small diameter gravity sewers.
SS	Settled sewerage system
STEP	Septic tank effluent pumping system.
uPVC	Unplasticised polyvinyl chloride
USA	United States of America
USEPA	United States Environmental Protection Agency
VGS	Variable grade sewers
WRC	Water Research Commission

GLOSSARY OF TERMS

Ablution unit	A room or a building housing toilets, and/or baths or showers.
Access chamber	A chamber constructed in the sewer line allowing for access of a person. Also termed *manhole.*
Access eye	An access hole at a bend in a drain pipe, ordinarily covered by a metal plate wedged or bolted over it, which enables the pipe to be rodded (see *rodding*) (Scott & Smith, 1980).
Anaerobiosis	Life in the absence of free or dissolved oxygen, typically resulting in the production of methane, ammonia, nitrogen, hydrogen sulphide and carbon dioxide (Scott & Smith, 1980).
Anal cleansing material	Material used to clean excreta off the anal area after defecating, eg: toilet paper, maize cobs, stones, newspaper, leaves, sand, water, etc.
Aqua-privy	A sanitation system which does not need a p-trap , but rather uses a section of pipe to connect the toilet to a septic tank, usually positioned beneath the ablution unit. The pipe extends below the water level in the septic tank, thus providing a seal against odours and ingress of insects.
Attenuate	Reduce the intensity or rate of flow
Bacteria	Single-celled microscopic organisms that multiply fast by splitting in two. They are fundamental to the purification of sewage in sludge digestion. Some cause illness in man (Scott & Smith, 1980).
Biochemical oxygen demand	A measure of the amount of pollution by organic substances in water. It is expressed as the number of milligrams of oxygen per litre of water required by the micro-organisms to oxidise the organics. (Scott & Smith, 1980)
Black water	Water from flush toilet bowls, so called to distinguish it from sullage or "grey water" (Scott & Smith, 1980).
Chemical oxygen demand	A measure of the amount of pollution by both organic and inorganic substances in water. It is expressed as the number of milligrams of oxygen per litre of water required by the micro-organisms to oxidise the organics plus the amount of oxygen required for chemical oxidation of inorganic substances (Scott & Smith, 1980).
Cistern	A tank containing water. When related to toilets the cistern is a small tank, containing about 9 to 13 ℓ which discharges into the toilet bowl.
Cleaning eye	See *access eye.*
Cleanouts	See *access eye.*

Common effluent drain	Solids-free sewers in Australia.
Communal drainfield	A soakaway serving several homes (ie: a community) and septic tanks.
Construction tolerance	The deviation allowed from the design levels, positions or size. When the tolerances are exceeded the work may be rejected.
Corrosion	Attack on the surface of materials. In water or sewage there are three main causes: (1) scouring, (2) presence of dissimilar metals close to each other, (3) chemical or biochemical attack (Scott & Smith, 1980).
Curvilinear	In a curved line. The use of the term implies that sharp changes in direction are excluded.
Densification	The process of increasing the number of residents per square metre of land.
Design criteria	The accepted minimum standards of performance assumed during design. These standards have developed over time by observation of systems that work well, or as the result of experimentation.
Digested sludge	Sewage sludge which has undergone anaerobic digestion or passed through an aerobic digester should have a fibrous structure and a peaty smell, which is not unpleasant, unlike raw sludge, but may still contain organisms that cause disease (Scott & Smith, 1980).
Effluent	That which flows out.
Erf	Proclaimed property with a single or corporate owner.
Excreta	Solid and liquid waste matter excreted from the bodies of humans and other animal species.
Faeces	Solid waste matter from the human body. Also see *excreta*.
Grey water	Water from basins, baths and sinks. Excludes water from flush toilets.
Hydraulic head	The energy in water that enables it to do mechanical work. It is the sum of (1) elevation head (ie: physical height), (2) pressure head (ie: the height to which a static column of water can be carried by pressure at that point), (3) velocity head (ie: the energy due to the movement of the water.) (Scott & Smith, 1980).
Hygiene	The science and practice of keeping the person and the environment clean.
Level	The vertical position above a given datum.
Level of Service	The comfort, convenience and cost-effectiveness provided.
Liquor	Liquid, comprising mostly water, in sewage treatment.

Maintenance	The actions required to reinstate a system that is malfunctioning, and the actions required to prevent malfunctioning.
Manhole	A chamber installed over a sewer to provide access. Large enough to accommodate a man.
Operation	The actions required on a continuous basis for a system to function.
Peak flow	The highest flow rate.
Primary treatment	The sedimentation in sewage treatment that releases the top water for biological treatment and removes organic solids as sludge.
Raw sewage conveyance systems	Sewers which convey solids such as faeces and paper, as well as liquids. The solids float in the liquid, or are forced down the sewer by the momentum of the liquid.
Retention period	The time during which sewage is kept in a tank, so as to enable it to undergo treatment. Theoretical retention time is the volume of the tank divided by the flow through it. The actual time may be considerably less, because of poor distribution or flow.
Reticulation	The network of pipes, usually referring to water supply pipes or sewage conveyance pipes.
Rodding	Clearing blockage by inserting steel rods into the sewer.
Sanitation	The science and practice of removing harmful substances from the environment, and/or treating them to render them harmless before releasing them into the environment. Refers particularly to removal and treatment of excreta.
Scouring velocity	Self cleansing velocity. The rate of flow at which all solids are taken into suspension and the pipe is left clear of material.
Scum	Any material that floats on top of still water (Scott & Smith, 1980).
Septic tank	A tank in which anaerobic digestion takes place.
Septic tank effluent pumping system	Solids-free sewers operating under pressure supplied by pumping units.
Service lateral	Sewer serving and individual property, connecting the septic tank to the collector sewer.
Sewer	A buried pipe that leads waste waters away for treatment and disposal (Scott & Smith, 1980).
Sewerage	A network of sewers (Scott & Smith, 1980).
Skilled work	Work requiring a knowledge of the materials and techniques to be used, and entailing training in these techniques.

Sludge	Solids settled out from water, but still containing 55% to 99% water (Scott & Smith, 1980).
Small diameter gravity sewers	Solids-free sewers flowing only with gravity. An American term.
Soakaway	A hole in the ground for disposal of rainwater, sullage or treated sewage effluent (Scott & Smith, 1980).
Straightness	Lack of deviation from a straight line.
Sullage	Water from baths, wash-basins and sinks. Also termed greywater.
Surcharge	Put under pressure. A surcharge chamber is a tank which stores water until sufficient has been accumulated so that the pipes downstream will flow under pressure when the water is released into them.
Toilet	The unit which forms the seat. Squat plates are included in this definition. In flush systems the toilet will also have a bowl as receptacle for excreta and urine. During flushing the bowl is emptied.
Uphill	From a lower to a higher geographical elevation.
Variable grade sewers	Solids-free sewers with sections flowing "uphill". An American term.
Vent pipe	A pipe allowing escape of gases from a sewer or drain pipe, a pit or a tank. The vent pipe usually rises above the roof so that odours are dispersed by the wind.

1. INTRODUCTION AND BACKGROUND

1.1 DESCRIPTION OF THE SETTLED SEWERAGE (SS) SYSTEM OF SANITATION

A settled sewerage (SS) system is a system of sanitation which uses an on-site tank to settle solids out of the effluent, and conveys the liquid portion of the effluent to a central collection point by means of a sewer network (sewerage). The liquid transported in the sewers is termed *settled sewage*. The solids remain in the tank where they are acted upon by anaerobic bacteria and converted to carbon dioxide, ammonia, water and a residue, termed sludge. The volume of sludge builds up in the tank and must be removed at intervals, usually by vacuum tanker, and transported to the treatment works.

Table 1.1 shows some of the more common sanitation systems, including also settled sewerage systems, with their elements, while Table 1.2 gives a comparison of SS systems with the raw sewage conveyance (RSC) systems.

SS systems have the following elements :

1. A flush toilet (water closet), using either pour flush, sullage flush or cistern flush.
2. An on-site container (septic tank) which receives raw sewage from the toilet, as well as greywater. The addition of water is essential, although the source of the water, whether from flushing the toilet or sullage water from a wash trough, or both, is immaterial. The function of the tank is primarily to provide settlement of the solids in the toilet effluent, but a measure of anaerobic microbiological activity is also commonly required, since this reduces solids volume, increases the amount of solids settled and reduces odour;
3. A mechanism for removing the sludge from the tank at periodic intervals;
4. Sewers which convey only the liquid portion of the settled sewage from the tanks to a communal drainfield or treatment facility;
5. A treatment and/or disposal facility.

A diagram of an SS system is shown in Figure 1.

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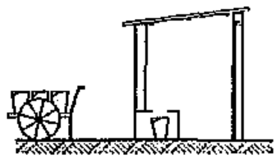
Trench system

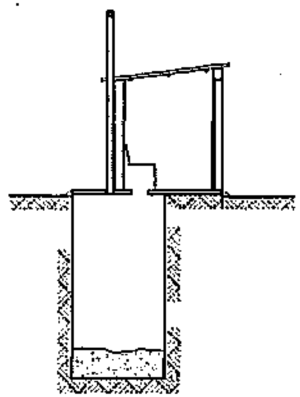
- Toilet: None
- Flush: None
- Liquids: Drain into ground
- Solids: Buried

Bucket system



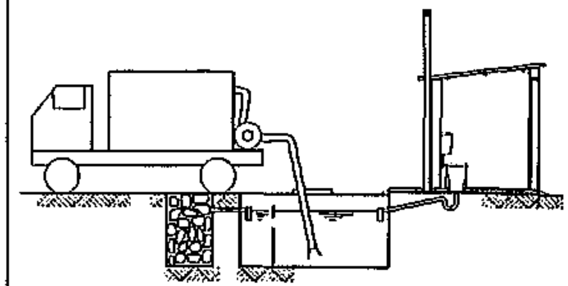
- Toilet: Box pedestal or none
- Flush: None
- Liquids: Carted to treatment works
- Solids: Carted to treatment works

Pit-type latrine



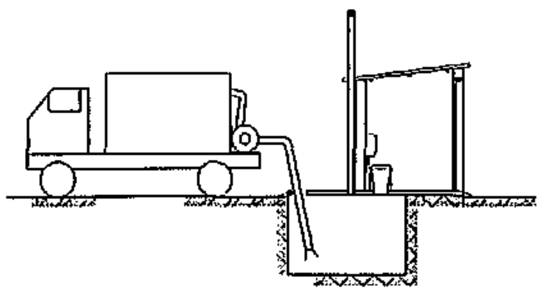
- Toilet: Box pedestal or none
- Flush: None
- Liquids: Drain into soil
- Solids: Remain in pit, eventually buried

Septic tank and drainfield system



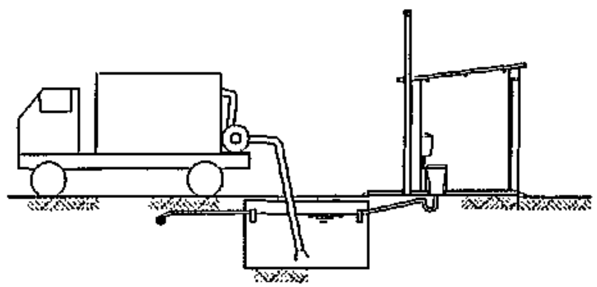
- Toilet: Flush type pedestal or aqua-privy pedestal
- Flush: Cistern, sullage or pour-flush
- Liquids: Drain into drainfield and from there into soil
- Solids: Remove and cart to treatment works

Conservancy tank system



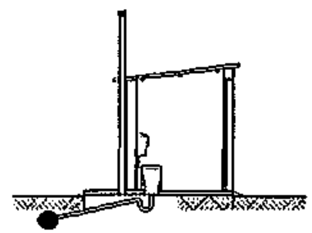
- Toilet: Flush type pedestal or aqua-privy pedestal
- Flush: Cistern, sullage or pour-flush
- Liquids: Remove and cart to treatment works
- Solids: Remove and cart to treatment works

Settled sewerage system



- Toilet: Flush type pedestal or aqua-privy pedestal
- Flush: Cistern, sullage or pour-flush
- Liquids: Drain to treatment works through sewers
- Solids: Remove and cart to treatment works

Raw sewage conveyance system



- Toilet: Flush type pedestal
- Flush: Cistern flush
- Liquids: Drain to treatment works via sewers
- Solids: Drain to treatment works via sewers

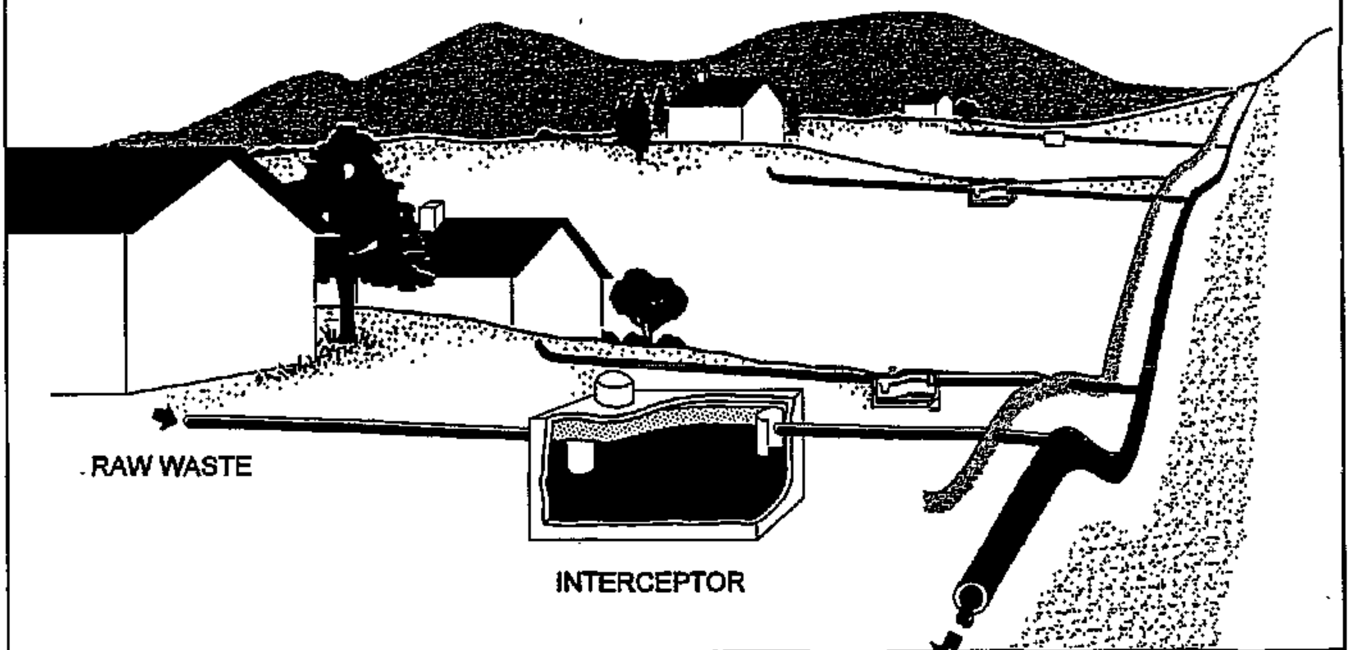
Table 1.1 : ***Generic Classification of Sanitation Systems***

Table 1.2 : Comparison of elements of the settled sewerage system with elements of raw sewage conveyance systems

ELEMENT	Settled sewerage system	Raw sewage conveyance system	Affected Party
1. Room or structure	Any	Any	-
2. Toilet	Flush system	Flush System	-
3. Water	Automatic addition preferred. Low volume flushes can be used.	Requires automatic addition. 9-litre flush generally recommended.	User (less cost for water).
4. A pipe connecting the seat to the on-site elements of the system	Required. Preferably with water-seal.	Required. Essentially with water-seal.	-
5. On-site elements	Building pipework. Septic tank. Effluent pipework.	Building pipework. Raw sewage pipework.	User (space and aesthetics). Operator (emptying of tanks).
6. Solids disposal	Retained in tank and emptied from time to time, depending on solids accumulation rate.	Transported with liquid effluent to treatment point.	Operator (solids in pipes can result in blockages).
7. Liquids disposal	Transported to central treatment point through pipe network.	Transported to central treatment point through pipe network.	-
8. Treatment	Settlement and primary treatment in septic tank. Reduced complexity, volume and costs of central treatment works due to reduced biological and chemical oxygen demand.	All conventional treatment actions at central treatment works.	Operator (lower cost of treatment).

Building
Technology

CSIR



SETTLED SEWERAGE SYSTEM

FIGURE 1

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1.2 ADVANTAGES OF SETTLED SEWERAGE SYSTEMS

The advantages of SS systems are a direct function of the solids-free nature of the effluent transported in the sewers. Conversely, the use of a settling tank on the property, although it has advantages, is also the major disadvantage in the system because the tanks require emptying at intervals.

Advantages resulting from the tank on the property are :

- solids do not have to be moved a great distance from the ablution unit to the septic tank and therefore low flush volumes can be used. This results in lower daily water consumption and smaller water reticulation pipes;
- rubble, plastic or inappropriate anal cleansing materials dumped into the system are intercepted by the tank;
- considerable savings relative to conventional sewerage can be realised by using an SS system where there are already existing septic or conservancy tanks;
- flow attenuation is provided by the tanks, resulting in a lower peak on the sewers and consequently smaller pipe diameters and pumps;
- smaller sewage works and simpler treatment processes can be utilised due to the digestion in the tank;
- pumps do not have to have solids-handling capacity.

Advantages resulting from solids-free sewers are :

- pipes can be sized according to hydraulic principles and designed to flow full, allowing for smaller pipes;
- velocities can be lower since there is no transportation of solids;
- slopes can be flatter due to the lower velocity requirements;
- "uphill" sections, where flow is due to hydraulic head (as opposed to gravity) can be used;
- horizontal alignment can be curvilinear;
- manholes are not required, and are in fact not favoured, since they provide an entry point for soil, rubble, surface runoff and root intrusion;
- construction is simpler and more rapid since horizontal and vertical tolerances are greater.

Cost advantages of SS systems are:

- the use of smaller diameter pipes, which reduces material costs,
- the reduction of excavation due to flatter gradients,
- the potential for deviating around obstacles rather than removing them,
- the exclusion of manholes,
- reduction in maintenance frequency,
- the reduction in treatment works size and complexity,

- the use of smaller, liquids-handling, pumps,
- the reduction in water use,
- the reduction in water reticulation size,
- low operation and maintenance costs.

1.3 EXISTING INTERNATIONALLY SETTLED SEWERAGE SYSTEMS

Settled sewerage (SS) systems were introduced in Zambia in the 1950's, with 80 connections completed in early 1954 in the Balovale suburb of Lusaka II. The Zambian systems generally drain aqua-privies and are termed "sewered aqua-privies". Information on the number of systems installed in the 1950's and 1960's under the then African Housing Board is sketchy, and much of the information available is derived from study tours to Zambia in 1993 and 1995. During the tours it was found that some local authorities were not even aware that there was an SS system in operation within their area of jurisdiction.

The systems in Zambia, which have been in existence for 30 to 40 years are generally not maintained due to lack of manpower and equipment. Problems experienced centre largely on the fact that tanks are not emptied and the high sludge level prevents the draining off of the liquid effluent into the sewers. The water-seal on the aqua-privies is not maintained, due to water shortages, and the ablution units are malodorous. It should be noted that it is highly unlikely that a raw sewage conveyance system would still be functional after 30 years under the same conditions, namely without maintenance and with regular water shortages.

SS systems were introduced in Southern Australia as a solution to the failure of individual drainfields. The first system was installed in Tea Tree Gully, followed by Pinnaroo, completed in 1962. The first Australian town to include all its erven (493 connections) in an SS scheme was Bamera. By 1982 an estimated 752km of solids-free sewers had been installed in Australia in 65 towns, a further 16 schemes were in the design or construction phase, and 41 towns had applied for feasibility surveys for settled sewerage systems.

Australian design criteria, which are laid down by the South Australian Health Commission, are fairly conservative, namely:

- minimum pipe diameters of 100mm, at a minimum grade of 0,4%. For 150mm and 225mm diameter pipes grades of 0,25% and 0,15% respectively are accepted;
- manholes are used at junctions of two or more drains that each serve 40 erven or more. Flushing points are provided where manholes would have been provided in a conventional sewerage system, ie: at changes in direction, minor junctions and at 120m intervals;
- minimum cover of 300mm in untrafficked areas is accepted.

The first SS system introduced in the USA was in 1976 at Mount Andrew, Alabama, serving 31 erven. This experimental system included sections of sewer flowing uphill as well as pipes with diameters as small as 50mm, and was termed "variable grade sewers" (VGS). The scheme has been monitored and to date (20 years later) no problems have been experienced. By 1992 there were 250 SS schemes, and at that stage over 25% of the applications for funding for "alternative" sewer projects submitted to the EPA were for SS systems. "Alternative" sewer projects cover all projects which are not raw sewage conveyance systems, and include vacuum sewerage systems and Septic Tank Effluent Pumping (STEP) systems.

The EPA guidelines (Browne, *et al*, 1991) recommend:

- minimum flow velocities under peak conditions, of 0,15m/s, rather than minimum slopes;
- 50mm diameter pipes, which have been used successfully in conjunction with flow control devices in the septic tanks, although 100mm diameter is the most commonly used minimum size;
- minimum use of manholes, which are not recommended as they are seen as a source of problems, since grit and rubbish can enter the system through them. Cleanouts are placed as for Australian schemes, except that a spacing of up to 300m on straight sections is accepted;
- adequate venting must be provided on depressed sections.

All the American systems have performed well and no obstructions have occurred, even though flushing has not been performed. Odours have occurred on some schemes, but corrective action was successful. Corrosion in pumping stations was initially a problem since the septic atmosphere was not anticipated. Infiltration was a significant problem where existing tanks were used. Routine maintenance consists of weekly inspection of mechanical equipment and pumping of tanks every 5 to 7 years.

Recent information indicates that the settled sewerage technology has also been adopted in South America, Thailand and Japan.

1.4 SETTLED SEWERAGE SYSTEMS IN SOUTH AFRICA

It is known that there are at least twenty-one SS systems in South Africa serving over 16 000 erven. While most of the existing schemes are under construction or have been in operation for less than a year, the first SS system was constructed at Marselle in the Eastern Cape in 1989 and has been operational for over six years. The potential for further systems being implemented in order to upgrade septic tank systems is considerable, since there are an estimated 1,4 million people served by septic tanks in South Africa (Palmer; 1995).

2. AIMS OF THE PROJECT

According to the White Paper on Sanitation (June 1996), there are an estimated 21 million people in South Africa without adequate sanitation. Although most communities request raw sewage conveyance systems (ie: conventional waterborne sanitation), the country cannot afford to provide all those needing sanitation facilities with this technology in the foreseeable future, and less costly alternative technologies must be sought. Settled sewerage is one such technology.

Interest in settled sewerage technology in South Africa is increasing, as is evidenced by consistent sales of a document containing design standards and methods by the CSIR Division of Building Technology, and by high levels of attendance at workshops on the technology.

Engineers and local authorities do require, however, that more information be made available with respect to the post-construction behaviour and costs of settled sewerage systems under local conditions. The aim of this project is, therefore, to determine the operation and maintenance requirements of settled sewerage systems installed in South Africa.

This research document forms the basis for the guidelines both for engineers and for community leaders (separate documents for each) for the operation and maintenance of SS systems.

3. PROJECT METHODOLOGY AND DATA COLLECTION

3.1 LITERATURE SURVEY

An extensive literature survey was done and some sixty documents considered relevant to the study were studied. Design data on the systems in South Africa was obtained from publications, from the design consultants or from the local authorities.

The full list of references is included in section 9. Most references dealt with predicted or theoretical behaviour and only two references, both from the United States Environmental Protection Agency, evaluated actual operation and maintenance requirements and behaviour of SS systems in the field.

3.2 INSPECTION AND EVALUATION OF EXISTING SYSTEMS

Because of the paucity of data on actual conditions in the field, nine existing SS schemes in South Africa and six in Zambia were inspected, and as much information as was available on the operation and maintenance practices was obtained by interviewing municipal personnel. The report on these tours is given in Annexures A and B of this report. As the remaining systems in South Africa have been in use for less than a year, it was not anticipated that an inspection at such an early stage would yield information of value with regard to operation and maintenance procedures.

During the inspection of the systems, a tank was considered to be "working" when it was odour-free and the settling out of solids was occurring. Effluent was not tested for evidence of microbial activity, but it must be borne in mind that a measure of anaerobic digestion is expected in the tank, thus reducing the loading at the treatment works. The sewers were considered to be "working" when effluent could be drained from the tanks and could flow to the treatment works.

An attempt to set up a coherent database of SS systems for comparative purposes was unsuccessful, since different sources gave sets of data that could not be correlated, and useful information on design standards, costs, etc., was not consistently available.

4. OPERATION AND MAINTENANCE OF SETTLED SEWERAGE SYSTEMS : PROJECT FINDINGS

4.1 HEALTH AND SOCIO-CULTURAL ASPECTS

The principle that a sanitation system must not only provide privacy, and is not necessarily adequate because it provides a receptacle for excreta, is widely accepted. Middleton, *et al* (1981), give three sets of criteria for sanitation systems, namely social, economic and technical. The system should be socially acceptable and financially affordable to the beneficiary, and environmentally acceptable and economically affordable to government. Implicit in the technical criterion is that any sanitation system must provide adequate protection from disease.

In this section SS systems are measured against the criteria for an adequate and effective sanitation system.

4.1.1 Health and Environmental Aspects

To meet health and environmental criteria a sanitation system must

- *provide an effective barrier between excreta and the user.* SS systems require the addition of water, which may be from a water closet or from sullage. There is therefore no reason why a water-seal should not be provided, thus introducing the required barrier to disease;
- *prevent conditions conducive to breeding of both insect vectors and vermin.* SS systems include a water-tight container, and effluent is conveyed in water-tight pipes, both of which prevent access of vectors;
- *prevent contamination of the environment from infected excreta.* The watertight container pipes, where properly constructed, contain the excreta and effluent and separate it from the environment.

The SS system can also accept sullage, thus addressing this potential source of environmental contamination.

Marais (1965) also indicates that the health benefits of sanitation are part of improving environmental health which includes

- promoting good domestic hygiene; and
- ensuring proper use of ablution units by all members of the household.

SS systems meet these requirements at the same level of service as raw sewage conveyance systems since they discourage vermin, are non-odorous and light, and can provide safe, easy-to-use and pleasant conditions which make it attractive to all users.

4.1.2 Socio-cultural Aspects

Socio-cultural acceptability can only be determined by the specific users. Very little information on the acceptability of SS systems, or in fact any other specific sanitation system, to the user was found in the literature. Generally it can be said that technologies imposed on people without adequate consultation are likely to fail or to go unused (Gunn; 1988), and that communal facilities are rarely acceptable and frequently unused due to vandalism (Kaoma; 1980).

SS systems can accommodate most socio-cultural requirements, since they provide the user with the same level of service as a raw sewage conveyance system. Theoretically they should therefore meet with a minimum of social resistance. However, this is not always the case. Interviews with users of South African SS systems established that:

- where conservancy tank systems were in use before the installation of the SS system the users accepted the SS system, and believed the level of service to be the same as that of a raw sewage conveyance system. This still did not detract from the perception that a raw sewage conveyance system was the only "proper" system available;
- where the tanks were installed at the same time as the sewers, the users disliked the tanks on the erven. Some users believed the tanks are unhealthy, while others did not like the appearance of the tanks where these are visible above ground. Users agreed that the system was effectively no different from a raw sewage conveyance system from a user's point of view, but were still adamant that a raw sewage conveyance system was better. It was of interest to note that one community rejected the system because they wanted conservancy tanks that were emptied by tanker, as is the case in the neighbouring high-income area, rather than tanks which are drained by sewers;
- unsuitable toilet types and poor construction have resulted in a rejection of the technology, even though they in no way represent a failure of SS systems technologically;
- densification on existing erven may eventually make it difficult to reach the tanks for emptying, as well as lead to overloading of the tanks and consequent odour problems. Furthermore, the tanks will eventually not provide adequate settling time for solids as the number of users increases, and the pipework may not be able to accommodate the increased flows;
- the community in some areas are reluctant to have tanks pumped out because of the inconvenience and intrusion (USEPA, 1989);

- some American users would like to have the space taken up by the tank for development (Simmons and Newman, 1984). This has not been the case in South Africa, since SS system schemes have been used in towns where the erven are large, or alternatively the residents have simply constructed dwellings over the tanks.

The aspects listed above can be addressed by providing extensive decision-making information to the community. Education of users is crucial to the success of all sanitation schemes, as is involving the community in the decision-making with respect to the type of system to be installed, location of tanks, aesthetics, location of ablution units, etc. The range of choices available when using a settled sewerage system, which is as great as that of raw sewage conveyance systems, should be made available to the community, albeit at a cost to them.

The issue of tanks taking up valuable room on the property can partially be addressed by locating the tank in a position chosen by the householder, and partially by encouraging multiple uses of the tank slab. For example, slabs can be incorporated into the driveway, form a step outside the back door, form the floor of the ablution unit, etc. The intrusion due to tanks having to be emptied can be greatly minimised by locating the tanks at the front of the erf, or by providing a service lane.

The problem of future densification can be addressed partly by allowing additional capacity for expansion in the sewers and the septic tanks, and partly by providing additional infrastructure as it becomes necessary. The former may increase the cost of the whole scheme unnecessarily. The minimum pipe diameter of 50mm adopted for the service lateral on an erf frequently has spare capacity, and current design norms adopted in South Africa leave spare capacity in the form of "freeboard" in the collectors. Increase in flow can therefore be accommodated by allowing the pipe to flow full for short periods during the day. The design will have to accommodate this, however.

The most significant problem arising from densification is on sections flowing under hydraulic pressure (ie: uphill), since inadequate capacity in these sections can result in the effluent backing up into the sewers upstream of the uphill section and subsequently discharging into the adjacent septic tanks. This problem can be dealt with by building a surcharging / attenuation / storage chamber directly upstream of the uphill section.

4.2 DESIGN ASPECTS

It is not the object of this study to address the design of SS system, but some mention of design aspects that have given rise to problems, or conversely have resulted in trouble-free operation of an SS system, will be discussed.

Aspects which are given in the literature as affecting the successful operation and maintenance of SS systems are listed in Table 4.1, with comment on the South African experience in respect of these recommendations.

Table 4.1: Design factors affecting the operation and maintenance of SS systems

No	Element	Design Approach	Effect on Operation and Maintenance in SA schemes
1	Manhole covers in tank	a) Not recommended, as garbage can be dumped into the tank(Marais; 1965) b) Access openings to be a minimum of 150mm above ground to prevent inflow of rainwater (Marais; 1965)	a) Disposal of garbage into septic tanks was reported at Marselle b) No problems with entry of rainwater into the system were reported in South Africa
2	Manholes and access chambers	a) The use of manholes to be kept to a minimum since they provide points of access for rubble and grit. Where manholes are used the lids should be tamper proof / lockable; (Marais; 1965), (Otis, Mara; 1985), (Burrows, van der Linde; 1994)	a) Marselle reported entry of solids into the lines, both from manholes and from the tanks. The latter is due to removal of the outlet tee-pieces by the householders.
3	Cleaning Eyes	Place underground to prevent tampering. (Burrows, van der Linde; 1994)	This has been adopted successfully in Hermanus. In Warden and Lusaka II the cleaning eyes are close to the surface in the road reserve and are damaged during routine maintenance of the gravel shoulders.

No	Element	Design Approach	Effect on Operation and Maintenance in SA schemes
4	Vent Pipes	Use vent pipes on ablution unit drains for release of gases till further information is available (Marais; 1965, Vanderlyn; 1992) Use vents at high points on sections flowing under hydraulic pressure (Otis, Mara; 1985)	Odours were reported only at Hermanus. These originated in combined main outfall sewer and installation of water-seals between the SS system lines and the outfall resolved the problem.
5	Flow rates	Make additional allowance in pipe sizing for a) Possible increase in population served b) Changes in fittings which may increase the amount of water used (Kaoma; 1980) c) Hydraulic flushing which is effective in removing biological slimes (Region V; 1989)	a) No problems were reported with the capacity of the lines as a result of densification in Cathcart and Marselle. b) At Lusaka II toilets are pour-flush sullage flush with water collected from communal standpipes. The system is designed to accommodate upgrading to on-site water supply. c) No SA systems have yet been flushed. A section of perspex pipe in the Warden system showed no signs of slime build-up. However, the section is in the main outfall and therefore has a consistently high flow volume and velocity. Effluent lines from septic tank to subsurface drainfields, which had been in operation for longer than 30 years, showed no sign of slimes build-up (Fey, 1978).

No	Element	Design Approach	Effect on Operation and Maintenance in SA schemes
6	Septic tank	a) Septic tank sizing and design must accommodate • Storage period of 12-24 hrs to allow sedimentation	a) Septic tanks retained from existing conservancy schemes, which were generally large and served fewer users, were operating effectively. Tanks less than 1,7 m^3 serving many users contained a thick floating layer of undigested excreta, even though they provided adequate volume for 24-hour retention.
		• Adequate time for biological digestion by anaerobic bacteria (Swart, 1994; Otis and Mar, 1985; Vanderlyn, 1992.) b) Two-chamber tanks limit the possibility of entry of solids into the pipes, and provide forced surge attenuation (Simmons and Newman; 1984) c) The need for desludging of tanks requires strong organisational capacity (Otis and Mara; 1985) d) Tanks should also be close to the street front to simplify emptying. (Swart; 1994)	The layer of undigested excreta in the smaller tanks suggests that effective and sufficient bacterial action is not taking place. b) Most of the SA schemes use single-chamber tanks and have not experienced solid entry into the lines, except where tee-pieces were removed. c) Desludging of tanks has only occurred at Marselle, where problems were experienced because the residents could not afford the payments. The cost of desludging the tanks was later added to the monthly flat rate payment for services and no further problems have been experienced.
7	Scouring velocities at peak flow	Laboratory experiments indicate that pipes down to 35mm can be used, and that flow velocities of 0,15m/s during peaks are adequate for prevention of build-up of biological slime (Brown, *et al*, 1991)	50mm diameter pipes used both as house connections and as collector mains (in Warden) have been trouble free, with the exception of initial construction-related problems.

No	Element	Design Approach	Effect on Operation and Maintenance in SA schemes
8	Inlet and Outlet Tee-pieces	a) Provided to prevent grit and solids from entering the system (Otis and Mara; 1985); b) Inlet and outlet should be baffled to provide quiescent conditions for settlement (Otis and Mara; 1985); c) The outlet of the tank should be smaller than collector sewers to reduce the possibility of sewer blockages (Otis and Mara; 1985). d) Inspection ports should be provided above both inlet and outlet (Otis and Mara; 1985)	a) Outlet tee-pieces have blocked, restricting outflow from the tanks, in almost all the early SS system schemes in South Africa. Modifications to the tee-piece design have resolved this problem successfully on all projects. b) Inlets and outlets are generally baffled only by the provision of the tee-piece c) Outlets are the same diameter or smaller than the mains in all cases d) Inspection ports are generally supplied only above the tank outlet. In Warden the ports were not always placed directly above the outlet, and these tanks must be emptied to allow the maintenance men entry if blockage of the outlet tee-piece is suspected.

No	Element	Design Approach	Effect on Operation and Maintenance in SA schemes
9	Appurtenant Fittings, fixtures and equipment	a) All to be non-corrodible / non-ferrous b) Concrete in areas of flowing septage should be coated with a chemically resistant material due to corrosive gases from the septage (Otis, Mara; 1985). c) In-line settling sumps may be provided to intercept any solids that do get into the lines (Otis; 1986)	a) Cast iron y-junctions at Marselle have corroded and resulted in blockages. R800 000 (1996) was budgeted for correcting this problem, as well as construction-related problems, and the scheme is now operating without problems. b) No concrete corrosion was reported in any of the tanks or manholes. c) In-line sumps have not been provided, but problems were experienced at Marselle with solids reaching the pump sump. Subsequent to the recent remedial work carried out at Marselle the effluent is reported to be solids free. A settling sump upstream of the pump sump could prove cost-effective.
10	Odours	Inlets to pump stations and manholes should be below water level to control odours resulting from turbulent flow (Otis, Mara; 1985)	Odours are not commonly experienced on South African schemes. In Hermanus odours originating in the main outfall sewer (which carries conventional effluent, Septic tank effluent and effluent from sump used for dumping conservancy tank effluent) were escaping via the SS system. The installation of water-seals/traps between the main outfall and the SS system resolved the problem.

No	Element	Design Approach	Effect on Operation and Maintenance in SA schemes
11	Toilet type	a) Pour-flush toilets can be only be introduced once yard taps are provided (Kalbermatten, *et al*; 1980). b) Where low-flow systems are used a second chamber is imperative to prevent blockage of the small-diameter sewers (Kalbermatten, *et al*; 1980).	a) The SS system at Lusaka II is not operating effectively since users must collect water from a communal standpipe to flush the toilets, although there is at present provision for sullage disposal into tanks. The system can at best be described as a self-topping aqua-privy system, and where inadequate water is added to the system units are operating as pit latrines.

4.3 CONSTRUCTION ASPECTS

One of the advantages listed for SS systems (Smith; 1993) is that construction tolerances are greater than those for raw sewage sanitation, thus allowing for more rapid construction. Emslie (1986) recommends SS systems as suitable for labour-intensive projects because the greater tolerances accommodate the use of unskilled labour. SS systems have the following construction advantages over conventional systems (Brown, *et al*; 1991):

- strict level and straightness control are not required since only fluids are conveyed;
- on-site design changes can be made to avoid obstructions.

Seven of the nine South African schemes inspected had experienced problems due to poor construction, ranging from one or two localised problems on some schemes, eg: inadequate compaction (which is not unique to the SS system), to extensive problems such as were seen at Marselle. Lack of construction supervision was sometimes due to a decision by the client, in an attempt to save money, not have full-time supervision on the works. The types of construction-related problems found are:

- missing outlet tee-pieces;
- absence of connections between the tanks and the sewers;
- the use of several 90° bends, in conjunction with short sections of line laid in haphazard directions, between the tank outlet and the main collector;
- missing fittings (such as junctions);
- junctions facing upstream;
- local high spots adopted without attention to the hydraulic grade line;
- pipes laid without attention to smooth jointing;
- dirt and construction rubble in the pipes;
- outlets constructed on the same level as inlets;
- the use of cold-drink cans for end-caps.

This list indicates that the greater tolerances with respect to level and straightness have frequently been misinterpreted as a wholesale abandonment of good construction practice. The possibility of rerouting lines around obstructions has led to greater licence with respect to depth than is advisable. Quality control has not been stringent, possibly in the belief that all local variations in grade can be accommodated by the SS system. SS systems, such as that at Hermanus, where design standards have been adapted to suit solids-free sewers, but where strict quality control has nevertheless been implemented, are functioning without construction-related problems.

The high incidence of construction-related problems on SS systems in South Africa indicates the need for a standard construction specification. Such a specification will be developed by the CSIR from internal funding.

4.4 OPERATION AND MAINTENANCE OF THE SYSTEM

In general, SS systems in the USA are trouble-free. The statements by James Kreissl that "experience with the sewers has been excellent. The sewers have proven to be largely trouble-free with low maintenance requirements" (Brown, *et al*; 1991), and by Paul Ochodnicky, secretary of Westboro Sanitary District: "We have a very good system and have experienced a minimum of maintenance and cost" (Otis and Sirotiak; 1987), are typical of comments on the system by SS system operators in South Africa as well. On the latter scheme drain cleaning had not been necessary for 11 years after installation and at Mount Andrew there had been no pipe maintenance for 13 years after installation. Australian systems have reported only minor problems in 20 years, despite infrequent maintenance by unskilled personnel (Otis and Sirotiak; 1987). In Zambia the problems relating to the systems were immediately alleviated by emptying the tanks of sludge.

Odour and corrosion problems occasionally occur on SS systems because the effluent is septic and therefore gives off malodorous and corrosive hydrogen sulphide gas. Corrosion is dealt with by using non-corrodible materials, while odour problems have been reported on very few schemes internationally, and could all be addressed. At Lafayette, Tennessee, the problem was resolved by installing gas traps downstream of the tank outlet. Only 6% of tanks needed gas traps (Dedman; 1988).

Initial concern that a build-up of biological slime in the pipes would cause blockages or a reduction in capacity have not been substantiated in practice. Sections of pipe were cut out at Mount Andrew and only grey residue was found, and no slime build-up (Simmons, Newman; 1985).

A study of the actions undertaken by American towns with alternative conveyance systems indicates that maintenance programmes varied from daily, to once a year (most communities), to "as needed". Only 4 of 32 towns flushed the system. Twenty-two of the respondents quoted problems with inflow and infiltration. Other common problems included odours at pump stations, blockages of sewer pumps, overloaded tanks and grease(Region V; 1989).

A review of 12 American SS systems (Region V; 1989) indicates that all have performed well, no obstructions have occurred, even though flushing has not been performed. Odours occurred but corrective action was successful. Corrosion in pumping stations was a problem since septic atmosphere was not initially anticipated. Infiltration was a significant problem where existing tanks were used. Routine maintenance consists of weekly inspection of mechanical equipment and pumping of tanks every 5 to 7 years (Brown, *et al*; 1991). Typical operation and maintenance requirements of SS systems, as derived from the literature survey, are listed in Table 4.2, with the occurrence of these activities in South African SS system schemes.

Browne, *et al* report that in the USA the operation and maintenance requirements of SS system are generally simple and require no specialised skills or qualifications, other than familiarity with the system. Duties of operators will be making service calls, new connection inspections and administration. Usually pumping of tanks is contracted out. Maintenance equipment is usually a truck-mounted centrifugal suction pump.

No specialised training for personnel is necessary, but basic plumbing skills are desirable. Where pumps form part of the scheme, a basic understanding of them is beneficial. Local plumbing and electrical contractors are often used for skilled work. Australian schemes are maintained by unskilled personnel (Otis and Sirotiak; 1987).

An ***operation and maintenance*** manual is essential to each project (Brown, *et al*; 1991). Items to be included in the manual are:

1. System, and components, description. Shop drawings, as-built plans and profiles with service connections.
2. Description of normal operation, emergency procedures and fail-safe features.
3. System testing, inspection and monitoring- recommended to be described, with purpose and schedule.
4. Preventative maintenance procedures and schedules - with clear description.
5. Troubleshooting - describe common problems, diagnosis procedures and corrective action
6. Safety - alert to required safety precautions, potential hazards and methods to avoid/mitigate. Emphasise the dangers of working with septic waste and hydrogen sulphide.
7. Record Keeping Logs and forms - samples to be provided.
8. Equipment shop drawings and manuals - include installation and maintenance manuals and shop drawings of all major equipment. List manufacturers, suppliers and contact personnel.
9. Utilities list - list all in area, with maps and contact names and phone numbers.
10. System drawings - As-builts required, detail positions of service connections and maintenance log of each connection to be included.

Table 4.2 Operation and Maintenance Requirements of SS systems

Recommended Activity	South African Situation
Supervision and attendants at communal facilities (Kaoma; 1980).	Communal SS system facilities not found in South Africa.
Regular inspection of tanks to determine sludge level (Kaoma; 1980).	Not done, as schemes have not been in operation long enough. In the absence of regular inspections the sludge may reach the outlet, resulting in a blockage which may lead to overflowing of tanks.
Periodic desludging when tanks are 2/3 full (Kaoma; 1980; Swart; 1994, Human, *et al*; 1995).	Tanks are usually emptied when problems are encountered. To date no routine emptying of tanks has been required.
Clear blockages (Swart; 1994), although these rarely occur due to the solids-free nature of the effluent.	Blockages in South African schemes have been almost entirely construction-related, with the exception of the Marselle scheme where solids entered the lines via the tank outlet after tee-pieces were removed.
Inspection of pump sumps for the need to desludge due to poor construction workmanship or full tanks (Swart; 1994)	Only true for Marselle. No solids have occurred in other schemes.
Monthly ablution unit inspections (Swart; 1994).	Not done in SA.
Annual flushing of drains to remove slimes (Swart; 1994, Otis and Sirotiak; 1987, Human, *et al*; 1995, Burrows, van der Linde; 1994)	Not done in SA.
Monitoring of infiltration from cracked tank covers.	Not noted in SA.
Monitoring for entry of grit, sand and debris through manholes (Otis and Sirotiak; 1987).	Noted only at Marselle. Other schemes do not have many manholes.
Monitoring for severe corrosion of ferrous metals in lift stations (Otis and Sirotiak; 1987).	Noted only at Marselle. Other schemes used non-corrosive fittings and pumps.
Dealing with odour problems (Otis and Sirotiak; 1987).	Noted in ablution units at Lusaka II where no water-seal was present. Also initially a problem at Hermanus, but was found to be unrelated to SS system.
Emptying of tanks periodically (Otis and Sirotiak; 1987).	Not yet necessary in SA schemes.
Inspection and clearing, if necessary, of outlet pipes (Human, *et al*; 1995).	Initially a problem in some SA schemes. Subsequently resolved by modification of the design of the outlet tee-piece.
Monitoring of watertightness of tanks at the same time as emptying of tanks (Burrows, van der Linde; 1994).	Only applied at Hermanus. Other schemes have not indicated problems with leakage.
Monitoring for slime build-up on outlet tee holes. Abnormal build-up is an early warning of a malfunctioning tank (Burrows and van der Linde; 1994).	Initially a problem on some tee-pieces, but the problem was resolved by increasing the size of the holes from 5mm to 12mm.
Checking structural integrity during emptying (Region V; 1989).	Done only during construction.
Inspection of physical conditions of tanks, sewers, manholes and cleaning eyes (Region V; 1989).	Preventative maintenance generally not done on SA schemes.
Inspection and approval of all new construction (Walker, Ingham; 1980).	Done in terms of National Building Regulations
Maintenance of files on each property and line, and do two yearly inspections. Annual inspection (Walker & Ingham; 1980 and Otis and Mara; 1985).	Not done on SA schemes.

Normal maintenance actions required include call-outs by users, usually due to back-ups and odours (Brown, *et al*; 1991). Emergency calls will result from obstructions, which are rare.

Browne, *et al* also recommend good record keeping, including

1. A daily log of all actions
2. Maintenance reports for all equipment.
3. Flow records.
4. Tank inspection and service connection reports, which should be filed for review just before call outs.

4.5 INSTITUTIONAL ASPECTS

The term "Institutional Aspects" is used in this report to cover non-technical aspects relating to the local authority, such as policy and legislation affecting sanitation, educational requirements, collection of payment, the type of organisation required for successful operation and maintenance, etc.

4.5.1 National Policy and Legislation

The National Policy on Sanitation (Draft White Paper, June 1996), and the ability of SS systems to comply with those principles is set out in Table 4.3

Many new schemes in rural America are adopting alternative technologies because policy favours the adoption of innovative and alternative sanitation technologies by:

a) providing greater subsidies on such schemes;
b) providing a government guarantee against failure of the technology (as opposed to failure due to poor design or construction).

The Draft White Paper on Sanitation supports low-cost sanitation alternatives, but does not deal with alternative high-technology systems such as settled sewerage, vacuum sewers and pressure sewers.

The responsibility for the provision of sanitation facilities therefore remains with the local authority, who must still comply with the current National Building Regulations (NBR). In terms of the NBR the local authority is empowered to set the minimum standards of service in the area under its jurisdiction, and is responsible for the removal of sewage from the erven, either immediately or at periodic intervals, by means of pipes or tanker. Residents

Table 4.3 Compliance of SS systems with National Policy

No.	Policy Requirement	SS Systems' Compliance
1	Development should be demand driven (ie: reflect willingness to pay as well as need).	SS systems can provide a level of service equal to raw sewage conveyance systems, and can therefore meet the demand for flush systems.
2	Basic services are human right; the basic minimum acceptable sanitation facility is the properly constructed Ventilated Improved Pit (VIP) Latrine.	SS systems meet the requirements of an adequate sanitation system, and provide a higher level of service than a VIP. SS systems also provide for sullage disposal.
3	Some for all rather than all for some.	SS systems can be the final stage of upgrading of lower levels of service.
4	Water has economic value and is a scarce resource.	SS systems can operate on lower flush volumes since solids are not conveyed in the pipe system.
5	The environment is to be protected in development.;	SS systems provide containment of the excreta and sullage and therefore provide a high level of protection for the environment.
6	The user pays.	The user is more likely to accept the need to pay for a high level of service, as provided by SS systems, than for the basic level of service.
7	The user must pay for operation and maintenance. Where users cannot afford this a lifeline tariff will be applicable for the basic minimum level of service.	A correctly operated SS system should have lower life-cycle costs than a raw sewage conveyance system, thus making it more affordable.

are obliged to pay fully for all services provided, and the local authority is empowered to levy rates to cover the cost of this service. The majority of the local authorities therefore require residents to provide flush toilets linked either to municipal sewers, to septic tanks with drainfields, or to conservancy tanks.

Under the previous government former black townships fell largely under provincial government or homeland governments. As the majority of residents in these areas were unable to afford to provide their own sanitation facilities, these authorities usually provided facilities. Long-term insufficiency of funds and accelerated urbanisation meant that many schemes using bucket systems, pit-latrines or on-site digesters were developed. The operation and maintenance costs were seldom recovered from the users and sewage disposal systems were provided for out of current budgets, thus reducing even further the available pool of funds for provision of facilities.

With the incorporation of these areas into the newly established local authorities there is renewed pressure to reduce the operation and maintenance burden on the local authority, especially against the background of non-payment for services. From our discussions with the responsible authorities during inspection of the systems, it is evident that the officials are committed to supplying all the residents in their area with adequate sanitation facilities, but cannot afford to convert all existing schemes to flush systems with raw sewage conveyance systems immediately within current budgetary constraints. This problem is exacerbated by the need to provide adequate water supply from the same pool of funds.

Local authorities therefore must consider adopting a sanitation system that can be upgraded. One of the routes for upgrading would be to provide ventilated on-site digesters until such time as erf water connections are provided. The digesters may then be converted to conservancy tanks or SS systems.

4.5.2 Responsibility

Since there is great potential for manipulation, for political gain, of the issue of infrastructure which is perceived to have failed, the responsibility for every element of a sanitation system must be clearly defined, understood and accepted by all the parties.

Several models for the division of responsibility are in use as shown in Table 4.4, some with more success than others.

Model 1 is usually applied to financially viable communities, and has the line of responsibility of the local authority drawn clearly at the erf boundary. The local authority performs no actions on the erf, and bears no costs for operation and maintenance on the erf. The residents bear the full cost of the scheme by way of a loan which is repaid out of the monthly charges for sanitation, or by means of a special levy. The full cost of the operation and maintenance of all collector mains, treatment works, administration of the scheme, etc., is borne by the community and paid by means of monthly rates. This model is common in the United States of America (Brown, *et al*; 1991). Model 2 is as for model 1 except that the residents pay an increased monthly rate for sewage provision and the local authority takes responsibility for the tank on the erf, including the emptying. Unusual work, such as tank replacement, or excessively frequent emptying, will be executed by the local authority but the costs will be for the account of the householder.

Table 4.4 : Models for responsibility for elements in SS systems

Activity / Item	Responsibility			
	Model 1	Model 2	Model 3	Model 4
Supply and Install - Pipework from house to tank	User	User	User	Local Authority
Supply and Install - Tank	User	User	Local Authority / Govt Subsidy	Local Authority / Govt Subsidy
Supply and Install - Pipework from tank to collector main	User	User	Local Authority / Govt Subsidy	Local Authority / Govt Subsidy
Operate and maintain all pipework on erf	User	User	User	Local Authority
Operate and maintain tank	User	Local Authority	User	Local Authority
Bear costs of clearing all blockages in pipework on erf	User	User	User	User
Bear costs of clearing tank blockages	User	Local Authority	User	Local Authority
Arrange for and bear cost of emptying the tank	User	Local Authority	User	Local Authority
Pay cost of installation of collector mains	User (proportionately)	User (proportionately)	Local Authority / Govt Subsidy	Local Authority / Govt Subsidy
Pay monthly amount to cover the operation and maintenance cost of collector sewers and treatment works	User	User	User	User
Execute operation and maintenance of collector sewers	Local Authority	Local Authority	Local Authority	Local Authority
Operate and maintain of treatment works	Local Authority	Local Authority	Local Authority	Local Authority

Model 3 is common on government-subsidised schemes, where the costly on-site tank and its connection to the collector main are installed by the local authority, and then handed over to the user, who thereafter accepts responsibility for all the on-site elements. After construction this model is therefore identical to Model 1. Usually the capital cost of the scheme is subsidised by more affluent areas or by government grant. Model 3 has failed in some areas, notably Zambia and Marselle, because communities are too poor to carry the relatively high cost of emptying the tank as and when required. Steps taken by the users, such as removal of the tee-pieces to allow the sludge to enter the pipe network, digging of cesspits next to the septic tanks to accommodate the overflow, etc., have been fairly creative. The local authority has eventually been forced to empty the tanks at its own cost. These authorities have then adopted Model 4, recouping the costs by means of an added levy on the monthly flat rate payed by the residents.

Under South African conditions it may be necessary to adopt Model 4 in townships where low income groups predominate, and model 2 is recommended for financially viable communities because the effective operation of the septic tank is crucial to the trouble-free operation of the sewers. The need to convey the model adopted and the relevant responsibilities is essential, since many communities have a poor understanding of institutional arrangements. Some communities even believe that it is the responsibility of the contractor to maintain all elements of the works at his own cost, even those on private property and those which may have been abused or vandalised.

It is of note that a study at Stinson Beach, California, indicated that systems utilizing on-site septic tanks would be successful only if it was managed by a central authority. This was implemented, and now each unit has a file and inspections are done every two years (Walker, Ingham; 1980). This concept is reinforced by recommendations that SS systems be operated and maintained at local level, and that the responsibility of the local authority should include all appurtenances, whether on private or on public property (Otis, Mara; 1985). The maintenance of tanks by the owners is not recommended because the successful operation of the system is dependent on the successful operation of the tank.

4.5.3 Organisational Arrangements

Very little information was available from the literature regarding the type of organisation required to operate and maintain SS systems. A very valuable survey was, however, contained in "Alternative Sewers : Operation and Maintenance. Special Evaluation Project" (Region V; 1989). This document indicates that most of the 40 American towns with alternative sanitation systems (which includes SS systems) surveyed, had a top official (mayor or president), a board or council, and an operation and maintenance man. Larger municipalities had a separate operation and maintenance department with a director and several personnel. The councils have the responsibility for billing and collection of payment (Region V; 1989). These frameworks would not be materially different for raw sewage conveyance systems, but the number and skills of personnel may differ.

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All but two of the South African SS systems inspected had similar structures to the smaller American towns, with the exception that an additional level is often present between the board and the operation and maintenance man, namely the town engineer. The latter may be responsible for roads, stormwater, water, parks, the cemetery, the showgrounds, the treatment and the purification works, etc. The maintenance man usually has one or two unskilled assistants, and this team is usually also responsible for bucket systems in adjacent areas and operation and maintenance of the sewage treatment works and pump stations. The tanker driver may also be the operation and maintenance man, and usually reports to the town engineer. A raw sewage system would require a similar mix of skills, namely: a driver, a plumber and several unskilled assistants.

In towns such as Fouriesburg and Clarens, which have relatively small areas with RSC systems and larger areas served by SS systems, the maintenance personnel state that there are hardly any call-outs to the SS system, but continual callouts for blockages to the RSC system. In Cathcart it was estimated that three call-outs had been made from the SS system in eighteen months, all related to

- tanks which were full, and therefore perceived to be blocked, and
- blocked tee-pieces.

By comparison there are an average of two call-outs per month in the area served by RSC systems. The two areas are about the same size and have similar socio-economic characteristics.

In the case of Marselle, the township falls under Kenton-on-Sea. Marselle has no tanker, the tanker from the nearby Kenton-on-Sea is hired when necessary.

Lusaka II has been incorporated into the Krugersdorp transitional local council area, and the SS system is the responsibility of the City Engineer, Sanitation, who has a staff of engineers and technicians. To date no operation and maintenance actions have been necessary on the scheme, so information on the type and number of personnel required was not available.

Local authorities may choose to contract out both the clearing of blockages in the sewers and the emptying of septic tanks to local contractors.

4.5.4 Education and Training

The SS system must be well understood, particularly the manner in which it differs from conventional systems. Good user education is therefore a vital aspect of the SS system, which is equally important for effective operation of RSC systems. Users and operators should also be informed of where their responsibility for operation and maintenance lies, and what the cost recovery mechanism is (Swart; 1994).

This need for education of the user was evident on most of the SS system schemes visited. In almost all cases there was a need to inform users that a tank full of liquid is a normal operating condition and is necessary for the functioning of the SS system, and it is only when the tank is full of sludge that it must be emptied. The difference between liquid and sludge is not clearly understood by the users. In some cases users had no understanding at all of how any system of sanitation works.

All the operators of the SS systems, with the exception of Sterkstroom municipality and Krugersdorp local authority, had a thorough understanding of the system.

The education needs which were identified during discussions with both the users and the operating personnel include:

- health and hygiene
- sanitation technology
- costs of Services
- components of SS systems
- operation of SS system
- maintenance of SS system
- trouble-shooting
- responsibility for components of the system.

4.6 COSTS

SS systems are considered less costly than raw sewage conveyance systems, in terms of both initial capital cost and life cycle costs. Areas of cost savings are (Smith; 1992, Otis and Mara; 1985):

- lower material costs due to smaller pipes. This is particularly true if long erf frontages are involved as the savings per erf are then greater;

- lower excavation costs due to flatter slopes and following ground line;
- greater tolerances result in lower labour costs from using unskilled labour;
- reduced requirement for manholes;
- reduced treatment costs due to initial on-site treatment and lower peak inflows;
- lower operation and maintenance costs due to reduced blockages;
- reduced water demand.

In comparing the relative costs of two sanitation systems, the cost of treatment plant requirements, pump stations, operation, maintenance, tank emptying, water consumption, relocation of services, capital costs and operation and maintenance costs should be included (Swart; 1994). SS systems are estimated at up to 60% less than conventional systems where tanks are not provided (Swart; 1994), and about 13% less where tanks are provided (Emslie; 1986), while the cost of treatment works is estimated to be about 65% of the cost of conventional processes.

A cost comparison, given in Table 4.5 (Timmermans; 1990), for the Marselle scheme in South Africa indicates that the installation cost of the SS system scheme was greater than that of the raw sewage system when the comparison was limited to the sewers and tanks only. However, savings realised on the water supply network, pump stations and the existing treatment ponds, which could be retained unchanged, made the SS system scheme more viable.

Table 4.5 : Savings on elements of SS systems : Marselle

Element	SS system	RSC system
Sewers	R 404 000	R 730 000
Septic tank	R 1 000 000	-
Treatment	R 208 000	R 213 000
Water Augmentation	-	R 800 000
Water Reticulation	R 500 000	R 570 000
TOTAL	R 2 112 000	R 2 313 000
Monthly operation and maintenance (estimated, per erf)	R12-50	R17-50

In the United States of America SS systems have been cost-effective in rural areas where the unit length of sewer per user is as much as five times the American national average of 3m/user. The sewers account for 80% to 90% of capital costs and 65% of total annual costs (Otis and Sirotiak; 1987). Savings on initial capital costs (Otis and Sirotiak; 1987, Sundaram, Orth; 1989) for some schemes internationally are:

- 15% at Westboro, Wisconsin - all new tanks were installed;
- 30 to 50% at Mount Andrew, Alabama - all new tanks were installed;
- 15% at Chonburi, Thailand - all new tanks, and
- 25% also at Chonburi, Thailand - retain existing tanks.

Cost benefits are greatest where there is low population density and flat terrain. In an extension of the Chonburi comparison it was shown that where density dropped to 16 persons per hectare the cost saving increased to 29%. Less pump stations were needed and a total saving of 43% applied to the full project. Annual energy costs for running the pump stations also dropped, as a result the increased efficiency of solids-free pumping, by about 33% (Sundaram, Orth; 1989).

Australian costs are reported (Otis, Mara; 1985) to be 25%-30% lower than the cost of raw sewage conveying schemes. The costs of the septic tank and on-site pipework are excluded, as they are borne by the users.

Typical savings realised in South Africa are given in Table 4.6 below. Due to variations in elements included in the costs obtained, eg: pumpstations, bulk outfall sewers, Table 4.6 is given to indicate only the typical savings achieved with the use of settled sewerage system, rather than a comparison between the costs of specific schemes. Little data exists on actual operation and maintenance costs, but after 25 years of experience in Australia, the major costs are related to desludging of the tanks (Otis, Mara; 1985).

Specific operation and maintenance costs for SS system schemes in South Africa were not available.

Table 4.6: Costs of SS systems in South Africa

SCHEME	NO OF ERVEN SERVED	DATE COMPLETE	COSTS OF SETTLED SEWERAGE SYSTEM			COSTS OF Raw sewage SYSTEM		SAVING
			SEPTIC TANKS	TOTAL	COST/ ERF	TOTAL	COST/ ERF	
CLARENS	505	Jul 1995	R 71 000 (Existing tanks retained and upgraded)	R1 474 000 includes tanks and contribution towards treatment works	R2 920	R2 500 000	R4 950	41%
FOURIESBURG	330	Nov 1992	Existing retained	R 803 000	R2 433	R1 420 000	R4 303	43,5%
WARDEN	650	Feb 1993	Existing retained	R1 530 000	R2 354	Comparative costs not available		
CATHCART	569	mid-1995	Included	R1 250 000	R2 197	R1 400 000	R2 460	10,7%
RICHMOND / LOUIS PIENAAR	271 263	Jun 1995	Richmond: Existing retained Louis Pienaar: new tanks provided	R1 803 000 including pump station	R3 376	Comparative costs not available		
MARSELLE	550	Feb 1989	R1 000 000	R2 112 000 includes cost of treatment works	R3 840	R2 313 000	R4 205	8,7%
STERKSTROOM	410	Jul 1994	Existing retained	R1 100 000	R2 671	Comparative costs not available		
VOËLKLIP (Hermanus: Phase 1)	1600	1993	Existing retained	includes contribution to cost of treatment works	R5 927	Not available	R8 750	32%
MELMOTH	420	Sep 1995	Existing retained	R1 105 109	R2 631	Comparative costs not available		
TSHIAME	1200	Jul 1994	Included	R3 240 600	R2 700	Not avail	Not avail	15%

Note :This Table is not intended as a comparison of costs between schemes, but an indication of savings for particular schemes. Information on all aspects and comparative costs could not be obtained on all schemes. The estimated saving on Tshiame was obtained from the consultants.

5. SUMMARY AND CONCLUSIONS

Settled sewerage systems are currently found in seven countries throughout the world, having been in use for over 30 years in Zambia and Australia, over 20 years in the United States, and more recently in South Africa, South America, Thailand and Japan. In **these countries settled sewerage is not considered to be a step in the route to upgrading to a RSC system.**

Design standards in Zambia and Australia are conservative, allowing for a minimum pipe diameter of 100mm, while American and South African schemes have generally adopted minimum pipe diameters of 50mm. Neither Australia nor America have recorded blockages or other problems with the sewer networks or the septic tanks, while Zambia has extensive problems with both. Actual experience in all countries, excepting Zambia, indicate that blockages seldom occur in solids-free sewers. The problems in Zambia cannot successfully be traced to their origin within the scope of a short tour of inspection, since they appear to be due several causes, namely : inadequate technical knowledge of the local operation and maintenance personnel, inadequate funds for personnel and equipment at local authority level, inadequate user education and unreliable water supplies. Furthermore, in at least two towns in Zambia the blockages may be due to the coupling of raw sewage (solids-conveying) sewers to the very flat (1:700 to 1:800 slopes) solids-free sewers. Furthermore, septic tanks are not desludged, with the result that tanks overflow or sludge is forced into the sewers. **The perception that solids-free sewers block more easily is well-founded only where solids have erroneously entered the system. However, there should be no entry of solids into a SS system. The failure of SS systems in many towns in Zambia should be seen against the background of the failure of the raw sewage conveyance systems and other infrastructure in the same area.**

In South Africa settled sewerage schemes have been installed in high-, middle- and low-income communities. While construction related problems have affected the first six years of operation in Marselle (low-income), no problems have been reported subsequent to the rehabilitation of the scheme. On other low-income schemes in South Africa the sewers have operated without problems, and the problems related to the tanks have been primarily due to a lack of user understanding, although there are also indications that factors such as low-volume flushes and anal cleansing materials negatively affect the operation of small septic tanks. **The same lack of understanding would probably have resulted in blockages of the sewers in a raw sewage conveyance system. It is therefore maintained that settled sewerage, with the use of suitable design parameters, is suitable for low-income communities.**

Many of the operation and maintenance advantages of settled sewerage systems derive from the use of septic tanks on the erven, namely: the exclusion of rubble, plastic and inappropriate anal cleansing materials from the sewers, which minimizes blockages, and the resultant solids-free nature of the system, with attendant reduction in material usage, costs, etc.

This study has shown, both from the literature accessed and from the field inspections of nine settled sewerage systems in South Africa, that settled sewerage systems

- provide adequate protection against sanitation-related diseases to both the user and the environment;
- should be as acceptable to users as raw sewage conveyance systems, since they can provide the same level of service to the user. However, the aspects of the system disliked by the users can largely be addressed by ensuring community participation in the decision-making, and allowing individual choice in location of tanks and types of fittings;
- have a potential disadvantage with respect to the ability of the system to accept increased flows due to densification. However, the problem is not insurmountable, and can be dealt with by provision of additional septic tanks and installation of surcharge and attenuation chambers.

In the USA and Australia operation and maintenance expenditure on settled sewerage systems has been almost negligible, with the exception of the emptying of the septic tanks. In Zambia the experience was that the systems functioned well up to 20 years after installation with no maintenance, but 35 to 40 years after installation numerous problems in the systems were directly attributable to inadequate operating conditions (such as lack of water) and lack of maintenance. The cause of the problems on at least two schemes are also due to the use of the solids-free sewers to carry raw sewage. Maintenance actions reported in the literature reflect mainly monitoring and inspection functions, and the emptying of septic tanks. South African experience, with the exception of some teething problems and construction-related problems, reflects the American and Australian experience. Operation and maintenance problems observed on South African schemes can largely be addressed by altering design aspects.

In all schemes visited it was noted that education and training would have reduced the operation and maintenance activities required. Furthermore, to pre-empt the occurrence of a Zambian-type collapse of services it is essential that the responsibility of the user and those of the local authority be clearly defined and understood. The potential for collapse of South African local authorities is high because townships which were previously managed by provincial departments or former "homeland" governments now form part of new local authority structures, and these are obliged to provide services in terms of the current National Building Regulations. These local authorities will not have access to central government funds to cover their running costs, so the country-wide non-payment for services may lead to a situation such as prevails in Zambia, where cash-strapped local authorities cannot provide a service at all. In such a case a system which functions with minimal operation and maintenance will serve the user best.

Settled sewerage lends itself to provision of independent networks, each served by small local treatment facilities, which can (with limited training) be operated and maintained by the community. This approach would relieve the local authority of much of the operation and maintenance burden.

The models of responsibility most favoured place the responsibility for the operation and maintenance of the septic tanks and the sewers under the jurisdiction of the local authority, and the responsibility for the payment for all operation and maintenance functions with the user.

The construction costs of the all schemes where costs could be obtained were lower than the cost of equivalent raw sewage conveyance systems. This included schemes where septic tanks were provided as part of the project. Savings range from 8,7% to 43,5%. Unfortunately, cost data on operation and maintenance could not be obtained.

Call-outs were primarily due to blockages in the tanks, which occurred at the inlet tee-piece (occasionally) or the outlet tee-piece (more commonly), and were due to plastics and other floatable material, and in some cases, fats. The problems at the outlet tee-pieces were successfully addressed by design changes, but user education is required to prevent blockages on the inlet tee-pieces. The number of blockages reported is not high and in Fouriesburg, Hermanus and Cathcart, where both settled sewerage and raw sewage conveyance systems are found, maintenance personnel reported more call-outs to the latter.

The perception that settled sewerage systems are more costly to install, operate and maintain was not substantiated by any of the information collected. On the contrary, all information obtained indicates that settled sewerage systems are less costly to install, and have fewer operation and maintenance requirements.

The inspection of nine operational settled sewerage schemes in South Africa indicates that the technology has been successful, apart from some minor teething troubles and some construction related problems. **The system has been shown to be the equal of a raw sewage conveyance system in terms of capital cost, ease and cost of operation and maintenance, and level of service provided to the user.**

6. RECOMMENDATIONS

The following recommendations are made in respect of operation and maintenance of settled sewerage systems in South Africa:

Recommendation 1: Where solids-free sewage and raw sewage are conveyed through the same pipe sections the design standards for raw sewage conveyance systems should be adopted.

Recommendation 2: It is essential to the success of the settled sewerage system, and in fact for any sanitation system, that communities be involved in the decision-making and at the planning stage.

Recommendation 3: Suitable test procedures, specifically catering for settled sewerage systems, and well-defined construction tolerances be prepared before implementation of each settled sewerage project.

Recommendation 4: Serious consideration should be given to providing systems which do not require operation and maintenance input from the local authority, such as Ventilated Improved Pit latrines, where a community has a poor record of payment for services. Where settled sewerage is used local area networks, that drain to communal treatment ponds which can be managed by the residents in the event of failure of the local authority structure, should be considered.

Recommendation 5: Recommendations for design criteria to minimize operation and maintenance are that:

- in-line solids traps be considered to limit problems due to solids entering the sewers;
- access to the tanks and the sewers be limited by minimizing the size of openings in the tanks, replacing manholes as far as possible with cleaning eyes and use of concrete manhole covers;
- changes in water availability over the design life of the system be taken into account;
- potential densification be considered during the design phase;
- septic tanks be sized conservatively according to conventional design criteria;
- peak daily velocities exceed 0,15m/s;
- outlet tee-pieces be provided with access for fluid along the vertical leg of the fitting;
- inspection ports be provided above both tee-pieces;
- a flush toilet, with flush volumes greater than 3,5 *l*/s, be provided.

Recommendation 6: An operation and maintenance manual containing information on the elements of the system, operation, maintenance and monitoring procedures and requirements, safety, record keeping, etc., should be prepared for each project.

Recommendation 7: Education and training specifically related to settled sewerage systems, but also encompassing basic health and hygiene concepts, responsibility for the system and the need for payment, be conducted.

Recommendation 8: Technology transfer actions

During the project technology transfer took place throughout the study in the following manner :

- technical information was imparted to town engineers and local authorities verbally where there was a lack of understanding of the settled sewerage technology, and copies of relevant papers and documents were made available to those who requested further information. A need was expressed for a training workshop for engineers.
- considerable time and effort was spent with householders during the inspection of the systems, explaining the principles and processes involved and trouble-shooting actions required. It became clear that verbal explanations by technically orientated people would not be sufficient to transfer an understanding of the system to the users, even in cases where there was no language barrier.

Based on the above it is proposed to submit two proposal for funding to the Water Research Commission, namely :

- distribution of copies of the Community Leader's Guide to local authorities currently using the SS system, free of charge, with a request that they supply information on the usefulness of the document as an educational and decision-making tool
- distribution of the operation and maintenance guidelines to all local authorities which participated in the project, with a request that they comment on the usefulness of the document
- presentation of workshops, in regional centres, on settled sewerage technology. The workshops would cover choice, design, construction and operation and maintenance of the technology.
- Guidelines for facilitators on settled sewerage projects : to be developed from three field studies using the guidelines for community leaders developed under project K5/708, as well as a model of the settled sewerage system.

7. FURTHER INVESTIGATION

Aspects of settled sewerage systems requiring further study are :

a) **The sizing and design of septic tanks.** Conventional septic tank design may be conservative, and more information is required to allow for the optimization of tank size.

b) **An evaluation of the effect of varying flush volumes, anal cleansing materials and tank configuration on biological processes in the tank.** The objective of this is improve understanding of the septic tank as an anaerobic digester.

c) **Costs of operation and maintenance, including the economics of tank emptying related to septic tank size.** This will require an evaluation of the method of identifying and addressing problems, and of a time and motion study. A comparison between the costs and activities of a raw sewage conveyance system and a settled sewerage system serving similar communities is imperative for a full understanding of the cost savings of settled sewerage systems.

d) **Disposal of sludge through the sewerage network rather than using tankers.** The main cost of operation and maintenance of settled sewerage systems, and one of the major causes of problems in Zambia, relate to the desludging of tanks. If this can be done without the need for expensive equipment the advantage of settled sewerage over raw sewage conveyance system would be greatly enhanced.

e) **Use of local contractors and manually operated equipment of simple design for desludging of septic tanks.** The objective of this is to remove the need for large and continuous capital outlay, to provide employment opportunities locally and to remove a cost burden from the local authority.

f) **Evaluation of the cost effectiveness of education and training.** This would require investigating operation and maintenance requirements before and after an education and training programme.

g) **Preparation of a sample operation and maintenance manual.** This would entail preparing a suitable manual for a given town, and evaluating operational and maintenance effectiveness and efficiency before and after implementation of the processes advised in the manual.

h) **Testing of the operation and maintenance guidelines for community leaders.** The guidelines should be tested in several communities (rural, urban) and using several approaches (no explanation, assisted learning, use of models) to establish their efficacy and suitability.

I) **Development of construction guidelines, quality control techniques and maintenance methods.** An investigation of suitable construction techniques and testing of the theory that unskilled labour can be used for installation of settled sewerage systems, is required. Also needed are suitable test methods to ensure quality during construction and suitable equipment and techniques to deal with common maintenance problems.

j) **The solids conveying capacity of low volume flushes.** Arising from the recommendation that ablution units and septic tanks be sited to suit the home-owner, it is necessary to determine the minimum slopes and maximum distances which raw sewage can be transported from the toilet to the tank with 3,5 *ℓ*, 4 *ℓ*, and 6 *ℓ* flush volumes.

k) **The use of sections flowing under hydraulic pressure.** An experimental scheme using sections flowing under pressure, similar to that at Mount Andrew, Alabama (USA), is required in South Africa, to test the feasibility on African schemes, where entry of solids is more common.

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SECTION 9 : ANNEXURES

ANNEXURE A : FIELD INSPECTION REPORT
(SOUTH AFRICA)

ANNEXURE A : FIELD INSPECTION REPORT

SETTLED SEWERAGE SYSTEMS IN SOUTH AFRICA

TABLE OF CONTENTS

1. INTRODUCTION

This Annexure contains the information obtained during inspections of existing Settled Sewerage (SS) systems in South Africa. The inspections covered ten systems, and took place during February and August 1996. The oldest system in operation is at Marselle (completed in 1989), while the majority had been in operation for about two years. The system at Tshiame is not in use and is therefore not discussed further.

Prior to each inspection formal discussions were held with the local authority, and design information was obtained where possible. Users were also interviewed, and aspects of the system were discussed informally with the maintenance personnel.

2. OBJECTIVES OF FIELD TRIPS

The objectives of the field trips were to:

a) assess whether the systems were functioning in accordance with theoretical predictions and experience elsewhere in the world;
b) establish the nature and frequency of problems encountered;
c) obtain information on successful preventative maintenance and trouble-shooting practices;
d) obtain information on the operating systems in place.

In addition to objectives a) to d) above, the field trips were used as an opportunity to:

e) establish the perceptions of the residents, operators (ie: the local authority) and maintenance staff of SS systems;
f) establish the attitudes of the users to the system;
g) identify whether failure of theory, design or detailing, or construction problems were responsible for problems experienced.

The information obtained from the field trips, combined with such theoretical and published matter as is available, will form the basis of guidelines for the successful operation and maintenance of SS systems in South Africa. Detailed information on each of the schemes inspected is given in section 3 of this Annexure. Copies of the questionnaires used are included in section 5 of this Annexure.

3. SYSTEM INSPECTION REPORTS

3.1 CLARENS

3.1.1 Activities

Prior to the visit to Clarens Ms du Pisani and Mr Austin interviewed the design consultants, Laubscher, Human and Lombard (LHL), who have also designed six other schemes in the Free State and the Eastern Cape. Information obtained from LHL has been included in this report.

In Clarens Ms du Pisani and Mr Austin interviewed the town engineer, Mr Michael Johns, who also assisted during the inspection of the system and in obtaining comments on the system from local residents.

3.1.2 Project description

Clarens is located in the foothills of the Drakensberg in the Golden Gate area of the Free State. Of the 505 erven in the town serviced by an SS system, only 244 are developed. A new development, constructed to house people working on the Lesotho Highlands Scheme, is serviced by a raw sewage conveyance systems. The community served by the SS system comprises predominantly retired professionals, holiday home-owners and an artist's colony, with an average occupancy of 2 people per erf.

The town has many old buildings built of local sandstone, some of which are national monuments, as well as old trees. Roads are gravel and stormwater drainage is via surface channels. Water is provided to the erven, but the water supply is limited to a local earth dam with a small catchment area and water restrictions are frequently imposed. Slopes in the town are generally good, with all erven located in such a way that they can drain to the sewage treatment works. Excavation material was predominantly soft.

The erven connected to the SS system were formerly serviced by conservancy tanks. Prior to that septic tanks and soakaways were used. The existing tanks, which generally have a capacity of about 3000 ℓ but are not all constructed to the same design, were retained. Some tanks have two chambers. The SS system was completed in July 1995 at a cost R1,474 million, which included a R0,39 million contribution to the cost of the treatment plant, and R71 000 for modification of the septic tanks. A raw sewage conveyance system would have cost R2,5 million.

The SS system comprises 23,9km of pipework, ranging from 63 mm diameter. Pipes of 75mm, 90mm and 160mm diameter were used for the balance of the system. Manholes are not provided. The SS system drains under gravity to a sewage treatment works based on a biological filter. The use of an SS system enabled the local authority to use the works without increasing the capacity.

3.1.3 System operation

The municipality is responsible for the sewers and for emptying the tanks, but maintenance of the tanks is the responsibility of the home-owner. Operation and maintenance costs form part of the annual budget derived from monthly charges to the households, and no separate record is kept of plant, labour or management time spent on the sewerage. It was therefore not possible to obtain a cost for operation and maintenance functions of the Clarens Town Council.

The municipality owns a "honeysucker" tanker which is available to desludge the septic tanks. Both water jets and rods are available for clearing blockages. To date the equipment has not been used for the SS system, so that it was not possible to obtain an assessment of the adequacy of the equipment. A fee of R18-06 per visit had previously been charged where a conservancy tank was emptied more than once a month. Routine emptying of tanks is planned over a five-yearly cycle regardless of whether the tanks are full at that stage, or earlier if required in isolated instances. The depth of sludge is measured with a clear perspex tube. Blockages are detected when tanks overflow. The planned method of restricting flow in lines during maintenance is by use of inflated balloons in the upstream pipe section. The pipes will be flushed annually to prevent scum build-up. The town engineer checks tanks at random as part of a pro-active approach to locating problems. Clarens has experienced minor odour problems and some construction problems. The system has otherwise been trouble-free.

3.1.4 System inspection report

The Clarens SS system, which had been in operation for seven months at the time of the site visit, had experienced no problems. It was therefore not possible to view problem areas.

A typical septic tank with an estimated volume of $3m^3$, under construction at a new home, was inspected. Generally the septic tanks in Clarens have been constructed to different designs, but now new tanks are constructed to a standard design issued by the consultants and are similar to the one inspected.

3.1.5 Perceptions and understanding of the SS system

The town engineer of Clarens is also familiar with the bucket system, pit latrines, septic tank and soakaway systems, conservancy tank systems and raw sewage conveyance system, and considers the SS system superior to all of them because of the ease of operation and the general lack of problems. The only reservation which he expressed about the system is the lack of inspection points (such as manholes), which would allow him to observe the operation of the system and deal with potential problems pro-actively.

Users have been educated informally in respect of the SS system and interviews with members of the community indicate that they have a very good understanding of the manner in which a the system works. The system is well accepted, with the proviso that adequate support is available for dealing with problems. An aspect which raises concern is that the residents believe that the way in which to detect when the tank is full is to wait for the tank to overflow.

3.1.6 Summary and conclusion

The inspection of the Clarens system was productive from the point of view that the scheme is an example of a trouble-free operation and an effective preventative maintenance strategy.

3.2. FOURIESBURG

3.2.1 Activities

Design information on the Fouriesburg system was obtained from the design consultants, Laubscher, Human and Lombard (LHL). In Fouriesburg Ms du Pisani and Mr Austin interviewed the town engineer, Mr I. Venter, and the technician responsible for the maintenance of the SS system, Mr J. Meyer, who also assisted during the inspection of the system and in obtaining comments on the system from local residents.

3.2.2 Project description

Fouriesburg is located in the foothills of the Drakensberg close to the Lesotho border and is a rural settlement serving the local farming community with a population comprising predominantly retired and trades people. There are altogether 330 erven in the town, of which 228 erven are now connected to an SS system. The balance of the erven are undeveloped. A further 36 erven are serviced by a raw sewage conveyance system. The occupancy is estimated at about four people per erf.

Most of the buildings in the town are old and generally not as well maintained as the buildings in Clarens. Water is provided to the erven. Slopes in the town are generally good. Excavation material was predominantly soft, and even the rock that was encountered could be removed with heavy plant.

The erven connected to the SS system were formerly serviced by conservancy tanks. Prior to that septic tanks and soakaways were used. The existing tanks, which have capacities of about 4000 ℓ to 8000 ℓ and are not all constructed to the same design, were retained. The tanks mostly have one chamber. The SS system was completed in November 1992 at a cost R0,803 million. A raw sewage conveyance system would have cost R1,42 million.

The system comprises 13,45km of pipework, including 50 mm, 63mm, 75mm, 90mm, 110mm and 160mm diameter pipe. One manhole was provided in the main sewer, but none on the reticulation. Cleaning points are provided at the upper end of each line and at points throughout the system. Two pump stations are in use, the first for the SS system and the second for the small area with the raw sewage conveyance system. The sewage from both areas drains to a maturation pond system, which existed before the SS system was installed. These ponds would not have been adequate if a raw sewage conveyance system had been installed in the town.

3.2.3 System operation

The municipality is responsible for the sewers and for emptying the tanks, but maintenance of the tanks is the responsibility of the home-owners. Operation and maintenance costs form part of the annual budget derived from monthly charges to the households. The costs were perceived to be limited to the wages of one labourer (about R13 000 per annum), minimal supervisory time and the electricity used by the pumps (about R4 000 per annum). The annual budget for operation and maintenance is at present R20 000 per annum, and is adequate.

The municipality owns a tanker, equipped with a pump, which is available to desludge the septic tanks, as well as hoses and rods for clearing pipe blockages. The equipment has been adequate to deal with the problems experienced to date. The SS system pump station has operated without problems since installation, while the conventional pump station (which is fitted with a macerator) has blocked once.

The Fouriesburg SS system had been in operation for three and a half years at the time of the site visit and had never been flushed out as recommended in the literature. The only significant problems have resulted from the blocking of the outlet tee-pieces on the septic tanks.

An attempt has been made to relieve the problem by drilling numerous 12mm diameter holes in the tee-piece, but this has not been as effective as hoped, and at present the tee-pieces are kept clear by manually scraping any plastics, paper, etc., off with a steel brush attached to a long handle. The septic tank at the butchery consistently overflows due to fat blocking the outlet tee-piece, which would probably be relieved by the installation of a fat trap. The butchery has undertaken to clear the outlet every day.

Only two blockages in the sewers have been experienced since the installation of the SS system, and both have been attributed by the town engineer to poor construction. Only one tank, that at the post office, has been emptied since the installation of the SS system. The minimal amount of problems experienced with the SS system over the past three-and-a-half years compares favourably with the nine serious, and numerous other minor, blockages on the raw sewage conveyance system, which has been in operation for seven years (since 1989) .

3.2.4 System inspection report

Two septic tanks, the SS pump station and the oxidation ponds were inspected during the visit and all appeared to be working well, with no odours present. Both the tanks and the pump sump had formed the anticipated thin layer of scum above a clear supernatant liquid.

3.2.5 Perceptions and understanding of the SS system

The town engineer of Fouriesburg is familiar with the septic tank and soakaway system, conservancy tank system and raw sewage conveyance system, and considers the SS system to be superior because of the relative reduction in problems. He also suggested that more inspection points (such as manholes) are needed. The town engineer also prefers the double-chamber septic tanks because he believes that the incoming flow short-circuits to the outlet and can cause problems.

Although users have not been educated in respect of the SS system by the local authority at any stage, the community generally have a good understanding of the manner in which an SS system works. The system is accepted because of the cost benefits, but a raw sewage conveyance system is nevertheless preferred. Once again it is of concern that the only way in which residents can determine whether their tank is full is to wait for it to overflow.

3.2.6 Summary and conclusions

As Fouriesburg Town Council supports the SS system, having experienced less problems than with the raw sewage conveyance system and limited problems only with the outlet tee-piece, it can be concluded that this scheme is one of the success stories of SS in South Africa. The detailing of the outlet tee-piece has been unsuccessful since it is costing the Council the full wages of one labourer. The continued blockages at the butchery are due to the fat washed into the tank.

3.3. WARDEN

3.3.1 Activities

Design information on the Warden SS scheme was obtained from the design consultants, Laubscher, Human and Lombard (LHL).

In Warden Ms du Pisani and Mr Austin interviewed the town clerk, Mrs de Jager, and the technician responsible for the maintenance of the SS system, Mr Daniel Cronje, who also assisted during the inspection of the system and in obtaining comments on the system from local residents.

3.3.2 Project description

Warden in the eastern Free State serves the local farming community, and has a population comprising a mix of skilled, professional people, retired farmers and self-employed people. There are altogether 650 erven of which 479 are connected to the SS system, the balance being undeveloped erven. The residents are on average in the middle to upper income group. The occupancy is typically two to four people per erf.

Most of the buildings in the town are old and generally well maintained. Most roads are surfaced and water is provided to the erven. Slopes in the town are generally fair. Rock was encountered at shallow depths during excavation.

The erven connected to the SS system were formerly serviced by conservancy tanks. Prior to that septic tanks and soakaways were used. The existing tanks, which have capacities of about 6000 ℓ and are not all constructed to the same design, were retained. The tanks mostly have one chamber. The SS system was completed in February 1993 at a cost R1,53 million.

The system comprises 31,71km of pipework, including 50 mm, 63mm, 75mm, 90mm, 110mm and 160mm diameter pipe. Three manholes were provided at junctions of four or more pipes. Cleaning eyes are provided at the top of all lines, and also distributed throughout the network, although the maintenance staff report that the existing number of cleaning points is inadequate for their needs. Sewage from the eastern section of the town is pumped to the maturation pond system, while that from the western section drains under gravity. The ponds existed before the SS system was installed. The use of an SS system enabled the local authority to use the ponds without increasing the capacity.

3.3.3 System operation

The municipality is responsible for the sewers and for emptying the tanks, but maintenance of the tanks is the responsibility of the home-owners. Operation and maintenance costs form part of the annual budget derived from monthly charges to the households. There is no dedicated staff for the sewerage system, therefore the staff used for all service maintenance is used when problems occur. The budget for the operation and maintenance of the SS system could therefore not be obtained. The costs were perceived to be limited to the time spent on the garage, the café and the hotel.

The suction tanker owned by the municipality, which is used mainly for the bucket system in the adjacent low-income area, is used to empty the septic tanks when necessary. To date tanks have only been emptied for maintenance purposes and not because of high sludge levels. Water jets are used for clearing pipe blockages. The equipment has been adequate to deal with the problems experienced to date, with the exception of the blockages downstream of the hotel.

The Warden SS system had been in operation for three years at the time of the site visit. During that time problems have resulted from the blocking of the outlet tee-pieces on the septic tanks. An attempt has been made to relieve the problem by removing the original strainer and drilling numerous 12mm diameter holes in the tee-piece. Later slots were cut into the tee-pieces, and have proved more effective. Other problems experienced since the installation of the SS system are attributed by the maintenance personnel to poor construction.

Certain tanks, namely those at the garage, the café and the hotel experience repeated blockages. The problems at the garage and the café stem from the lack of functional fat traps, which were to be installed by the user on instruction from the municipality. Where fat traps do exist they are not emptied out when they become full. The cause of the problems at the hotel has not yet been established, although an inspection of the tanks indicated that they were operating effectively, both as settling tanks and anaerobic digesters. A blockage downstream of the hotel also could not be cleared with a high-pressure water jet since this was back-venting into the septic tanks and thus losing pressure.

3.3.4 System inspection report

Five septic tanks and the SS pump station were inspected during the visit, viz three domestic, the hotel's tanks and the garage's tanks. All were working well, with no odours present, although both the garage and the hotel tanks had been emptied recently. All the tanks had formed the anticipated thin layer of scum above a clear supernatant liquid. The municipality could not establish the cause of the blockages. The pump sump had a layer of fat floating on the top. This fat is apparently a major cause of blockage and subsequent burn-out of the pump.

At one of the tanks the cast-iron cover had started rusting and there was some fly movement in and out of the tank. The owners' attention was drawn to this and they undertook to attend to it immediately. The outlet tee-pieces for several of the tanks inspected had not been placed directly below the access cover, and were therefore difficult to clean when blockages occurred.

The tanks have to be emptied and a worker must climb in to attend to the problem.

An interview with the hotel owner yielded the information that a lot of foreign objects have been removed from the sewer system, including roots, stones and newspaper. There is no fat trap.

No obvious cause of overflowing at the tank could be found. In view of the fact that the hotel was closed when the SS system was designed, it is possible that the downstream sewers are in fact not adequately sized for the hotel's run-off, or the hotel outlet may be below the hydraulic grade line.

Warden maintains a register of call-outs by the public. A review of this register for 1994 and 1995 (previous books not retained) showed an average of about 45 call-outs a year. This figure is, however, not representative of problems. Residents have been accustomed to conservancy tanks and mistake the high water level in the tank for a high sludge level, and request emptying long before it is necessary. When call-outs are made for this reason, the occasion is used to educate the users.

3.3.5 Perceptions and understanding of the SS system

The maintenance personnel are familiar with bucket, septic tank and soakaway and conservancy tank systems and consider the SS system superior. The need to address the outlet tee-piece detail was stressed, as was the fact the system appeared to fail badly when fats and grease were discharged into it. The major problems at the pump station were due to grease and fats clogging the pump.

The maintenance personnel also stressed the need for more cleanouts since they could not pinpoint the position of blockages without "diagnostic" points.
Although users have not been educated in respect of the SS system by the local authority at any

stage, the community generally have a good understanding of the manner in which an SS system works, with the exception of one aspect, namely that the liquid level in the tank is always at the outlet level, and that the tank is in fact not "full" at that stage. The emptying service was therefore requested quite frequently, and the maintenance staff then explained the difference between "sludge" and the supernatant liquid to the homeowners, with the fact that the liquid would drain off through the pipes.

3.3.6 Summary and conclusions

Warden Town Council supports the SS system but has problems with blockage of the outlet tee-pieces, and fats and grease from the garage, the café and the hotel. Construction-related problems are also reported. Apart from this the system has resulted in a cost saving for the council since it no longer needs to operate as many suction tankers.

3.4. MARSELLE

3.4.1 Activities

Information on the Marselle SS scheme was obtained from Mr Ronnie Crouse of the Eastern Cape Provincial Administration (ECPA) and from a report prepared by the CSIR in November 1993, entitled "Guidelines for the Design, Operation and Maintenance of Settled Sewerage Systems in South Africa with reference to the Marselle Case Study".

In Marselle Ms du Pisani, Mr Murdoch and Mr Austin interviewed the Boesmansriviermond Municipal staff member responsible for operation and maintenance, as well as a representative of the contractor at present involved in repairing the SS system.

3.4.2 Project description

Marselle is a low-income rural community located near the holiday towns of Kenton-on-Sea and Bushman's River Mouth. There are 1700 erven, of which 950 are connected to the SS system. The population comprises predominantly unemployed people, pensioners and children, with two to four people per erf. The SS system initially serviced a portion of the 950 erven, and aqua-privies were provided on the balance of the erven. The aqua-privies mostly functioned like pit latrines since insufficient liquid was added to maintain the water level required, and tanks were not filled with water after emptying of sludge. The initial SS system was completed in 1989, while the erven with on-site digesters were converted to full flush systems and connected to the SS system between 1994 and 1996. Project costs were not available.

The town was built and administered by the former Cape Provincial Administration until 1994, when Marselle was incorporated into the Boesmansriviermond Transitional Local Council area. Subsequent to the initial development, some upgrading has been carried out and all erven now have water connection, electricity and flush toilets. The roads are gravelled with a surface stormwater system. Although slopes in the town are generally good, one pump station is required to lift the collected sewage to the maturation pond system.

HDPE class 10 pipes of 63 mm diameter were used from the tank to the main line. The smallest common sewer is 80mm LDPE class III, increasing thereafter according to capacity needs. Manholes are provided at changes in direction. Both Calcamite and Atlas plastic tanks were used, each with a capacity of 1,75 m^3 and a 50mm overflow.

3.4.3 System operation

The Boesmansriviermond TLC is responsible for the sewers from the outlet of the tank.

Emptying and maintaining the tanks is the responsibility of the home-owner. The operation and maintenance budget for Marselle is R6 200 per annum (1995). R800 000 was allocated for repairs to the system in 1996. Emptying of the tanks costs R25-00 per visit, but many residents have simply removed the outlet tee-piece, thus allowing the sludge to enter the system, and thereby obviating the need to empty the tank but causing blockages in the system. A flat rate of R1 per month for emptying of tanks is now included in the municipal charges. Non-payment for services is, however, a continuing problem.

The Boesmansriviermond TLC provides a tanker service for emptying of tanks. A "Hydrovac" has recently been purchased for dealing with line blockages, at a cost of R20 460. The advantage of this jet/vacuum combination is that it obviates the need for a sludge pump, and also allows hardened material to be loosened in the tanks and then sucked out. This equipment has been very successful. Rods, used previously, were not at all successful due to the small pipe sizes and construction problems. Typical construction problems were the inclusion of vertical 90° bends and sometimes several bends in series in the house connections.

Because of the numerous problems experienced with the Marselle SS system the Boesmansriviermond TLC commissioned BKS Incorporated Consulting Engineers to investigate the causes of the problems, and recommend solutions. Their findings are as follows :

- corrosion and collapse of the cast-iron junctions are causing blockages;
- junctions installed against the flow;
- clearing of blockages is inhibited due to insufficient access in the form of rodding eyes;
- deformation of the tanks resulting in blocking of the outlet;
- ingress of roots via the manholes;
- the tank configuration impedes the access of the suction hose during emptying.

3.4.4 System inspection report

The numerous problems at Marselle made this inspection a particularly valuable learning experience. Examples of all the problems identified by BKS were viewed, and in addition the following problems were viewed :

- **a thick layer of undigested excreta floating on top of the contents of the septic tanks**
  This layer can become thick enough to block the outlet. The cause of this layer is not known, but it could be due to ammonia toxicity inhibiting the anaerobic digestion, inadequate retention time or an inadequate water/excreta ratio for biological activity. Alternatively, the layer could be hardened residue left in the tank when tanks were converted from a dry to a flush system, which has subsequently floated to the top, bringing fresh excreta with it.
- **outlet tee-pieces that had fallen off, or been removed**
- **the occurrence of a black, lumpy sludge in pipes**
  This sludge, which had probably entered the pipes from those tanks where the outlet tee-piece had been removed by the residents, becomes very hard when dry. Since a pump with no solids handling capability was installed, the sludge has caused problems at the pump station.
- **poor construction**
  This includes lines with innumerable and unwarranted bends (ie: not in accordance with the design), inadequate jointing where different classes of materials were joined, lines meandering across erven and lines occasionally turning back on themselves.
- **overflowing tanks**
  Caused by blockages in the lines downstream and blockages in the outlet tee-pieces.
- **uPVC pipe had been used instead of the HDPE initially specified**
  The latter would require less bends due to its relative flexibility.

Marselle also experienced problems with blocked tee-pieces, and also resorted to drilling 12mm holes in the sides of the tee-pieces. This has been successful.

3.4.5 Perceptions and understanding of the SS system

Mr Ronnie Crouse of the ECPA has been greatly discouraged by the experience of Marselle, although he does point out that many problems are due to incorrect detailing, such as the tee-piece and cast-iron junctions, as well as poor construction.

The maintenance personnel believe that the problems have been greatly exaggerated and that the system is working well except for a few specific problems. They also believe that some of the problems may be due to building activities on the erven, where additional structures are being built. Foundations are cast directly above the pipes and later settle, causing the pipe to collapse, or pipes are damaged and "repaired" by wrapping rags around them.

Some initial informal education of the users in respect of the SS system was done, but much has been negated due to changes in occupation. Interviews with members of the community indicate that they have no understanding of the system, and many are not aware of the pipe system. Although they concede that the system works just like a raw sewage conveyance system, they insist that they prefer a raw sewage conveyance system.

3.4.6 Summary and conclusions

At the time of finalising this report the rehabilitation work at Marselle had been completed, and the system was reported by BKS to be functioning without problems. Effluent at the pump station was also reported to be solids-free.

The problems at Marselle could bring the concept of SS systems into disrepute. As the rehabilitation works did not involve relaying of pipes, alteration of tanks, or any other major systemic or design changes, but only replacement of junctions and correction of construction defects, this affirms the applicability and suitability of the SS technology for Marselle.

Although most of the problems reported at Marselle were due to unsuitable detailing, or poor construction, the failure of the tanks to work as primary anaerobic digesters is also of concern. The inspection of the Marselle system was productive since it justified the theoretical design norms by the failure of details that did not comply with these norms.

3.5. CATHCART

3.5.1 Activities

Information on the Cathcart SS scheme was obtained from Mr Steve Landolt of Cahi de Vries. Ms du Pisani, Mr Murdoch and Mr Austin interviewed Willie Coetzee, the Town Clerk, Mr Harry Proudman, Jurie van der Vyfer and Christoffel Jayaja, the technical personnel directly responsible for operation and maintenance of the sewerage systems.

3.5.2 Project description

An SS system was installed in Daliwe, adjacent to Cathcart, which lies about 250km north of East London, in the eastern Cape Province. There are 569 erven connected to the SS system, which was completed in 1995. The population comprises predominantly unemployed people and their extended families. The average number of people per erf at the time of installation of the system was six, but subsequently considerable densification has occurred, and there are now up to 30 people on some erven. The cost of the SS system was R1,25 million, while a raw sewage conveyance system would have cost R1,4 million. The treatment works for the whole town was at that stage being improved, to comply with a directive from the Department of Water Affairs and Forestry, and an additional capacity of 10-15% was required to accommodate Daliwe, which was at that stage served by a bucket system.

Houses in Daliwe have been constructed of metal sheeting, mud and local stone. All erven have electricity, water connections and flush toilets. The roads are gravelled and there is a concrete-lined surface stormwater system. Slopes in the township are steep and rock occurs on the surface.

Pipe sizes used in the SS system range from 50mm diameter to 110mm diameter. Class 6 uPVC water pipes were used, but were manufactured in white for this project to prevent confusion between water and sewer lines. A minimum gradient of 1:300 was adopted for the sewers with an average pipe depth of 600mm to 700mm, and full-bore flow was accepted. No manholes were provided. Septic tanks with a capacity of 1,2 m^3, with two chambers, were constructed in-situ of cement blocks and covered with a concrete slab. The tanks are approximately 800mm wide and 1600mm long, with the first chamber occupying about 2/3 of the volume. Inspection openings and a suction hose access (about 200mm x 200mm), have been cast into the tanks above the inlet and the outlet.

3.5.3 System operation

The Cathcart Local Authority is responsible for the sewers from the outlet of the tank, and for emptying of the tanks. Maintaining the tanks is the responsibility of the home-owners. There is no separate budget for operation and maintenance of the SS system, since the same personnel and equipment are used for Cathcart, Cati-Cati (raw sewage conveyance systems), the treatment works and Daliwe. Emptying of the tanks is included in the flat rate for services, which is at present R17,00 per month for Daliwe. This excludes the cost of electricity.

The local authority owns a "Hydrovac" for emptying the tanks, as well as rods and water jets for clearing blockages on both the raw sewage conveyance and the SS systems. This equipment has been very successful, but a longer hose would be preferred. The Hydrovac has not been tested on long sections of line. Rods are used in the SS system to clean the tee-pieces.

In the period that the SS system has been in operation only three blockages, all at the outlet tee-piece, have occurred. Blockages are due mainly to plastics. The local personnel suspect that, since the ablution units are separate from the houses, plastic bags are used inside the house during the night and then flushed down the toilet the next morning. Plastic bags may also be used for anal cleansing.

3.5.4 System inspection report

Two tanks were inspected at Cathcart, one of which was blocked due to plastics clogging the outlet tee-piece. The second tank was reported to be full, but our inspection revealed that there was a thick layer of undigested excreta floating on top of a liquid layer. The liquid was draining into the SS system as expected.

The extensive densification on some of the erven, resulting in 19 to 30 people using one ablution unit, would mean that the tanks were not providing adequate retention time.

3.5.5 Perceptions and understanding of the SS system

The people interviewed agreed that there was no difference in the operation of their waste disposal system and a raw sewage conveyance system, but did not like the system because of the tanks on the erven. The tanks were very visible due to the steep grades.

The maintenance personnel do not favour the system, and they anticipate future problems due to blockages. The system is considered more troublesome than the raw sewage conveyance system in the adjacent township, even though the latter had an average of two blockages a month as compared to the SS systems three blockages in twelve months. The blockages were all on the outlet tee-pieces, and due to foreign matter in the tank.

No education of the users in respect of the SS system was done, and the community had very little understanding of the system.

3.5.6 Summary and conclusions

The problems at Cathcart are primarily due to use of plastics for anal cleansing. A raw sewage conveyance system would probably also have blocked under the same circumstances. Possible problems may arise due to the densification on the erven.

3.6. STERKSTROOM

3.6.1 Activities

Design information on the Sterkstroom SS scheme was obtained from the design consultants, Laubscher, Human and Lombard (LHL).

In Sterkstroom Ms du Pisani, Mr Murdoch and Mr Austin interviewed the person directly responsible for the operation and maintenance of the SS system, Mr Christo de Wet, who also assisted in obtaining comments on the system from local residents and during the inspection of the system.

3.6.2 Project description

Sterkstroom is a rural community in the eastern Cape Province, about 230km north-west of East London. The population comprises mostly retired people. There are altogether 410 erven, of which 275 are connected to the SS system. The balance of the erven are undeveloped. The town was formerly serviced by conservancy tanks, and before that by septic tanks and soakaways. The SS system was completed in July 1994 at a cost of R1,1 million, which excluded the construction of septic tanks.

The town has a high standard of services, with electricity, water on the erven, flush toilets, surfaced roads and a surface stormwater system. Slopes in the town are fair to flat. Some rock was encountered, but generally excavation was soft.

Pipe sizes range from 63mm to 160mm diameter and are manufactured from white uPVC. Manholes are not provided. Existing tanks, which generally have two chambers and a capacity of about 4 m^3, were retained.

3.6.3 System operation

The Sterkstroom Municipality is responsible for the sewers from the outlet of the tank and for emptying the septic tanks. The cost of emptying of the tanks is R15,00, payable by the home-owners. Maintaining the tanks is the responsibility of the home-owners. The operation and maintenance budget could not be obtained.

The Sterkstroom Municipality owns a tanker for emptying the tanks, but no other maintenance equipment. If problems occur the required equipment will possibly have to be borrowed from Queenstown.

The Sterkstroom SS system had been in operation for eighteen months at the time of the site visit. During that time no problems had been experienced. Twenty tanks have been emptied in this period. This is not a reflection on the SS system since the sludge was not removed from the tanks before commissioning the SS system. No blocking of the outlet tee-pieces on the septic tanks was reported.

3.6.4 System inspection report

Two typical septic tanks and the maturation ponds were inspected during the visit, and were working well. Sterkstroom has no problem areas relating to the SS system.

3.6.5 Perceptions and understanding of the SS system

The maintenance personnel at Sterkstroom have a superficial understanding of the SS system, but since the system has been trouble-free this has not, to date, had any effect on the operation and maintenance of the system. Although the presence of numerous cleaning eyes is reported by the consultants, the operation and maintenance personnel perceive the absence of access points as a problem.

There was no education of the users in respect of the SS system, but the community appear to have an understanding of the basic principles of the system.

3.6.6 Summary and conclusions

The inspection of the Sterkstroom system was productive, since it indicated that an SS system will work well if designed, detailed and constructed correctly.

3.7. RICHMOND

3.7.1 Activities

Design information on the Richmond SS scheme was obtained from the design consultants, Laubscher, Human and Lombard (LHL).

In Richmond Ms du Pisani, Mr Murdoch and Mr Austin interviewed the Town Clerk, Mr Piet Conradie, who also assisted in obtaining comments on the system from local residents and during the inspection of the system.

3.7.2 Project description

Richmond is a middle-income rural community in the Karoo, about halfway between Cape Town and Johannesburg. 178 of the 271 erven in Richmond and 263 erven in the adjacent township of Louis Pienaar are connected to the SS system. The balance of the erven in Richmond are undeveloped. The population of Richmond comprises mostly retired and self-employed people, while that of Louis Pienaar comprises mostly unemployed people. Richmond was formerly serviced by conservancy tanks, while Louis Pienaar was serviced by a bucket system. The SS system was completed in June 1995 at a cost of R1,8 million, which excluded the construction of septic tanks in Richmond, but included the cost of septic tanks in Louis Pienaar. The project included the construction of a new pump station which services both the SS system and an existing raw sewage conveyance system serving the adjacent Sabelo township. The old pump sump was retained and now acts as a drop manhole.

The town has a high standard of services, with electricity, water on the erven, flush toilets, surfaced roads and a surface stormwater system. Louis Pienaar was not inspected. Slopes are good, and rock was found in Louis Pienaar. In Richmond excavation was soft.

Pipe sizes range from 50mm diameter from the tank to the sewer main, and 63mm to 160mm diameter for the reticulation. Structured wall sewer pipes and uPVC water pipes were used for the system. Manholes were not provided. Existing tanks in Richmond, some of which have two chambers and a capacity of about 4 m^3, were retained. New brickwork tanks were constructed in Louis Pienaar, with a capacity of 2 m^3.

3.7.3 System operation

The Richmond Municipality is responsible for the sewers from the inlet of the tank, and therefore for both emptying and maintaining the tanks. The operation and maintenance budget could not be obtained, but is essentially the cost of maintaining and operating one tanker, and the salaries and benefits of the driver and two assistants.

The Richmond municipality owns a tanker for emptying the tanks, cleaning rods and air compressor which is used to clear blockages.

The Richmond SS system had been in operation for a year at the time of the site visit. During this period considerable problems were experienced due to poor construction. These include blockages, a tee-piece left out of a line, tanks that had not been connected and the use of cold drink tins or rags to cap cleaning eyes. The latter caused odour problems. Infiltration occurs through both the lines and tanks during the rainy season. Neither were submitted to pressure tests during construction. The tank at the petrol filling station on the N1, which has a restaurant and is patronised by holiday-makers, has to be emptied every day.

No blocking of the outlet Tee-pieces on the septic tanks was reported.

It was noted that vandalism, which is a problem in Sabelo where there is a conventional system, has not occurred on the SS system.

3.7.4 System inspection report

The septic tanks at the hotel and the garage were inspected, as well as the old pump sump. The tank at the hotel was operating well. At the garage, which has two tanks, one serving the kitchen and one the ablution units, a thick layer of undigested excreta was floating on top. This caused blockages and as a result these tanks are pumped out every day. Exactly the same formation was noted in the pump sump. This also has to be removed every day to prevent the outlet pipe to the new pump station from blocking.

A sample of the floating matter in the pump sump was analysed by the CSIR in Pretoria and found to contain mainly silicon, carbon and nitrogen. The two latter elements are typically found in excreta, but the high silicon content cannot be explained.

3.7.5 Perceptions and understanding of the SS system

The maintenance personnel at Richmond have an adequate understanding of a SS system, but are disillusioned by the numerous construction problems and the necessity of emptying tanks at the garage on a daily basis. An SS system will probably not be chosen again, even though the savings were considerable.

3.7.6 Summary and conclusions

It was clear from our inspection that the majority of the problems at Richmond arose from poor construction quality control. Although SS systems can accept lower standards with respect to level and straightness control, it is strongly recommended that at least the same quality control as would be exercised for a water reticulation main be applied to SS systems.

The presence of the undigested layer of excreta on top of the tank at the garage as well as in the old pump sump is of interest because a similar layer was found at Cathcart and Marselle. The reason for this layer at Richmond probably is the same as that for Marselle, namely a lack of microbial activity. However, the cause of the problem at Richmond is probably the lack of quiescent conditions in the pump sump.

3.8 HERMANUS

3.8.1 Activities

Design information on the Hermanus SS scheme was obtained from the Town Engineer of Hermanus, Mr James van der Linde.

Ms du Pisani and Mr Murdoch interviewed Mr van der Linde and his assistant, both of whom assisted in obtaining comments on the system from local residents and during the inspection of the system.

3.8.2 Project description

Hermanus local authority is responsible for a series of formerly independent holiday towns along the coast from Kleinmond to Stanford, as well as some black and coloured townships which formerly were the responsibility of the Cape Provincial Administration. Altogether 3 200 erven in the area are connected to SS systems, with 800 in Sandbaai, 1 600 in Voëlklip and 1 200 in Vermont. The balance of the 8 500 erven are connected to a raw sewage conveyance system, still using conservancy tanks, or are undeveloped. The sanitation infrastructure is therefore a mix of technologies, with the raw sewage conveyance and SS systems sharing the main outfalls and pump stations. Effluent from the remaining conservancy tanks is also dumped into a nearby sump, which then discharges into a main outfall.

The SS system was installed in phases, with the 1600 erven in Voëlklip completed in 1993, and the 800 erven in Sandbaai completed in 1994. The scheme in Vermont has only recently been completed. The costs of the schemes were not available, but Mr van der Linde estimated that, on average, the SS systems cost 30% less than a raw sewage conveyance system.

The holiday towns under the local authority are attractive, with a good standard of service. All the areas serviced by SS schemes have electricity, water on the erven, flush toilets, and a surface stormwater system. In some of the areas gravel roads serve the holiday homes, and in other areas the roads are surfaced. Many of the homes stand empty for the greater part of the year, and are used only during the holiday season. Slopes are variable, with very flat areas in Sandbaai and broken rolling terrain elsewhere. Shallow rock was encountered in Sandbaai, where 40% rock was measured, while elsewhere no rock was found.

The SS system is well suited to the conditions in Hermanus, namely :

- flat slopes,
- shallow rock,
- widely varying flow volumes throughout the year, and
- large areas of the town already served by septic tanks.

Pipe sizes range from 50mm diameter from the tank to the sewer main, and 63mm to 110mm diameter for the reticulation. Class 4 uPVC water pipes were used for the system, with Y-junctions specially manufactured for the projects. The latter were tested at the CSIR. Manholes were not provided. Existing tanks were retained where the capacity was greater than 1,7 m^3, but all newly installed tanks must be in accordance with a 5 m^3, two-chamber, standard design prepared by the local authority. The designs and sizes of existing tanks vary, with both one and two-chamber tanks occurring. The size of the tank was based on experience that the larger tanks consistently perform well as a primary digester, while problems with undigested excreta have been observed only in smaller tanks. The construction cost of the tanks is borne by the developer and included in the erf price, rather than in the project cost of the SS system, which is borne by the local authority.

The Town Engineer took an active part in determining the design norms for the SS system.

The norms adopted are given below :

Minimum pipe diameter for a common sewer :	63mm
Clean-out points at:	200m
Tank size :	5m^3
Tank depth (minimum);	1,2m
Minimum flow velocity at peak :	0,3m/s.
Junctions :	Y-shaped
Maximum acceptable flow depth :	80% of diameter
Inlet to outlet height difference:	50mm

Testing of the system was required during construction, and included testing of the tanks for water-tightness and ensuring that there were no blockages in the lines, by inserting ping-pong balls of different colours and monitoring their reappearance at the end of a line.

3.8.3 System operation

The local authority is responsible for the sewers from the outlet of the tank and for emptying the tanks. Maintenance of the tanks is the responsibility of the home-owners. The total operation and maintenance budget could not be obtained, but the following figures for monthly household charges were provided :

	Basic Charge	Per pan
Conventional sewers :	R37-00	R33-00
SS sewers :	R14-00	R33-00
Conservancy tanks :	R70-40 (covering emptying of the tank twice a month, plus additional emptying costs R110-00 per time).	

The operation of the conservancy tanks is uneconomical for the local authority, since it costs R184-00 a time to empty a tank.

The budget allocated from these funds for operation and maintenance is sufficient. The main activities of the operation and maintenance team, which comprises a supervisor, two labourers and an LDV, are a daily inspection of the 20 pump stations serving both the SS and raw sewage conveyance systems, clearing blockages in the raw sewage conveyance system and dealing with complaints. The SS system sewers have to date needed no maintenance work.

The local authority owns a tanker were emptying the tanks and a high-pressure water jet for clearing blockages. There have been only four blockages in the Septic tanks in the past two years, and the available equipment was adequate for dealing with these problems. The local authority plan to flush the system at regular intervals to prevent build-up of slime in the pipes.

The portions of Hermanus SS system had been in operation for a two and a half years at the time of the site visit. The main problems experienced during that time have been blockages of the outlet tee-piece. The design of this fitting has subsequently been modified to include 12mm holes in the vertical section of the tee-piece, and this new design has been successful.

Odour problems were experienced on the SS system shortly after completion. The cause of the odour was traced to septic effluent flowing from the sump, used for dumping effluent from the remaining conservancy tanks, through an outfall common to this sump and the SS system. Water-seals, installed between this main outfall sewer and the SS sewer lines, solved the problem.

3.8.4 System inspection report

Several septic tanks of varying design, including the Sani-Tree, Calcamite, and a tank constructed according to the council design, were inspected, as well as one of the pump stations. All tanks were operating well. In order to obtain the capacity specified by the local authority, two Sani-tree tanks had been installed in series. These tanks are small round tanks divided into two chambers by a central panel, and consequently the first chamber contained all the sludge, and the second chamber and second tank contained only liquid. The solids capacity of the two tanks in series was therefore limited to that of the first chamber of the first tank.

3.8.5 Perceptions and understanding of the SS system

The town engineer has an excellent understanding of SS systems, and is fully committed to the technology. The excellence of the design and construction of the SS systems in Hermanus and the subsequent trouble-free operation are directly attributable to his active involvement in setting design standards and ensuring testing during construction.

As there are several different makes and configurations of septic tank in Hermanus, the inspection focussed on inspecting these. Unfortunately the residents were not at home at most of the sites visited and, due to time restrictions, only one resident was interviewed. He fully supported the system because of the cost saving.

3.8.6 Summary and conclusions

It was clear from our inspection that the lack of problems at Hermanus was due to good design and construction, driven by the understanding of the local authority of the technology.

3.9. KRUGERSDORP

3.9.1 Activities

Information on the SS scheme in Lusaka II, a township falling under the jurisdiction of Krugersdorp local authority, was obtained from the City Engineer's Department, Krugersdorp.

Ms du Pisani and Mr Murdoch interviewed Mr van Reenen, Mr Lombard and an assistant engineer, Mr Maree. A member of the local SANCO committee acted as a guide during the inspection of the scheme.

3.9.2 Project description

Lusaka II township was developed under the former Transvaal Provincial Administration, and the responsibility for the operation and maintenance of the town was transferred to the then Krugersdorp Municipality after completion of the construction. The municipality agreed to accept responsibility for the township only on condition that all network pipes were a minimum of 110mm diameter. Two pump stations with submersible pumps form part of the scheme. The project cost (1995) was R2,23 million.

Lusaka II is a low-income township with gravel roads. All homes have recently been supplied with electricity, but water is supplied via standpipes serving up to 10 erven. Upgrading of the water supply to erf connections is in the planning stage, and the roads are at present being upgraded.

A ablution unit is provided on each erf with a 1000 ℓ round plastic septic tank, and is essentially an aqua-privy. Water for flushing is collected from the standpipe in a bucket. There is no cistern. The homes are constructed of corrugated metal sheeting, wood, brickwork and cement blocks. Many are very well constructed, while some dwellings are no more than shacks. Slopes are good.

Pipe sizes range from 50mm to 75mm diameter, depending on whether one, two or more houses share a common line, from the tanks to the sewer main, and 110mm diameter for the reticulation. Larger pipes, of 250mm and 315mm diameter are used on the main outfall sewer. uPVC water pipes are used for pipes up to 75mm diameter, and uPVC sewer pipes. Manholes were not provided.

3.9.3 System operation

The local authority is responsible for the sewers from the erf boundary and, if at all possible, does not enter onto the erven. Maintenance of the tanks is the responsibility of the home-owners, and there is a charge for emptying of tanks. The total operation and maintenance budget for Lusaka II could not be obtained since it forms part of an overall budget including areas with raw sewage conveyance system. The budget is not considered sufficient to allow adequate operation and maintenance.

The local authority does not at present own a tanker for emptying the tanks, and owns only corkscrew rods for cleaning of sewers. To date the SS system has needed no maintenance.

3.9.4 System inspection report

The Lusaka II SS system had been in operation for less than a year at the time of the site visit.

Several septic tanks were inspected, and some of the community members were interviewed. Some of the tanks were operating as dry systems, others were operating well. All the toilets required the use of a plunger to push solids into the tank.

3.9.5 Perceptions and understanding of the SS system

The City Engineer's Department has a superficial understanding of SS systems. Blockages are anticipated since the septic tanks are used for disposal of rubbish, and problems with clearing blockages are anticipated since the pipes are so small. The use of water pipes is not considered a barrier to root penetration. It is further considered that the cost of emptying the tanks will be too high. Otherwise the system is considered to be robust with respect to vandalism. Problems have been experienced with rags blocking the pump impellers and causing burnout of the pumps at pump stations handling conventional sewage. Vandalism and thefts at the pump station are also common.

The need for education of the users was expressed several times during the interview, and interest was expressed in the proposed operation and maintenance guidelines.

A point relating to value-added tax, which affects the viability of providing lower levels of service initially, and upgrading later, was raised by Mr van Reenen, in that VAT is reclaimable on new

developments, but not when upgrading. Thus a local authority is immediately penalised 14% should it choose to install a low level of service and upgrade at a later date.
Four residents were interviewed, and they all preferred raw sewage conveyance systems and the principles of SS systems were not understood. Some residents did not add water to the tanks since they believed the tank would rapidly fill up with liquid, and then would have to be emptied at their cost. Odour was a problem at most of the systems inspected. Fetching of water was also considered to be a disadvantage.

3.9.6 Summary and conclusions

It was clear from our inspection that the SS system at Lusaka II is not operating in accordance with the theory, although no problems have been experienced to date. Education of both the users and the operators is required to ensure that this system does not fail in the future.

4. SUMMARY AND CONCLUSIONS

Table A4.1 summarises the findings of the system inspections.

Table A4.1: Findings of System Inspections

Scheme	Period of operation at time of inspection	Findings
3.1 Clarens	7 months	No problems experienced, except for minor odour problems.
3.2. Fouriesburg	3½ years	a) Blockages due to construction problems. b) Outlet tee-piece design initially a problem. Modified design is now more successful. c) Fats at the butchery caused blockages of tank outlet d) Fewer problems on SS, serving 228 erven, than on raw sewage conveyance system, serving 36 erven.
3.3 Warden	3 years	a) Construction-related problems. b) Outlet Tee-pieces initially blocked. Modified design has been successful. c) Blockages downstream of the hotel cause not identified. d) Septic tanks at garage, cafe and hotel, consistently block.
3.4 Marselle	7 years	a) Failure of the tanks to act as primary digesters. b) Blockages due to collapse of cast-iron junctions. c) Removal of outlet tee-pieces, resulting in entry of solids into the lines.
3.5 Cathcart	12 months	3 blockages in tanks due to plastics blocking outlet tee-piece.
3.6 Sterkstroom	2 years	No problems.
3.7 Richmond	1 year	a) Construction-related problems. b) Problems with capacity of tanks at garage.
3.8 Hermanus	Sections up to 3 years old	Blockages in tanks due to outlet tee-pieces.
3.9 Lusaka II	1 year	Inadequate water supply to tanks.

In summary, the problems experienced with the nine SS systems inspected relate mainly to poor construction, initially inadequate outlet tee-piece design (now corrected), fats blocking outlet tee-pieces, and failure of the septic tanks to act as primary digesters where small tanks are used in conjunction with large numbers of users. Septic tanks at non-residential erven needed to be pumped out frequently, and this accords with experience in the USA. Odour problems attributable to the SS system are rare, and were experienced at only one scheme. In general the SS systems inspected function in accordance with theoretical predictions and international experience.

The operators do not, as a rule, practice preventative maintenance. Standard water jets, rods and suction tankers proved adequate for the problems that did occur, except for one case in Warden where water from the pressure jets escaped through the tanks above the obstruction.

Operators are generally in favour of SS systems, with the exception of Krugersdorp and Cathcart. Users accept the system in areas where conservancy tanks were used prior to installation of the SS system, and do not like the system in areas where the tanks and pipes are newly installed.

5. QUESTIONNAIRES FOR SEPTIC TANK EFFLUENT DRAINAGE SYSTEMS IN SOUTH AFRICA

forming part of the research into

THE OPERATION AND MAINTENANCE OF STED SYSTEMS

PROJECT : ______________________________

DATE COMPLETED : ______________________________

DATE INSPECTED : ______________________________

INSPECTORS : ______________________________

MUNICIPAL REPRESENTATIVE : ______________________________

Conducted by **the CSIR Division of Building Technology**

QUESTIONNAIRES FOR MUNICIPAL OFFICERS

1. The System

1.1 Which system was used before the STED system?

Pit latrines ☐ Septic tanks ☐ None (new township) ☐

1.2 Which type of sewage treatment is used?

Maturation ponds ☐ Wetlands ☐ Process ☐

1.3 Did the sewage treatment facility exist before the STED system was introduced? ☐

If so, what modifications were made ? ______________________________

____

____

1.4 Number of pump stations : ☐

Type of pumps : Submersible ☐

Self priming ☐

____

____

1.5 Sludge disposal measures adopted :

Burning ☐ Treatment ☐ Burying ☐ Other ☐

Details

____

____

1.6 What was the installation cost of the STED ? (year of construction ________________)

Sewers	Conservancy tanks	Treatment plant	Pump stations	Total
________	________	________	________	________
				____

1.7 What was the cost of a comparable standard system?

Sewers	Conservancy tanks	Treatment plant	Pump stations	Total
________	________	________	________	________
				____

1.8 Pipe diameters installed :

50	63	75	90	110	125	160	200	225	250	Other
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

1.9 Pipe materials :

____

1.10 Are there areas where the pipes flow under pressure (ie: siphon or "uphill")? [Y] [N]

1.11 Slopes

Poor	Variable	Good
☐	☐	☐

1.12 Geotechnical aspects :

Soil types ________________________________

Rock ________________________________

1.13 How many erven are serviced?________________________________

1.14 Do septic tanks have a strainer to prevent large solids passing into pipe? [Y] [N]

1.15 Septic tank configuration : All one design [Y] [N]

Number of chambers ☐

Other detail ________________________________

____

2. Operation and maintenance budget

2.1 Activities covered by the budget :

Clear blockages	Y	N
Empty tanks	Y	N
Educate users	Y	N
Operate treatment works	Y	N

Other (specify) ______________________________

____

2.2 Unit costs of activities :

Clear blockages ______________________________

Empty tanks ______________________________

Educate users ______________________________

Operate treatment works ______________________________

Other (specify) ______________________________

____

2.3 Annual budget for operation and maintenance — Is this sufficient? Y N

____

2.4 If a new system were to be installed, would the same system be chosen? Y N

3. Characteristics of community served

3.1 Level of education / income of community

Middle to upper	Middle to Lower	Lower	Below subsistence
(>R4000pm)	(R2000-R4000pm)	(R800-R2000pm)	(<R800pm)
☐	☐	☐	☐

3.2 Do the users understand the system?	Y	N
3.3 Was there a user education programme at time of installation?	Y	N
3.4 Is there any ongoing user education?	Y	N

4. Operation and maintenance activities

4.1 Understanding of operation and maintenance personnel of system

Thorough	Adequate	Poor	None
☐	☐	☐	☐

Comments ____

____

4.2 What equipment is used to clear blockages?

Water	Rods	Other (specify)
☐	☐	______________________

4.3 Who owns this equipment?______________________________________

4.4 Are there charges for clearing blockages (specify)?__________________________

____

4.5 What equipment is used to empty septic tanks (specify)?

____

____

____

4.6 Who owns this equipment

?____

4.7 Is this equipment adequate (specify) ?

____

____

____

4.8 What alterations / improvements are suggested for equipment?

____

____

____

____

4.9 Are there charges for emptying tanks (specify)?

____

____

____

____

4.10 What type of problems occur in the system?

Blockages	Overloading	Tanks	Odour Overflow	Access	Misuse	None
☐	☐	☐	☐	☐	☐	☐

4.11 Causes of the problems (specify)

____

____

____

4.12 Are there areas with repeated problems?

____

____

Reasons______________________________________

____

____

4.13 How are problems discovered and handled?

____

____

____

4.14 Day-to-day actions required by system :

Desludging tanks	Flushing pipes	Blockages
☐	☐	☐

Ablution unit inspections/user education

Inspection of levels of sludge in tanks

Dealing with vandalism (specify)

Dealing with defects (specify type)

Other (specify)

4.15 How is the level of sludge in the tank measured (ie: when is it full)?

4.16 How often are tanks emptied?

4.17 Is this done routinely or on request of householder?

4.18 What experience does the maintenance personnel have of other systems?

____

____

4.19 Do the users understand the maintenance requirements of the system? [Y] [N]

4.20 Is user education needed? [Y] [N]

4.21 What operation and maintenance is required at pump stations?

____

____

____

____

4.22 What are the problems of the treatment works?

____

____

____

____

4.23 What operation and maintenance is done at treatment works (specify)

____

____

____

____

4.24 Are maintenance staff aware that tanks must be filled with water after desludging? [Y] [N]

4.25 Are maintenance staff aware that a high water or scum level does not mean that the tank should be emptied? [Y] [N]

5. **Recommendations from maintenance personnel in respect of**

5.1 Pipe cleaning

5.2 Dealing with blockages

5.3 Restricting flow in pipes while maintenance is under way

5.4 Measurement of solids

5.5 Maintenance routine

QUESTIONNAIRES FOR USERS

1. Do you have

   Inside taps ☐ a yard tap ☐ a standpipe ☐ a borehole ☐ a river / stream ☐

2. How many people live here usually

   0-2 ☐ 2-4 ☐ 4-6 ☐ 6-8 ☐

3. Do you know that there are pipes draining the fluid off the septic tank? Y N

4. Do you know that only liquids may go into these pipes and that solids (such as paper) stay in the septic tank until they are decomposed? Y N

5. How do you know when the tank is full? Don't know ☐

   ____

   ____

6. Who empties the tank?

   Householder ☐ Municipality ☐ Contractor ☐ Don't know ☐

7. What does it cost you to empty the tank?

   ____

   ____

8. Do you know of other sewerage systems?

   ____

9. What type of problems occur in the system?

   Blockages ☐ Overloading overflow ☐ Tanks ☐ Odour ☐ Access ☐ Misuse ☐ None ☐

10. Are you satisfied with the system? [Y] [N]

11. If not, what are your reasons ______________________________

____

12. Which system do you prefer and why?

____

____

13. Do you know of health hazards associated with the system? [Y] [N]

Detail ____

____

14. Do you have a grease or fat trap? [Y] [N]

15. Other comments / problems ____________________________________

____

____

16. What would you suggest to improve the system?

____

____

____

____

ANNEXURE B :SYSTEM INSPECTION REPORT

(ZAMBIA)

ANNEXURE B : FIELD INSPECTION REPORT

SETTLED SEWERAGE SYSTEMS IN ZAMBIA

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SETTLED SEWERAGE SYSTEMS IN ZAMBIA

1. INTRODUCTION

This report has been based on an unpublished document, prepared by L M Austin of the CSIR Division of Building Technology, detailing the findings of the August 1995 study tour to Zambia. Information has also been abstracted from other references dealing with the Zambian aqua-privy systems. The study tour was conducted between 8 and 13 August 1995 by a a team of five people, namely:

Mr K S Dube	Division of Building Technology of the CSIR
Mr L M Austin	Division of Building Technology of the CSIR
Prof G v R Marais	Department of Civil Engineering, University of Cape Town
Mr H C Chapman	Water Research Commission
Mr A Lagardien	Department of Civil Engineering, Peninsula Technikon.

Settled sewerage systems were inspected at Ndola, Kabwe, Kafue, Choma, Kalomo and Monze. Due to time constraints the systems at Livingstone, Kitwe, and the Matero suburb of Lusaka, which formed part of the original itinerary, were not inspected. The responsible authorities and users were both interviewed at each scheme, and ablution units, septic tanks, reticulation systems and oxidation ponds were inspected.

2. SYSTEM INSPECTION REPORTS.

2.1 NDOLA (KABUSHI SUBURB) : 9 AUGUST 1995

2.1.1 Activities

In Ndola the tour group interviewed the Wastewater Engineer of Ndola City Council, Mr John Chisha, who also assisted during the inspection of the system and in obtaining comments on the system from local residents of Kabushi township, a low-income housing suburb of Ndola.

2.1.2 Project description

The population of Kabushi is about 40 000, with an average family size of 8 people. Of a total of 4800 erven, only 748 are currently still served by a settled sewerage system, the balance having converted to raw sewage conveyance systems as a result of maintenance problems. The ponds have been abandoned and both raw sewage and solids-free sewers are now pumped to the new treatment works. Some homes are still served by pit latrines.

2.1.3 System operation

Operation and maintenance problems of Kabushi were reported by Mr Chisha to be :

- a lack of desludging equipment. There is only one vacuum tanker available to service Kabushi, and this cannot meet the demand. Servicing of the tanker is also problematical due to a shortage of spare parts. Due to the shortage of desludging equipment, the residents attempt to empty their tanks manually. Little success is achieved, however, because the sewer pipes are also mostly blocked;
- no user education;
- vandalism;
- theft;
- the limited financial resources of the council;
- constant water shortages. This is largely due to vandalism and theft of taps; vast quantities of water are simply left to run out of damaged pipe fittings and drain away into the sand. There is also a flushing problem caused by low water pressure in the high-lying parts, aggravated by extensive water wastage in lower areas.

A contributing factor to this wastage is that users pay a flat rate for water irrespective of the amount used. The rate is K500 (R2) per month for a communal septic tank and K1000 (R4) per month for an individual septic tank.

2.1.4 System inspection report

At some communal septic tanks, blocked sewer pipes cause the effluent to overflow into open drains, causing widespread pollution.

See photographs 1 to 4 at the end of this report.

2.1.5 Perceptions and understanding of the SS system

The residents are generally frustrated, but there is very little they can do about the situation. The use of magazines and newspapers for anal cleansing also contributes to the blockages. The residents further complained about the poor quality of water from the Kafue water works. They have been advised to boil the water before use but often cannot afford to do so. As a result diseases like typhoid and cholera are not uncommon.

2.2 KABWE (BWACHA TOWNSHIP) : 10 AUGUST 1995

2.2.1 Activities

In Kabwe the tour group was met by the acting Director of Engineering Services, Mr Yoram Banda, who delegated the sewerage technician, Mr Siyanga Muyumbewa, to assist during the inspection of the system in Bwacha township.

2.2.2 Project description

Bwacha is served by flushing aqua-privies and solids-free sewers draining into oxidation ponds. The sewer pipes are 100 mm in diameter.

2.2.3 System operation

The public health section of the Kabwe City Council is responsible for desludging and general maintenance of the system, but no maintenance of the system is carried out, primarily due to a lack of manpower and equipment. Users clear blockages that occur by themselves, usually by attempting to force the waste material through the sewers by means of sticks or wire. The tanks have also never been desludged, and the oxidation ponds are not maintained, as evidenced by fairly heavy reed growth around their edges.

2.2.4 System inspection report

Problems with blocked pipes were encountered, apparently due to vandalism with stones, rags, bottles and other rubbish, which was observed in manholes. Manhole covers were often missing or broken. The flat slope of the sewers (±1:800) does not allow for transportation of solids. Anal cleansing materials such as newspaper, cloth, etc., which had entered the pipes, also contributed to the blockages. Another major problem was the lack of water, with interruptions in supply lasting for a few days at a time, resulting in blockages in the toilets. The ponds appeared to be working, as no smell was observed.

See photographs 5 to 7 at the end of this report.

2.2.5 Perceptions and understanding of the SS system

The residents are not familiar with the technology and there are no user education programmes. They also complained about the lack of support from the local authority and blamed the occurrence of cholera and typhoid on the poorly maintained sanitation system.

2.3 KAFUE: 11 AUGUST 1995

2.3.1 Activities

Mr John Kapinga, the Building Inspector, took the group to the sewerage works where Mr Michael Makuka, the sewer superintendent, was delegated to conduct the inspection of the nearby township.

2.3.2 Project description

The scheme is provided with septic tanks with capacities of about 2,5 m^3, built above ground level in order to sustain a fall to the ponds. The sewers from the tanks are 100 mm diameter and the mainline sewers which lead to the ponds 150 mm.

2.3.3 System operation

Mr Makuka said the ponds had been cleaned out in 1993 when they were apparently full of sludge. The effluent from the ponds is pumped to the sewer works for further treatment but it was not possible to establish why this was being done, as it appeared to be a largely unnecessary action.
There is a single vacuum tanker for desludging which is owned and operated by the Kafue District Council and caters for the whole town. Sewer blockages are cleared under contract by high pressure jetting equipment. The contractors are paid by the government through the African Development Bank. If blockages occur in the service laterals then the persons responsible for the blockages are fined. Tank inspections are conducted weekly to ensure that full tanks are emptied before they affect the whole system. Ablution unit inspections and interviews with the users are conducted regularly by inspectors from the Health Department of the Kafue District Council. The pump station is also generally well maintained, although frequent electrical faults and problems caused by cloth and other foreign matter in the sewer lines were reported.

2.3.4 System inspection report

At least one pond out of three was still functioning satisfactorily. A blockage in the sewer pipes caused effluent to bypass the first pond and flow directly into the second pond.

The septic tanks have not been emptied at all but blockages and overflows were not noted.
It is possible that some of the particulate material breaks up and passes through into the ponds.

The sludge level was estimated by poking a stick into the tanks, and the level seemed very high. However, the effluent was still trickling into the sewers.

There appears to be a fair amount of maintenance carried out by the local authority, despite the usual problems of lack of equipment and manpower. Many of the ablution units were clean and tidy, although there is a lot of carelessness and vandalism by the users.

See photographs 8 to 10 at the end of this report.

2.3.5 Perceptions and understanding of the SS system

The users did not have many complaints, but did state that they would prefer flush toilets. Presently they obtain water for flushing from a yard tap outside the ablution unit. Newspaper is generally used for anal cleansing, as toilet paper is too costly.

2.4 CHOMA (SHAMPANDI TOWNSHIP): 11 AUGUST 1995

2.4.1 Activities

Due to a communication breakdown, the tour group was not accompanied on the site inspection of Shampandi township. The Deputy Director of Works, Mr J Mweemba, agreed to answer questions after the inspection.

2.4.2 Project description

A description of the scheme, other than that it consisted of toilets, septic tanks, sewers and abandoned treatment ponds, could not be obtained.

2.4.3 System operation

Residents informed the tour group that septic tanks have never been desludged, due to lack of equipment and that the blockages are compounded by stormwater washing sand into the pipes. The local authority is responsible for desludging the tanks and clearing blockages in the pipes but does not do anything, so one resident personally hires a local contractor for K1000 (R4) each month to maintain his tank and pipework. This contractor uses sticks to clear the blockages in the pipes, which temporarily alleviates the blockage problem.

2.4.4 System inspection report

The ponds were inspected and found to be dry, since the main inlet is damaged and blocked and sewage bypasses the ponds and runs into the natural streams. Septic tanks inspected were full of sludge. Some ablution unit structures are in the process of collapse, due to the Kalahari sands which overlay the region becoming saturated with effluent overflow at the blockages. Water for flushing is not always available since not all taps are working; the water is also impure and residents are advised to boil it before use. See photographs 11 to 13 at the end of this report.

2.4.5 Perceptions and understanding of the SS system

Mr Mweemba believes that blockages are due to the small diameter pipes and the flat gradient, which indicates a lack of understanding about the advantages of solids-free sewers. He was of the opinion that privatisation of the local councils could solve the problems.

The residents complained of odours and outbreaks of diseases such as cholera and dysentery. They maintain that the local authority is responsible for improving and maintaining the sanitation system, and would like an overhaul of the system, with the installation of new toilets and pipes.

2.5 KOLOMO: 11 AUGUST 1995

2.5.1 Activities

The tour group was welcomed by the Deputy Director of Works, Mr Zulu, and the Water Superintendent, Mr Siamasamu. The former provided a brief overview of the sanitation problems in the town, after which he led a visit to one of the housing areas in order to interview the residents. Due to time constraints the ponds were not visited.

2.5.2 Project description

A description of the project could not be obtained.

2.5.3 System operation

The town has no vacuum tanker, so that manual labour is used to reduce the sludge levels in the tanks. The tanks are not emptied completely, the sludge level being merely reduced to avoid blockages. There is also insufficient length of cleaning rods available, so they do not extend the full length between manholes. The pipes are therefore excavated and broken into to locate the blockages, but are not repaired, with the result that soil can enter the pipes. The council has severe financial problems and consequently has a shortage of manpower and materials (pipes, manholes) which hampers the maintenance efforts. There is apparently also a reluctance among residents to pay the nominal monthly rates and legal means occasionally have to be resorted to, such as attachment of household goods. The ponds are in need of maintenance, including removal of sludge, bushes and weeds.

Water pressure is generally low, resulting in poor flushing of toilets. The pH of the water is between 6,0 and 7,0 which causes corrosion of the supply pipes and further aggravates the water delivery problem. Blockages in the sewer pipes also cannot be solved by water jets due to the low pressures.

2.5.4 System inspection report

See photographs 14 and 15 at the end of this report.

2.5.5 Perceptions and understanding of the SS system

Mr Zulu believes that the system must be replaced, since the sludge has solidified in the sewer pipes, and that manholes be placed near the ablution units in order to facilitate clearing of blockages in the tanks. Residents were aware that the effluent could not flow down the pipes due to the blockages and that the full tanks contributed to the problem. Many desludge the tanks themselves manually, dig a hole, fill it with the waste material and then cover it again with soil. The users believe, however, that the council is the only body which can relieve their sanitation problems.

2.6 MONZE: 12 AUGUST 1995

2.6.1 Activities

The tour group was received by the Director of Works, Mr S S Mwala, who conducted the inspection of the oxidation ponds and the western residential township from which the effluent originated.

2.6.2 Project description

The western township is the only area of Monze which is sewered, since the eastern part of the town is still using septic tanks with soakaways. Each house has its own aqua-privy and groups of four houses share a communal septic tank. There are an average of ten people per house.

2.6.3 System operation

Mr Mwala had, at the time of the tour, been at Monze for only a year, and had found the system in a major state of disrepair and neglect. The ponds were not functioning and sewage discharged into the veld. Many sections of pipe were also damaged. During his first year in office Mr Mwala succeeded in repairing one pond, and also replaced some of the damaged pipes. Despite spending a great deal of money on replacing pipes, building septic tanks and re-routing sewer lines, Mr Mwala is of the opinion that much still needs to be done.

There is a critical shortage of equipment and manpower in Monze, and as a result the Public Health section of the Council, which is responsible for clearing the blocked pipes, also has a backlog.

The unreliable water supply, which was designed for 4 000 but is supplying 30 000, results in problems since the sewerage system uses flush toilets.

2.6.4 System inspection report

The sewerage system is subject to much abuse, with stones and mealie cobs causing many blockages. Vandalism and theft are also major problems and Mr Mwala is adamant that the residents are partly to blame for the poor state of the system. Other problems experienced by the residents were broken taps, cracks in the ablution unit structures and potential health hazards.

See photographs 16 to 18 at the end of this report.

2.6.5 Perceptions and understanding of the SS system

The residents' main problems are the frequent blockages and associated odours caused by effluent overflowing on their properties. He emphasised that users need to understand that the system is theirs and that they should not expect the Council to do everything for them.

3. CONCLUSIONS

Since data on the design of the systems, the operation and maintenance histories, the communal use of sewers for both settled and raw sewage, and comparisons between the state of solids-free and raw sewage conveyance systems, finances, etc., was not available, it is difficult to draw conclusions from the current state of the Zambian systems.

From published information (Kaoma J.) it can be established that much of the deterioration of the settled sewerage systems in Zambia has occurred in the last 18 years, and for almost 20 years before that the systems were operating satisfactorily, even with negligible operation and maintenance.

In the light of the Zambian experience it is clear that careful consideration should be given to providing any sanitation technology that requires ongoing financial inputs to communities that cannot afford to pay for services.