Waterborne Sanitation Operations and Maintenance Guide

SJ van Vuuren & M van Dijk

WATER RESEARCH COMMISSION

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WATERBORNE SANITATION OPERATION AND MAINTENANCE GUIDE

Report to the

WATER RESEARCH COMMISSION

By

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Executive Summary

The function of a waterborne sanitation system is to collect and convey wastewater in a hygienic manner. Operation and maintenance of this sewer system means making sure that all its components are kept in good operating condition. Planners, designers, the construction team and the administrators have a joint duty in providing an efficient system. The operator can then, based on the available resources provided, operate and maintain the system.

Municipal sanitary sewage collection and conveyance systems are an extensive, valuable and complex part of the country's infrastructure. The waterborne sanitation system consists of pipelines, conduits, pumping stations, pressure mains and other facilities used to collect the wastewater from residential, industrial or commercial sources and convey it to treatment facilities. The public expects these systems to function effectively at a reasonable cost.

Information has been synthesized from a wide variety of sources and tailored to South African conditions to produce a comprehensive guide on operation and maintenance of waterborne sanitation systems. Some sources of information were heavily relied upon in creating this guide. These include the document Alternative Sewer Systems *(WEF Manual of Practice, 2008); the NEIWPCC (2003) manual entitled* Optimizing Operation, Maintenance, and Rehabilitation of Sanitary Sewer Collection Systems*; the* Sanitary Sewer Overflow Solutions - Guidance Manual *(ASCE, 2004); and the* Sewer Design Manual *(Bureau of Engineering, 2007).*

This document comprises the following sections:

- *Types of maintenance*
- *Equipment required for maintenance*
- *Maintenance requirements and frequency*
- *Operational requirements*
- *Safety measures and practices*
- *Inspection forms and checklists*

The aim of this guide is to highlight the procedures, practices and policies in the operation and maintenance of waterborne sanitation systems. To provide further classification and background information photos, videos, software and additional literature were included on the accompanying DVD. Where this icon is shown in this guide movie clips, photos, additional literature or software are available in the **SewerAid** ***DVD*** *to visually enhance the understanding of the specific concept.*

'Low-cost maintenance is a consequence of good maintenance practice.'
(ASCE, 2004)

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GLOSSARY OF TERMS

Term		Description
Aerobic	:	A process in which dissolved oxygen is present.
Anaerobic	:	A process in which dissolved oxygen is not present.
Appurtenance	:	Machinery, appliances, structures and other parts of the main structure necessary to allow it to operate as intended, but not considered part of the main structure.
Attenuation	:	The reduction in magnitude/intensity/concentration of a substance dispersed in a liquid medium.
Average dry weather flow	:	The average non-stormflow over 24 h during the dry months of the year. It is composed of the average sewage flow and the average dry weather inflow/infiltration.
Average wet weather flow	:	The average flow over 24 h during the wet months of the year on days when rainfall occurred on that or the preceding day.
Base flow	:	The portion of the wastewater flow, including inflow and infiltration, that corresponds to the minimum flow recorded in a sewer. It typically equates to the 'minimum night flow' concept in water distribution systems.
Blockage	:	A deposit in a sewer resulting in restriction or stopping of flow.
Branch sewer	:	A sewer that receives wastewater from a relatively small area and discharges into a main sewer.
Bulk main	:	See Collector main.
Bypass	:	A pipe, valve, gate, weir, trench or other device designed to allow all or part of the wastewater flow to be diverted from the usual channels or flow. It provides an alternative route for the wastewater whilst the facility or device is being maintained.
Cesspool	:	A covered watertight tank used for receiving and storing sewage from premises which cannot be connected to the public sewer and where conditions prevent the use of a small sewage treatment works, including a septic tank.
Cleanout	:	An access opening (usually covered or capped) in a wastewater collection system used for inserting tools, rods or snakes while cleaning a pipeline or clearing a blockage. It remains permanently accessible after completion of the drainage installation.
Cleaning eye	:	See Cleanout.
Collection system	:	A network of pipes, manholes, cleanouts, traps, siphons, lift stations and other structures used to collect all wastewater from an area and transport this to a treatment plant.
Collector main	:	In collection systems, this is a larger pipe in which smaller branch and sub-main sewers are connected.
Collector sewer	:	The intermediate sized pipelines that convey the effluent from the reticulation to the main outfall sewers. These are usually in sizes ranging from 150 mm to 450 mm in diameter (PIPES, 2009)

Term		Description
Combined sewer system	:	A wastewater collection and treatment system where domestic and industrial wastewater is combined with storm runoff.
Conservancy tank	:	A covered tank that is used for the reception and temporary retention of sewage and that requires emptying at intervals.
Debris	:	Any material in wastewater found floating, suspended, settled or moving along at the bottom of a sewer. This material may cause blockage or settle out in a sewer.
Detention	:	The process of collecting and holding back stormwater or combined sewage for delayed release to receiving waters.
Discharge	:	The release of wastewater or contaminants to the environment. A direct discharge of wastewater flows from a land surface directly into surface waters, while an indirect discharge of wastewater flows into surface waters by way of a wastewater treatment system.
Diversion structure	:	A type of regulator that diverts flow from one pipe to another.
Domestic wastewater	:	Human-generated sewage that flows from homes and businesses.
Drain	:	A conduit, generally underground, designed to carry wastewater and/or surface water from a source to a sewer; a pipeline carrying land drainage flow or surface water from roads (Stephenson and Barta, 2005).
Drop manhole	:	A mainline or house service line lateral entering a manhole at a higher elevation than the main flow line or channel.
Dry well	:	A dry room or compartment in a lift station, near or below the water level, where the pumps are located.
Effluent	:	Treated water, wastewater or other liquid flowing out of a treatment facility.
Extraneous flow	:	Water entering the sewer from sources other than intended water used and wasted, or leaking, at source (e.g. stormwater and groundwater infiltration). Extraneous flows make up most of the base flow in most sewers.
Exfiltration	:	Liquid wastes and liquid-carried wastes which unintentionally leak out of a sewer pipe system and into the environment via cracks or malfunctioning pipe joints.
Force main	:	A pipe that carries wastewater under pressure from the discharge side of a pump to a point of gravity flow downstream. Also called a pressure main.
French drain	:	A conventional absorption field that comprises a trench that is filled with suitable material and that is used for the disposal of liquid effluent from a septic tank or wastewater.
Grease	:	In a sewage collection system, grease is considered to be the residues of fats, detergents, waxes, free fatty acids, calcium and magnesium soaps, mineral oils and certain other non-fatty material which tend to separate from water and coagulate as floatables or scum (NEIWPCC, 2003).

Term		Description
Grease trap	:	A device that is designed to cool down incoming hot wastewater to below 30°C, to enable grease and fat to separate from the water and to solidify at the surface level of the wastewater, and that prevents grease and fat from entering the sewer (also referred to as a grease interceptor).
Grey water	:	Wastewater from the bath, shower and possibly the washing machine that is 'less polluted' than waste from the other sources (e.g. the toilet and kitchen sink).
Grit	:	The heavy mineral material present in wastewater such as sand, coffee grounds, eggshells and gravel. Grit tends to settle out at flow velocities of below 0.6 m/s and accumulates in the invert of the pipe.
Grit trap	:	A permanent structure built into a manhole (or other convenient location in the collection system) for the accumulation and removal of grit.
Groundwater infiltration	:	Infiltration of groundwater (that typically enters the sewerage system through pipe defects located below the normal groundwater table).
Gully	:	A pipe fitting that incorporates a trap into which wastewater is discharged and that is normally connected to a drain.
Hydraulic grade line (HGL)	:	The surface or profile of water flowing in an open channel or a pipe flowing partially full. If a pipe is under pressure, the HGL is at the level water would rise to in a small tube connected to the pipe.
Infiltration	:	The ingress or seepage of groundwater into a drain or sewer system through defects in pipes, joints or manholes (Stephenson and Barta, 2005)
Inflow	:	Water discharged into a sewer system and service connections from such sources as, but not limited to, roof leaders, yard and area drains, around manhole covers or through holes in the covers, surface runoff, etc. Inflow differs from infiltration in that it is a direct discharge into the sewer rather than a leak in the sewer itself.
Inspection chamber	:	A chamber not deeper than 1 m and of such dimensions that permanent access may be obtained to a drain without a person being required to enter into such a chamber.
Interceptor sewer	:	A sewer that receives flow from a number of other large sewers or outlets and conduits the waters to a point for treatment or disposal.
Invert	:	The bottom of the inside of a pipe.
Lag	:	An interval of time before additional flow enters the system.
Lateral sewer	:	A sewer that discharges into a branch or other sewer and has no other common sewer tributary to it. It is also sometimes called a 'street sewer' because it collects wastewater from individual houses.
Lift station	:	A wastewater pumping station that lifts the wastewater to a higher elevation usually discharging into a downstream gravity sewer.

Term		Description
Load	:	Any matter transported by the flow in sewers (typically this would be sewage).
Main sewer	:	This is a larger pipe in which smaller branch and sub-main sewers are connected. It may also be called a trunk sewer.
Manhole	:	A chamber of depth exceeding 750 mm and of such dimensions that a person can enter such chamber to obtain access to a drain.
Offset	:	A combination of elbows or bends which brings one section of a line of pipe out of line with, but into a line parallel with, another section.
Outfall	:	The point, location, or structure where wastewater or drainage discharges from a sewer, drain or other conduit.
Outfall sewer	:	A sewer that receives wastewater from a collecting system or from a treatment plant and carries it to a point of final discharge. These are usually from 450 mm in diameter and larger.
Overflow manhole	:	A manhole which fills and allows raw wastewater to flow out onto the street or environment.
Peak dry weather flow (PDWF)	:	The peak non-stormflow during the dry months of the year. It is composed of the peak sewage flow and the peak dry weather inflow/infiltration.
Peak wet weather flow (PWWF)	:	The peak flow during the wet months of the year on days when rainfall occurred on that or the preceding day.
Pig	:	Refers to a poly pig which is a bullet-shaped device made of hard rubber or similar material used for cleaning of sewer lines.
Plumbing	:	The system of pipes and fittings required for the sanitation of a building (to the stand boundary where the plumbing joins the sewer).
Pumping station	:	This is usually an underground structure that the sewage is discharged into. The types vary but in smaller systems these comprise of a wet well, into which the sewage is discharged, and the wet well also houses submersible pumps which pump the sewage to its destination. In a larger station there may be a separate dry well, adjacent to the wet well, which houses the pumps. On some pumping stations the pumps may be housed above ground near the wet well.
Raw sewage	:	Untreated wastewater.
Regulator	:	A structure that controls the flow of wastewater from two or more input pipes (trunk lines) to a single output (usually a larger interceptor line). Regulators can be used to restrict or halt flow, thus causing wastewater to be stored in the conveyance system until it can be handled by the treatment plant.
Relief sewer	:	A sewer built to carry flows in excess of the capacity of an existing sewer.

Term		**Description**
Reticulation	:	This is the smallest element of a sanitation system and consists of the small-diameter pipelines that convey the effluent from the individual properties and along streets. They are usually in sizes ranging from 100 mm to 225 mm in diameter (PIPES, 2009).
Rising main	:	See Force main.
Rodding eye	:	A permanent access opening to the interior of a drainage installation that permits full-bore access to the interior of a drain for internal cleaning, but does not include an inspection eye or manhole.
Sanitation system	:	In the context of this guide all the components including the pipelines that convey sanitary wastewater away from where it is generated to the outfall works where it is treated and purified before it is discharged into the natural watercourses (PIPES, 2009).
Screen	:	A large sieve used for the purpose of trapping the load in sewage.
Sediment	:	Solid material settled from suspension in a liquid.
Sedimentation	:	The process of settling and depositing of suspended material carried by wastewater. Sedimentation usually occurs by gravity when the velocity of the wastewater is reduced below the point at which it can transport the suspended material.
Septic tank	:	An underground tank used for the deposition of domestic wastes. Bacteria in the wastes decompose the organic matter, and the sludge settles to the bottom. The effluent flows through drains into the ground. Sludge is pumped out at regular intervals.
Sewage	:	Wastewater, soil water, industrial effluent and other liquid waste, either separately or in combination, but excluding stormwater. Usually classified as wastewater derived from human communities – toilet, bathroom and kitchen waste.
Sewer	:	A pipe or conduit that is the property of the local authority and that is used for the conveyance of sewage.
Sewer gas	:	Gas in collection sewer lines that result from the decomposition of organic matter in the wastewater. When testing for gases found in sewers, test for lack of oxygen and also for explosive and toxic gases (NEIWPCC, 2003).
Sewer main	:	A sewer pipe to which building laterals are connected.
Sewer system	:	Collectively, all of the property involved in the operation of a sewer utility. It includes land, wastewater pipes, pumping stations, treatment plants, and general property. It may also be called sewerage or a wastewater system.
Sewerage	:	System of piping with appurtenances for collecting, moving and treating wastewater from source to end discharge.
Silt trap	:	See Grit trap. Also called sand trap.

Term		**Description**
Siphon	:	A pipe or conduit through which water will flow above the HGL under certain conditions. Siphons also called depressed sewers are designed to carry flow underneath an obstruction and to regain as much pressure head as possible after the obstruction has been passed.
Sludge	:	The suspended matter in industrial effluent or sewage remaining after partial drying.
Sludge removal	:	This is the process of removing sludge from treatment systems or tanks and can be carried out manually or automatically.
Soffit	:	The top of the inside of a pipe.
STEP system	:	Septic tank effluent pumping (STEP) system is an alternative sewerage system which uses smaller-diameter pipes to convey the pumped effluent.
Storage	:	A method for controlling combined sewer overflows by storing the combined sewage until the rainstorm subsides, then releasing it back into the conveyance system to be treated at the usual treatment plant.
Sullage	:	Wastewater emanating from baths, kitchen sinks, laundries and showers.
Surcharge	:	Sewers are surcharged when the supply of wastewater to be carried is greater than the capacity of the pipes to carry the flow. The surface of the wastewater in manholes rises above the top of the sewer pipe and the sewer is under pressure or a head (NEIWPCC, 2003).
Surcharged manhole	:	A manhole in which the rate of wastewater flow entering the manhole is greater than the capacity of the outlet under gravity conditions. When the wastewater level in the manhole is higher than the top of the outlet pipe the manhole is said to be 'surcharged' (NEIWPCC, 2003).
Suspended solids	:	Small particles of organic or inorganic materials that float on the surface of, or are suspended in, sewage or other liquids and which cloud the water. The term may include sand, mud, and clay particles as well as waste materials.
Terminal manhole	:	A manhole that is placed at the upstream end of a sewer and having no inlet pipe.
Trunk main	:	See Collector main.
Trunk sewer	:	This is a larger pipe in which smaller branch and sub-main sewers are connected. It may also be called a main sewer.
Wastewater	:	A community's used water and water-carried solids that flow to a treatment plant. Stormwater, surface water and groundwater infiltration may also be included in the term wastewater. The term 'sewage' usually refers to household wastes.
Waterborne	:	Transported by water.
Wet well	:	A compartment or tank in which wastewater is collected. The suction pipe of a pump may be connected to the wet well or a submersible pump may be placed inside the well.

ABBREVIATIONS

AC	:	Asbestos cement
ACS	:	Alternative collection systems
ADWF	:	Average dry weather flow
ASCE	:	American Society of Civil Engineers
AWWF	:	Average wet weather flow
CCTV	:	Closed circuit television
CSIR	:	Council for Scientific and Industrial Research
du	:	Dwelling unit
DMWS	:	Durban Metro Water Services
EDU	:	Equivalent discharge unit
HDPE		High-density polyethylene
HGL	:	Hydraulic grade line
IDP	:	Integrated development plan
I/I	:	Inflow/Infiltration
LCA	:	Life Cycle Analysis
MMS	:	Maintenance management system
NPSH	:	Net-positive suction head
O&M	:	Operation and maintenance
PE	:	Polyethylene
PPS	:	Pipe profiling sonar
PVC	:	Polyvinyl chloride
PWWF	:	Peak wet weather flow
SABS	:	South African Bureau of Standards
SANS	:	South African National Standards
SBGS	:	Small-bore gravity sewer
SDEP	:	Sewage Disposal Education Programme
SDG	:	Small-diameter gravity
SFD	:	Single family dwelling
SFS	:	Solids-free sewer
STEG	:	Septic tank effluent gravity
STEP	:	Septic tank effluent pumping
TDH	:	Total discharge head
U.S.EPA	:	U.S. Environmental Protection Agency
VCP	:	Vitrified clay pipe
VIP	:	Ventilated Improved Pit
WRC	:	Water Research Commission
WSDP	:	Water services development plan
WWTW		Wastewater treatment works

1. INTRODUCTION

The function of a waterborne sanitation system is to collect and convey wastewater in a hygienic manner. Operation and maintenance of this system means making sure that all its components are kept in good operating condition. Planners, designers, the construction team and the administrators have a joint responsibility in providing an efficient system. The greater part of the responsibility lies with the designers and builders of the system. The operator can then, based on the available resources provided, operate and maintain the system.

The aim of this guide is to highlight the procedures, practices and policies in the operation and maintenance of waterborne sanitation systems.

A waterborne sanitation system is naturally subject to a variety of operational problems. Depending on the wastewater flow characteristics, surrounding soil conditions, quality of construction, etc., the sewer pipeline can clog, scour, corrode, collapse or become damaged which leads to the deterioration of the collection system. A waterborne sanitation system is designed for a specific useful life and thus it is essential to provide adequate operation and maintenance to maximize the benefit gained from the infrastructure investment.

A properly designed waterborne sanitation system will minimize the operation and maintenance problems, which is why the design engineer should pay attention and be conscientious during the planning and design stage. General maintenance problems can be expected but a good design based on accepted standards will go a long way in minimizing these.

Many sewage collection systems perform poorly and many systems have received minimal maintenance for many years.

1.1 Types of maintenance activities

There are basically three accepted types of maintenance: corrective maintenance, preventative maintenance and predictive maintenance.

1.1.1 Corrective maintenance

This is a reactive type maintenance which is required when an item has failed or is worn out, and includes emergency maintenance. When the equipment or system fails the necessary maintenance has to be performed and often leads to downtime in production which is expensive. If this is the only maintenance performed the system will perform poorly, especially in the case of ageing systems.

There are two types of emergency maintenance: Normal emergencies and extraordinary situations. The normal emergencies would be a blockage in a pipe or a pipe break which could happen on a daily basis. The frequency of these types of emergencies could be reduced if an effective maintenance programme was in place. Extraordinary emergencies would typically be when there is a high-intensity storm or a flood, i.e. an unpredictable occurrence which results in the failure of the collection system.

1.1.2 Preventative maintenance

Preventative maintenance is a schedule of planned maintenance actions aimed at the prevention of breakdowns and failures. This is usually a proactive type maintenance strategy defined by a programme with planned maintenance activities. This type of maintenance can be scheduled according to historical needs in the system or based on a certain amount of lapsed time. Some elements which are required of a good preventative maintenance programme include the following (NEIWPCC, 2003):

- Planning and scheduling
- System mapping/GIS
- Computerized maintenance programme
- Records management
- Assets inventory and management
- Spare part management
- Cost and budget control
- Emergency repair procedures
- Training programme

1.1.3 Predictive maintenance

The 3rd type of maintenance is predictive maintenance which is based on the actual condition of a component and is also a proactive form of maintenance. This approach is the most recent development and offers cost savings over preventative maintenance, because tasks are performed only when warranted. This procedure assists in determining the condition of equipment by establishing performance data, monitoring performance criteria over a time period, and observing changes in performance in order to spot failure and predict when maintenance should be performed.

In practice, all these types of maintenance strategies are used to maintain sewer systems and the challenge is to find the balance between the various maintenance philosophies. Corrective maintenance takes resources away from predictive and preventative maintenance. In general, corrective maintenance is the least cost-effective option when maintenance requirements are high, and maintenance personnel may not be able to perform planned maintenance, thus leading to more corrective maintenance and emergency situations. Emergency maintenance is required when a system or equipment fails, creating a hazard to public health, the environment, or associated equipment. This type of maintenance is crisis-orientated, and involves repairs, on short notice, of malfunctioning equipment or sewers in order to recover system operation. Examples of emergency situations are a blocked rising main sewer line or a totally non-functional pump station.

1.2 Operation and maintenance programme

The benefits of an effective operation and maintenance programme are as follows:

- It will ensure that facilities and equipment are available as intended
- It will result in high reliability of equipment and facilities as designed
- It will maintain the value of the infrastructure investment
- Full use of the system over its intended design life will be achieved
- There will be a collection of accurate information and data on which the operation and maintenance can be planned and budgeted for
- It will reduce costs since planned maintenance and repairs are much more cost-effective than late-night emergency repairs

2. POLICY GUIDELINE

It should be the objective of every town, local authority or metropolis to protect the public from potential health hazards arising from wastewater discharges. To attain this objective the following guidelines are presented:

- A preventative maintenance programme to maintain the integrity of the wastewater collection and treatment system should be adopted
- Inspections on a regular basis of facilities followed by prompt and satisfactory repairs
- Response to sewer-related complaints with appropriate actions taken
- There should be a sound safety plan put into practice
- There should be respect for public ownership when carrying out sewer maintenance work
- Striving for good public participation through community participation during the planning process

3. MAINTENANCE EQUIPMENT FOR WATERBORNE SANITATION

The development of equipment to maintain sewer systems has come a long way and several sewer-line cleaning techniques are currently available. **Figure 1** illustrates some of the equipment used in 1899 for performing maintenance on sewer systems.

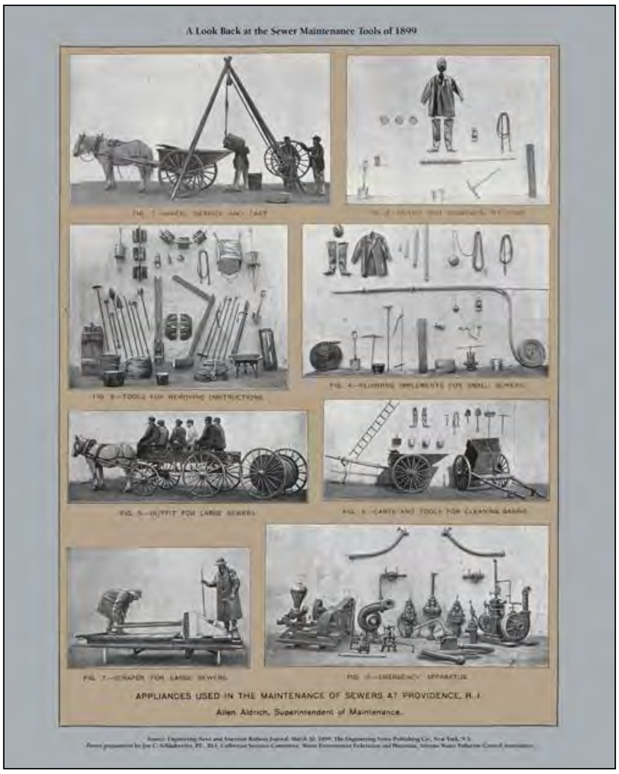

Figure 1: Appliances used in the maintenance of sewers in 1899 (Schladweiler, 2009)

Typical portable emergency equipment which the crew may need include:

- Bypass pumps
- Portable generator
- Air compressor, trailer-mounted
- Manhole lifters and gas-testing equipment
- Sewer rodding and/or flushing machine
- Portable lights and hand tools
- Chemical spray units (for insects and rodent control)
- Truck and trailer
- Vacuum tanker
- Repair equipment for excavation (backhoe, shoring equipment, concrete mixers, traffic control equipment, etc.)
- Confined space entry gear
- Disinfectant to clean and treat the area

3.1 Conventional gravity sewers

3.1.1 Rodding of sewer lines

A torque is applied to a steel rod as it is pushed through the sewer line which turns a cleaning device attached to the inserted end of the rod as shown in **Figure 2**. Rodding equipment can be used for routine preventative maintenance, such as breaking up of grease deposits, cutting roots, loosening debris, threading cables for bucket machines or TV inspection equipment as well as for emergency removal of blockages. The rodders are less effective in removing sand or gravel since the tools do not have the ability to move the material. The inserted head is designed to cut or scrape materials from the pipe walls.

Figure 2: Rodding of a sewer pipe

The original method is called hand rodding and is the oldest form of mechanically cleaning a sewer line. Larger mechanical power rodders contain a reel by means of which the steel rods are carried and an engine to provide the torque to rotate, push and pull the steel rods.

3.1.2 Balling of sewer lines

The equipment consists of an assortment of various sizes of sewer balls to fit the different sewer sizes, a tag line, winch, cable, reels, a water source and a dump pick-up. The ball is usually a spirally grooved, inflatable, semi-hard rubber ball.

The pressure due to a build-up of water head creates a high water-flow velocity around the ball which removes sand, grit, rock or grease from the sewer. Sewers need to be properly aligned and should not have any protruding service connections to make this an effective cleaning method. An example of wooden balls used in cleaning of large-diameter sewer lines in Paris (France) is shown in **Figure 3**. These giant, hollow wooden balls roll through the sewer pushing along the debris in front of them.

Figure 3: Wooden balls used for cleaning sewers (Flickr, 2009)

3.1.3 Flushing of sewer lines

Flushing is a method where the flow rate in a sewer is significantly increased to flush floating material and some grit and sand down the collection system. Water from a fire hydrant or water tank can be used for this procedure and thus only requires a hose to connect the water source and the sewer.

3.1.4 High-pressure water jetting

A truck-mounted high-velocity water machine, manhole hose guide, debris traps and a dump truck or debris trailer make up this cleaning unit. Water-jet cleaning is typically used to break up stubborn blockages or to remove debris such as grease that has built up on the inside of the pipe.

High-pressure water jetting is also commonly known as hydroblasting and it is a widespread abrasive water discharge operation. As such, it is very successful because of its powerful jet blaster effect. In most cases, because of its efficiency, hydroblasting will require only one operator for any given application.

Water that is pressurized by a truck-mounted pump as shown in **Figure 4** is used to clean and flush the debris from the pipe using specially designed cleaning heads attached to flexible high-pressure nozzles, see **Figure 5**. Water jetting provides a thorough cleaning of drain and sewer lines and is very effective for greater distances. Specially designed nozzles can be used which spin at a high rate emulsifying grease and soap deposits.

Figure 4: Truck-mounted pressure pump

Figure 5: High-pressure nozzle head (Drain Shooter, 2009)

3.1.5 Scooters used in sewers

This cleaning unit consists of a scooter assembly, water-tank truck, dump pick-up truck tag line and a power winch. The scooter is basically a steel frame on small wheels which has a rubber-rimmed steel shield with a diameter similar to the pipe diameter. The top half of the shield is hinged and is controlled with a spring system and the lower half is a rigid part connected to the scooter. Water pressure builds up behind the shield which acts as a plug and moves the scooter downstream. The progress can be slowed down by means of the restraining cable whilst the water forces past the shield rim and scours the pipe wall similar to the balling method. The debris is collected at the next manhole in a trap.

3.1.6 Kites, bags, tyres, parachutes and poly pigs

The main equipment includes a water-tank truck, pick-up truck and a power drum machine. The rigid rims of the bags and kites cause the scouring action and the kite's shape results in a forward jet of water that scours the pipe wall. A tyre with diameter approximately 50 mm smaller than the sewer diameter is connected to a restraining line and guided through the pipe similar to the balling process. A poly pig is used for large sanitary sewers and is not restrained by a line, but moves through the system due to the water pressure building up behind it.

3.1.7 Bucketing of sewer lines

This is a mechanical device used mainly for removing of debris from a break or an accumulation that could not be cleared by hydraulic means.

The cleaning unit consists of a power bucket machine, power bucket truck loader, dump truck and manhole jacks. A special bucket is pulled through the sewer line effectively scraping the sewer line clean.

The bucket has one end open with the opposite end having a set of jaws. When pulled from the jaw end, the jaws are automatically opened and when pulling from the other end these close. The collected materials are then physically removed from the pipe. It is a very labour-intensive process and therefore power buckets are normally used only for specific cleaning purposes, such as removing large amounts of debris from large-diameter sewers.

3.1.8 Cable machines

Cable machines operate in a manner similar to bucketing except that the winch is usually truck-mounted. The cable is pulled through the sewer line from one manhole to the next. A brush, cutter or bucket is attached to the cable and it is pulled back through the sewer to clear grease, roots, sludge, sand or grit from the line.

Figure 6: Cable machine for cleaning infrastructure (courtesy of Sight Lines Pipe Survey Services)

3.2 Vacuum sewers

Vacuum sewers use differential air pressure to move wastewater. This requires a central power source which runs a vacuum pump station to create a vacuum within a system of collection mains. These technologies differ from conventional gravity sewers and thus the operation and maintenance staff members must be properly trained to the specific needs of such a system.

Vacuum mains are laid at relatively shallow depths with isolating valves strategically placed in the network. In case of an operational problem in the system, crack or break in the piping system, a drop in vacuum pressure is indicated in the vacuum station. Isolation valves are systematically used to locate the exact area that is causing the pressure loss.

Repairs to damaged piping can then be completed while the system is under vacuum, maintaining service whilst the repairs are being made. Shown in **Figure 7** is a PVC vacuum line damaged by a directional drilling device installing a cable. The excavation was easy because the line was laid at a relatively shallow depth and a full-circle clamp could be placed on the pipe to seal the damage to the pipe.

Figure 7: Vacuum sewer repair (full-circle clamp)

Other sewer-line cleaning equipment utilized in vacuum sewer systems is similar to that used for conventional gravity sewers. The vacuum station would require regular maintenance which is similar to that required by a sewage lift pump station. In case of a blockage on the vacuum mains a rod could be used to unblock a section.

A list of spare parts provides an indication of the equipment required to maintain the vacuum sewer system. Faulty valves and controllers are not repaired on-site; these are rather removed and replaced with a spare. The typical equipment required for emergency maintenance includes a vacuum valve, sump breather unit assembly, sump breather installation parts bag, controller, controller-rebuild kit, clear vacuum tubing, O-rings, tube controller grease, tube vacuum-valve grease and surge suppressor.

The vacuum station also requires a replacement unit, standby equipment and spare parts. These range from spare pump seals to fuses. Oil, overhaul kit (vacuum pump), filter kit, motor-pump coupling set, seal kit for sewage pump, motor coupling (sewage pump), and gasket set (sewage pump) are some of the typical components that will require maintenance work to be carried out.

In addition to spare parts, certain specialty maintenance tools and equipment are needed such as portable vacuum data loggers, sensor pipe puller, valve repair stand, no-hub torque wrenches, vacuum gauges and controller test box.

3.3 Small-bore systems

Small-bore systems are also called small-diameter gravity sewers or septic tank effluent gravity (STEG) sewers and these systems convey settled effluent in small-bore sewers under gravity from an interceptor tank (or septic tank) to a centralized treatment plant or pump station from where it is conveyed to another collection system. These systems utilize smaller-diameter pipes placed in shallow trenches following the natural contours of the area.

In nearly every call-out case reported, the sewer backups occurred because of obstructions in the building sewer which would then require rodding or jetting equipment.

Operation and maintenance requirements of SBGS systems are generally simple in nature, requiring no special qualifications for maintenance staff other than familiarity with how the system works. The operator's responsibilities will be limited largely to maintenance call-outs, new service-connection inspections and administrative duties. In most systems, interceptor tank pumping is usually performed by an outside contractor.

Maintenance equipment is also limited. A truck-mounted centrifugal suction pump can be used to provide most emergency operation equipment needs. Sufficient hose should be available to reach between cleanouts.

Septage removal, i.e. cleaning of the interceptor tank would require a vacuum tanker, **Figure 8**, and the vacuum then lifts the settled sludge into the tanker (see **Figure 9**). Cleaning of the outlet screens can be done on site. Lift stations may need equipment for removing the pump or valves or tightening of bolts, etc.

Figure 8: Vacuum and jetting tanker (courtesy of Johannesburg Water)

The collector main pipes only require maintenance if some event or accident causes damage, and there are usually no preventative maintenance functions. Periodic flushing of low-velocity sections of the collector mains may be required. Hydraulic flushing is most often recommended for cleaning these mains, but no instances of these events have been documented in the United States experience for properly designed and installed systems (WEF, 2008). In other words no equipment is needed for regular maintenance.

To clean the air vents and air release valves only requires some typical work tools (spanners).

The distribution of causes for service calls related to STEP installations (including lift stations), as described in *Alternative Wastewater Collective Systems* (USEPA, 1991), is detailed in **Table 1.**

Table 1: Distribution of causes for service calls on STEP systems (USEPA, 1991)

Category	Percentage occurring
Electrically related	40-60
Pump related	10-30
Miscellaneous	20-40
Tank related	1-5
Piping related	5-10

Figure 9: Cleaning of interceptor tank

The equipment and spare parts required to perform the necessary maintenance on these pump stations include:

- Spare pump
- Float switches (liquid level sensors usually cause the electrical failures)
- Rodding equipment (although this is usually on the building sewer)
- Voltage and amperage meters
- Portable standby generators
- Disinfectants

3.4 Simplified sewerage systems

Methods for cleaning simplified sewerage systems include: Rodding, jetting (shown in **Figure 10**), hand excavation, solids removal and disposal and local pipe replacement. Sewer-line cleaning techniques and equipment used would be similar to those used in conventional sewer systems.

Figure 10: Van-mounted water jet unit used in Brasilia (Mara et al., 2000)

There are different types of cleaning equipment and methods a local authority or the community could select but this depends on the available budget, facilities, and the experience of the maintenance staff. The cleaning devices most commonly used are rodding machines and flushing equipment.

3.5 Pump stations

Pumping stations in sewage collection systems are designed to handle raw sewage that is fed from underground gravity pipelines or from other rising mains. Sewage is typically fed into and stored in an underground pit commonly known as a wet well. The well/sump is equipped with electrical instrumentation to detect the level of sewage present. When the sewage level rises to a predetermined point, a pump will be started to lift the sewage upward through a pressurized pipe system called a sewer rising main from where the sewage is discharged into a gravity manhole or WWTW.

A pump station could consist of the following components (**Figure 11**):

- Pump-station building /superstructure
- Inlet pipe work
- Screens, grinders or grit traps
- Sump (wet well)
- Pumps
- Pipe work and appurtenances

- Motors
- Power supply / generators
- Electrical, controls, and instrumentation
- Ancillary equipment (hoisting, odour control, noise control and ventilation)

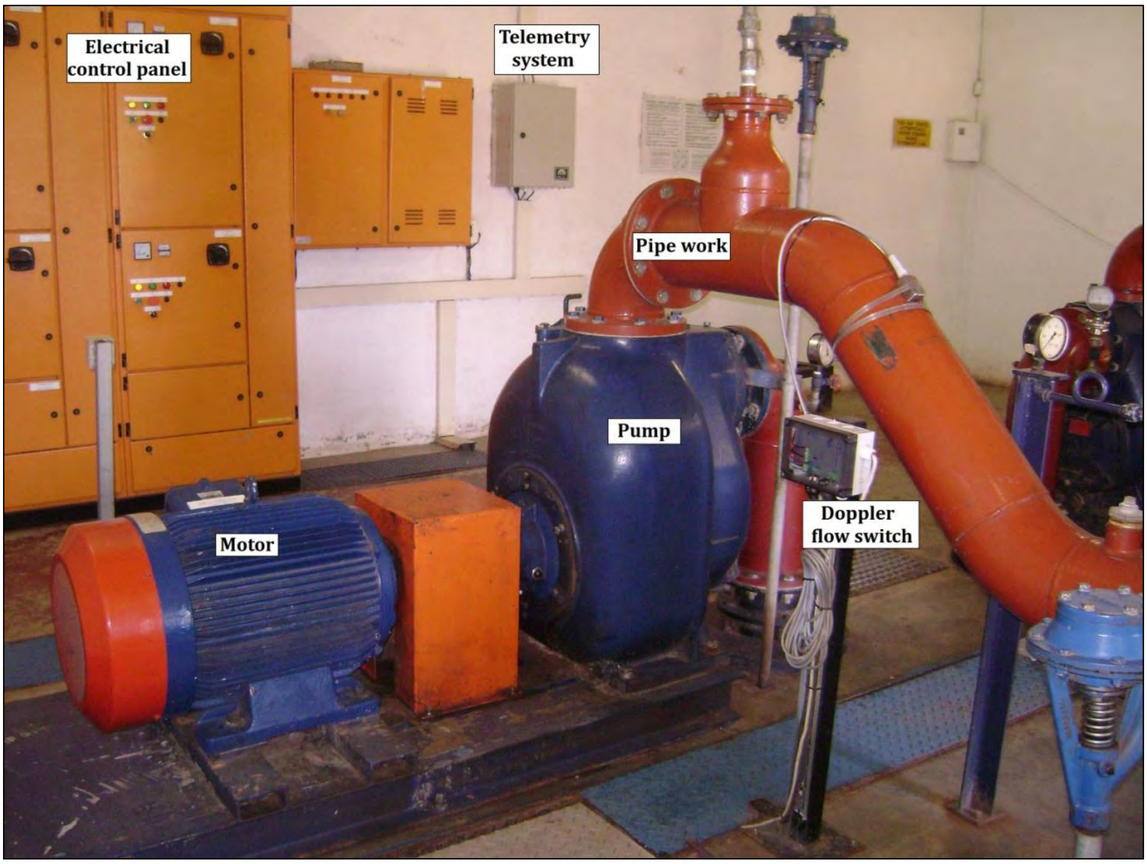

Figure 11: Typical pump-station components

Each of these components would require certain equipment to maintain and keep it in good working condition. The equipment that would typically be used for maintaining the pump stations include:

- Vacuum tanker (cleaning of sump)
- Submersible pump (cleaning of sump)
- General pipeline fittings and special tools (to quickly repair any rupture that may occur in the piping system)
- All working parts of the pumping units, liquid level sensors, check valves, and components of the control panels should be on hand to quickly restore operation in event of malfunction
- Block-and-tackle (for hoisting pump or motor)

The servicing or repair of the equipment would be done according to the manufacturer's manuals or catalogues. For example, air-release valve manufacturers can provide cutaway drawings that are beneficial to understanding how the valve works, and details of the listing assist in identifying the various parts used.

3.6 Other special structures

3.6.1 Junction and diversion structures

A junction structure is required when one or more branch sewer joins or enters a main sewer and at diversion structures, **Figure 12**, where the flow is diverted from one sewer to another. For large-size sewers these are usually built in cast-in-place reinforced concrete chambers provided with access points. Regular removal of accumulated sludge and debris employing the same maintenance equipment used in sewer networks is required.

Figure 12: Diversion structure

Steel gates used in diversion structures need to be cleaned and oiled or greased. Gates (stop logs) need to be lifted out of their slots and thus a block and tackle might be required.

3.6.2 Silt/grit traps

Grit traps operate passively by removing heavy entrained matter from the sewage by reducing the velocity and allowing settling to occur. Failure to remove the collected materials will reduce the efficiency of the devices and cause the grit to settle in the drain pipes reducing the capacity of the drains. Cleaning will ensure continued operation and reduced maintenance costs over the equipment lifespan.

Cleaning the smaller silt traps requires removing the grit by hand using a spade and wheelbarrow. The disposal of collected residuals could then be done by transporting it from site using a dump truck or trailer. The equipment required for maintaining a larger type silt trap includes a grapple bucket as shown in **Figure 13** and lifting equipment. In smaller systems hand-held equipment such as spades can be used. The silt must be removed from site and for this a dump truck or trailer can be used. In some cases a vacuum tanker could be used to remove the sludge and the heavier grit can be removed by hand.

Figure 13: Grapple bucket removing silt in Gugulethu (courtesy of BKS (Pty) Ltd)

3.6.3 Siphons

Mechanical devices such as balls or bucket machines are effective tools for cleaning inverted siphons. Hydraulic cleaning has been found to be effective for both small- and large-diameter siphons. Jet machines with the appropriate nozzles can be used to 'nibble' at the debris in the siphon. Steel gates used in inlet/diversion structures need to be cleaned and oiled or greased. Gates (stop logs) need to be lifted out of their slots and thus a block and tackle might also be required. Siphon inlet structures are occasionally used as silt traps and thus equipment for removing the grit from the inlet structure could also be required as described in **Paragraph 3.6.2**.

4. OPERATION AND MAINTENANCE - GENERAL

It is important that the operation and maintenance personnel continuously monitor the condition of the sanitation system to ensure proper functioning thereof. Inspection and testing provide the means for the monitoring activity.

4.1 Operation

Collection systems have little of what is traditionally referred to as 'operability' as compared to a wastewater treatment plant (i.e., the number of ways to route the wastewater is typically limited). However, the design of some collection systems does allow flow to be diverted or routed from one pipe to another or even to different treatment plants. This can be accomplished by redirecting flow at a pump station from one discharge point to another or opening and closing valves on gravity sewers and force mains. There are many reasons why the municipality or operator may want to divert flows; among them, to relieve overloading on a system of piping or the wastewater treatment plant or to add more flow to piping serving an area not yet fully developed to maintain a cleansing velocity.

4.2 Inspection

Physical inspections should be carried out on a regular basis as part of a preventative maintenance programme. Inspections in general are conducted to:

- Identify what is in the system
- Identify the location of system components
- Determine the condition of the components
- Prevent problems from developing

Physical inspections are performed at accomplish the following goals (NEIWPCC, 2003):

- *Identify defects in the system that can contribute to or cause backups, overflows and bypasses*
- *Identify chronic problem areas so maintenance can be planned and scheduled*
- *Identify defects that if not repaired will result in failure*
- *To enable evaluation of the seriousness of the problem*
- *Determine the system needs for long-term replacement and rehabilitation*
- *Develop a baseline for future comparison to determine deterioration rates*
- *Assist in setting and justifying rates*

- *To provide feedback and reports regarding the problems*

The first part of an inspection is a surface inspection based on visual inspection from street level. The inspection team would look for flooded or sunken areas, surface cracks on the ground along the sewer line route, signs of vandalism, damaged or stolen manhole covers and evidence of flooding or seepage from sewers.

The second part is to inspect the manholes or inspection chambers. The manholes or inspection chambers are primarily there for maintenance purposes but they should be checked for defects. This includes inspecting the covers, rings, barrel, steps and the bottom surface for any defective condition.

It is recommended that manholes and inspection chambers should be inspected once every year to ensure these are in good condition. Older manholes must be inspected as often as possible to detect leaks that create inflow/infiltration problems. New manholes need to be thoroughly inspected in a similar manner as the rest of the sewer line before acceptance.

The pipeline itself can then be inspected by means of a direct visual inspection where the large-diameter pipelines are checked for cracks, pipe or joint separations, corrosion, root intrusion, obstruction and other defects normally visible from on-surface inspection.

Closed circuit television inspection (CCTV) provides the most positive and reliable information on the internal condition of a small- or large-diameter sewer line. The CCTV unit would include camera, floodlight, pulleys, picture monitor and control centre, service truck, etc.

4.3 Testing

Testing is one of the methods used to gather information to develop a sewer operation and maintenance programme. There are a number of methods of testing a sewer line with each having its own applicability, see **Table 2**. See also sewer-evaluation activities in **Table 8**.

Table 2: Testing and inspection

Testing and inspection	Description
Air testing	This is to test the integrity of the sewer main line, service laterals and manholes. Inflatable or similar plugs are placed in the line and the space between these plugs is pressurized with air. A pressure drop indicates leaks in the line section being tested.
Vacuum testing	This is to test the integrity of the pipeline. A vacuum is created using plugs on both ends of the line.
Mandrel testing	This is to test whether the pipe has the proper flushing and vertical and horizontal tolerances.

Table 2: Testing and inspection (continued)

Testing and inspection	Description
Smoke testing	A section of a pipeline is isolated by plugging it at both ends, and then filled with smoke and where there is a crack the smoke will leak. This will allow the determination of potential points of entry of surface inflow into the collection system; the location of illegal connections into the collection system; and the location of broken sewers due to foundation settlement, manholes and other structures.
Dye water testing	Dye is applied to sewage in a sewer line and then its movement is traced as it flows through the sewer system. The typical application of dye testing includes the following: a) Buildings that may not show smoke at vents during the smoke test due to traps in the service connection pipes; b) Where a stormwater drain is suspected of being linked into the building sewer or later sewer; c) Any suspected surface inflow to the wastewater collection system; d) Testing for infiltration and exfiltration; and e) Flow velocity measurement.
Closed-circuit television (CCTV)	This is used for inspection of the pipe condition as well as alignment. Breaks, leaks, protruding laterals, root intrusion and other blockages can all be located by means of CCTV. Visual and CCTV inspections will provide verification that manholes and cleanouts are on the proper level and accessible in future.
Visual (pipe lamping)	Pipeline lamping consists of looking directly through a section of sewer line or by the aid of a mirror. The purpose is to determine whether or not the section of sewer line being inspected is straight and open. It also allows an inspector to visually examine the condition of the pipe within viewing distance of the manhole. Lamping is also defined as using reflected sunlight or a powerful light beam to inspect a sewer between two adjacent manholes. The light is directed down the pipe from one manhole and if it can be seen from the next manhole it indicates that the line is open and straight. Although this method of testing only provides limited information it has considerable value in the collection system maintenance. It is economical and a fast way of determining if a pipeline section is straight and clear.
Tape measurement	Simple tape measurements are also used to physically locate manholes and cleanouts in cases where they have been paved over or concealed in some way.
Sonic testing	Sonar-based equipment can be used to measure the internal cross-sectional profile of sewer systems. Sonar equipment is also useful for inspection of siphons which are filled with wastewater.

4.4 Maintenance

The objective of a good maintenance programme is to keep the system in a good operating condition so that it can function efficiently throughout its design life. Lack of maintenance can have health implications as well as cause damage to properties when things go wrong. Maintenance can be categorized into preventative and corrective maintenance (proactive and active maintenance). Preventative maintenance involves the inspection of the collection system and analyses of the data to identify problematic areas. Corrective maintenance refers mainly to emergency maintenance. This could include a sewer which has collapsed or blockage due to roots, grease or other obstructions, or excessive inflows or infiltration and the conditions require immediate action to correct the problem. The objectives would be to improve the service, reduce the emergency occurrences and minimize the cost of the preventative maintenance.

The greater the amount of preventative maintenance performed the lesser the amount of corrective maintenance required. A review of the historical maintenance costs can assist planners and designers to determine the exact amount of preventative maintenance to be carried out to strike a balance in terms of the benefit thereof.

A study performed by the American Society of Civil Engineers (in USEPA, 1999) reported that the most important maintenance activities are cleaning and CCTV inspections. **Table 3** shows the average frequency of various maintenance activities.

Table 3: Frequencies of maintenance activities (USEPA, 1999)

Activity	Average (% of system/year)
Cleaning	29.9
Root removal	2.9
Manhole inspection	6.8
CCTV inspection	19.8
Smoke testing	7.8

5. CONVENTIONAL GRAVITY SEWER – PIPE SYSTEM OPERATION AND MAINTENANCE

The most frequently received complaint about sewers is blockage, usually in smaller-diameter non-man entry sewers. Blockages or obstructions can be caused by sand and gravel deposits, domestic waste material not intended for the sewer system, grease build-up, damaged pipes, tree-root intrusion or any other condition which reduces or restricts the flow. The cause of the blockage will determine the appropriate cleaning procedure.

5.1 Manhole inspection

The manholes are primarily there for maintenance and need to be inspected regularly for defects. This includes the covers, rings, barrel, steps and the bottom surface for any defective condition. The objectives of the inspection are:

- To check for obstruction, debris in line and in the chamber, grease, etc.
- To ensure proper grading of the cover
- To ensure the cover has not been covered over or damaged by street resurfacing work
- To ensure structural integrity of the manhole or inspection chamber

It is recommended that manholes and inspection chambers should be inspected once every year to ensure that these are in good condition. Older manholes must be inspected as often as possible to detect leaks that create inflow/infiltration problems. New manholes need to be thoroughly inspected in a similar manner as the rest of the sewer line before acceptance.

5.2 Pipeline inspection

The pipeline can be inspected by means of a direct visual inspection where the large-diameter pipelines are checked for cracks, pipe or joint separations, corrosion, root intrusion, obstruction and other defects normally visible from on-surface inspection. Extreme care should be taken to provide sufficient safety measures as discussed in **Paragraph 12**.

Closed circuit television inspection (CCTV), **Figure 14**, provides the most positive and reliable information on the internal condition of a small- or large-diameter sewer line. The CCTV unit would include the camera, floodlight, pulleys, picture monitor and control centre, service truck, etc.

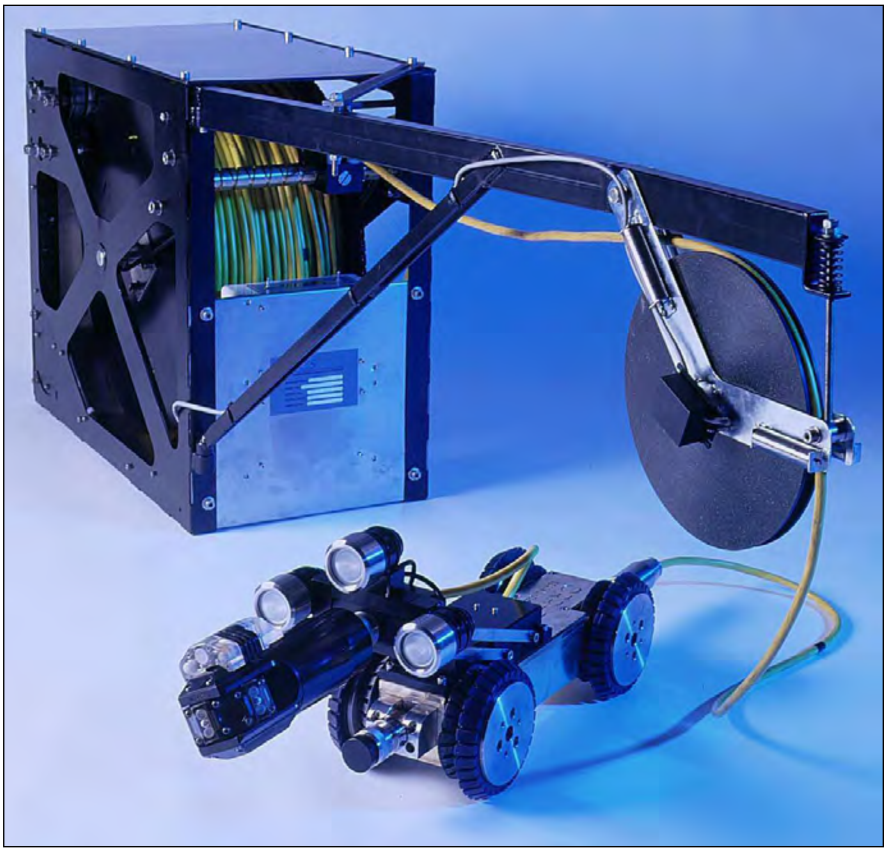

Figure 14: CCTV inspection equipment
(courtesy of Sight Lines Pipe Survey Services)

5.3 Maintenance methods

The cleaning and maintenance methods depend on the wastewater characteristics, fluctuations in flow, sewer alignment, pipe material, condition of sewer, and past history of sewer performance. Having a good record of all blockages, size of sewer, history of maintenance carried out, preventative maintenance performed as well as details of maintenance equipment used will assist in carrying out effective maintenance.

Blockages can be cleared or prevented by hydraulic, mechanical or chemical methods.

Mechanical and hydraulic cleaning of sewers is a cost-effective method of removing material that interferes with the functioning of the sewer. Hydraulic methods consist of cleaning sewers with water under pressure generating high water velocities which will be sufficient to break up the blockage and flush the grit, grease or debris downstream.

Mechanical methods consist of using equipment that scrapes, cuts, pulls or pushes the material out of the sewer pipeline.

Chemicals can also be a tool to help prevent root growth in sewer lines. Various chemicals such as enzymes, hydroxides, caustics, biocides and neutralizers are available for removing or controlling grease build-ups.

Some cleaning methods, application and limitations are discussed in **Table 4**.

Table 4: Mechanical and hydraulic cleaning methods

Method	Description
Rodding	Hand rods or power rodding machines (truck or trailer-mounted). A torque is applied to a steel rod as it is pushed through the line, rotating the cleaning device attached to the end of the rod. Efficient for sewer lines up to 300 mm but less useful for larger diameters. The method is ineffective for removing sand and grit accumulation but could loosen material to be flushed out of the sewer. Electrical power rodding machines are also available and can be used in smaller-diameter lines.
Balling	This method utilizes the pressure of water head to create high-velocity water flow around a ball. Various sizes of sewer balls, typically 150 mm to 1 000 mm, to fit the different diameters of sewers are used and this is very effective in removing high concentrations of sand, grit, rock and grease from the sewers. This is not a recommended method for sewer sections with basement fixtures and in steep-grade hilly areas due to potential flooding of connected buildings. Sewers which have bad offset joints or protruding service connections will result in the ball being lodged and thereby prevent effective cleaning thereof.
Flushing	This is a hydraulic method usually used at the upstream end of a collection system. Low or sluggish flow results in the deposition of solids in these sections of the collection system. Water from a fire hydrant or water tank is used to increase the flow rate in these sewer sections effectively flushing floatables and some sand and grit. Useful in combination with mechanical options such as rodding.
Jetting	This is a hydraulic method which directs high-velocity streams of water against the pipe walls at different angles to clean the sewers. This is a very effective cleaning method for flat slow-flowing sewers and is very efficient in removing sand, gravel, debris and grease in small sewers. High pressure water jetting can also be used for the breaking up of solid material in the manholes and the washing of other structures. Effectiveness of this method reduces as the size of the pipe increases.
Scooter	A steel frame on small wheels with a rubber-rimmed, round metal shield at one end is guided through the sewer line by means of the water pressure build-up and a cabled power hinge. The process is similar to the balling process where high turbulence forces loosened material to move downstream caught in a trap at the next manhole. Typically used in larger-diameter pipes and is very effective for removing heavy debris.
Kites, bags, tyres, parachutes and poly pigs	Kites, bags, tyres, parachutes and poly pigs are all devices used for cleaning larger sewers similar to the balling process. All these devices are propelled forward by the water pressure build-up and are very effective in moving accumulations of decayed debris and grease downstream. The washing effect upstream of the device also cleans out other deposits, including roots.
Bucketing	This is a very effective method for removing large deposits of silt, gravel and some solid waste. Thorough cleaning after the bucket has been pulled through the sewer line is still required afterwards. This is a tedious and time-consuming job with potential damage to the sewer pipe.

Table 4: Mechanical and hydraulic cleaning methods (continued)

Method	Description
Cable machines	Cable machines operate in a manner similar to bucketing except that the winch is usually truck-mounted. The cable is pulled through the sewer line from one manhole to the next. A brush, cutter or bucket is attached to the cable and it is pulled back through the sewer to clear grease, roots, sludge, sand or grit from the line.
Grease traps and sand/oil interceptors	The ultimate solution to grease build-up is to trap and remove it. These devices are required by some uniform building codes and/or sewer-use ordinances. Typically sand/oil interceptors are required for automotive business discharge. Need to be thoroughly cleaned to function properly. Cleaning frequency varies from twice a month to once every 6 months, depending on the amount of grease in the discharge. Need to educate restaurant and automobile businesses about the need to maintain these traps.

Table 5 defines the conditions under which particular cleaning methods are most effective.

Table 5: Effectiveness of cleaning techniques (USEPA, 1999)

Solution to Problem	Type of Problem				
	Emergency Stoppages	Grease	Roots	Sand, Grit, Debris	Odors
Balling		●		●	●
High Velocity Cleaning	•	●		●	●
Flushing					●
Sewer Scooters		●		●	
Bucket Machines, Scrapers				●	
Power Rodders	●	•	●		
Hand Rods	●	•	●		
Chemicals		●	●		●

● = Most effective solution for a particular problem

• = Least effective solution for a particular problem

Source: U.S. EPA, 1993.

5.4 Control of other problems

Not only common clogging problems in pipelines as discussed in the previous paragraphs need attention, but some other pipeline maintenance work problems also arise, such as root intrusion, odours, pipe corrosion and insect and rodent infestation.

Chemicals can be very helpful aids for cleaning and controlling root intrusion, odours, corrosion and rodent and insect infestation. If chemical dosing is to be considered careful planning and evaluation should be done taking note of the following:

- Chemicals cannot clear blockages in sewer lines
- The costs of chemical cleaners are high, therefore the cost-effectiveness of the proposed dosing should be checked
- Chemicals may be hazardous to the employees, end-treatment facility and/or the environment
- Ensure that the chemicals can indeed achieve the desired outcome

5.4.1 Odour control

The odours emanating from a sewage collection system are primarily caused by the production of hydrogen sulphide. Other odours from industrial wastewater may also be present. Odours are usually controlled if the system is properly designed, cleaned and maintained effectively.

Sewer odours are usually caused by low-flow velocity, long transmission lines in the system, high temperatures and poorly maintained collection systems.

Some other methods for controlling odours are to use a masking agent, although not always effective, or aeration and dosage of hydrogen peroxide are effective in controlling hydrogen sulphide generation. The most widely used chemical for hydrogen sulphide control has been chlorine, which can be injected into the collection system at various points. Pump stations can serve as a chlorine injection point. Chlorine in doses of between 10 mg/ℓ to 20 mg/ℓ is effective but expensive. It could also have a negative impact on the treatment process being toxic to most organisms in the wastewater at these levels.

Hydrogen peroxide concentrations of between 35% and 50% have been proven to be beneficial for the control of hydrogen sulphide as it oxidises the H_2S present, keeping wastewater aerobic; hydrogen peroxide is not detrimental to the wastewater treatment process.

Sewage piping designed for future ultimate design flows is often oversized for initial flows resulting in long pipe retention times and septic odours. Chemical dosing at pump stations can help minimize odour problems throughout the downstream sewer system. Bioxide® chemical solution has been utilized at pump stations to minimize odours. The Bioxide® material utilizes the inherent ability of the facultative bacteria normally present in wastewater to metabolize hydrogen sulphide and other malodorous reduced sulphur-containing compounds. The material provides nitrate-oxygen to the wastewater to support this biochemical mechanism.

Frequent and effective cleaning to prevent growth of slimes and deposition of solids is still the best maintenance method.

To reduce the release of odours from sewers, the water surface or profile should be kept as smooth as possible.

5.4.2 Insect and rodent control

The best way to control insects and rodents is to include the appropriate measures during the design phase. A tight collection system with proper fixture traps, connections, sealed joints and high quality appurtenances is essential in controlling insects and/or rodent infestation.

5.4.3 Root control

The best root-control method is the use of tight construction joints and immediate repair of cracks or breaks in the sewer system. Roots usually enter the pipe at the top through the joints and can create a significant obstruction, see **Figure 15**. A CCTV inspection could locate the intrusion and chemical or mechanical methods can be applied to remove these roots such as a root cutter, see **Figure 16**.

Figure 15: Excessive root obstruction

Figure 16: Root cutter (courtesy Johannesburg Water)

5.4.4 Grease deposit control

Chemicals such as bioacids, enzymes, bacterial cultures, hydroxides and neutralizers are available to control grease and soap deposits in wastewater collection systems. The most effective method for grease control is by making use of mechanical or hydraulic cleaning equipment, combined with strict enforcement of policies regarding the quality of effluents discharged into collection systems. .

6. MAINTENANCE OF SPECIAL STRUCTURES

Special structures are classified as structures which are constructed to overcome some condition imposed by the local topographic characteristics or to serve a specific purpose. These structures include siphons, junction or diversion structures, ventilation structures, silt traps and flow-gauging structures and need much the same regular maintenance as the rest of the collection system.

6.1 Siphons

Siphons refer to inverted siphons or depressed sewers which would stand full or half full even with no flow. Siphons are designed to carry flow underneath an obstruction and to regain as much pressure head as possible after the obstruction has been passed. The individual pressurized pipes or conduits are normally smaller in diameter than the gravity system resulting in higher wastewater velocities. The higher velocity serves to keep heavier solids in suspension and prevent deposition of solids.

Two considerations which govern the profile of a siphon are the requirement to provide for hydraulic losses and to ensure ease of cleaning.

- The friction loss through the barrel is determined by the design velocity, and additional losses due to side-overflow weirs and directional changes are also taken into account

- Siphons need cleaning more often than gravity sewers. The siphon should therefore have no sharp bends (vertical or horizontal) or changes in pipe diameter. The rising leg of the siphon should not be too steep complicating the removal of heavy solids.

Two potential maintenance problems associated with siphons are clogging and hydrogen sulphide generation. Due to their nature, debris often settles at the bottom of the siphon with grease accumulating near the top, requiring frequent cleaning (ASCE, 2004). Some design-related problems include lack of provision for effectively draining the pipes for cleaning, inadequate access to the site, limited working space to clean and maintain the pipe barrels and difficulty in replacing corroded metallic flow diversion plates.

Siphons are constructed with multiple pipes in order to match the pipes in active use with the actual wastewater being conveyed. This also provides redundancy in the event of blockage in one of the pipes. There is a need for frequent monitoring of the siphon due to the probability of solids deposition and thus it could require more regular maintenance to prevent overflows.

Regular inspection and frequent flushing, by means of bucketing, balling, rodding, jetting or by using kites, bags and poly pigs, assures removal of obstructions. To make maintenance easier the following should be considered during the design:

- Provide air jumpers for hydrogen sulphide control

- Provide acid-resistant lining on inlet and outlet structures

- Provide adequate working space inside the inlet and outlet structures for cleaning the pipe barrels. Verify required space for electrical cleaning equipment.

- Provide a cleanout point at the low point of the siphon to enable complete draining (if feasible). Alternatively a sump at the inlet end of the siphon can be provided to allow draining of the siphon prior to cleaning and inspection.

- Pressure-type manholes and covers should be considered when crossing streams to prevent river water from flowing into the structures.

6.2 Junction structures

A junction structure is required when one or more branch sewers join or enter a main sewer. In the sewage collection system manholes function as sewer junction structures. For large-size sewers junctions are usually built in cast-in-place reinforced concrete chambers provided with access points.

The maintenance problems associated with junction structures are the accumulation of sludge and debris. This is mainly attributed to poor design which causes eddies and poor flow patterns resulting in debris or sludge deposition. It then requires regular removal of debris deposition employing the same maintenance equipment used in sewer networks. During the design the following, however, needs to be considered:

- Avoid excessive widening of the main channel at the junction
- Set the invert of the branch line higher than the invert of the main channel where these join in such a way that normal flow lines of these intersecting sewers coincide at the junction.

6.3 Diversion structures

These structures, also sometimes called overflow structures, are used to divert flow from one sewer to another. The diversion can be from one interceptor to another or to a relief sewer. Debris accumulation, inadequate access and difficulty in replacing corroded steel gates are some of the main maintenance issues at these structures. The maintenance work includes regular cleaning by removing debris and keeping the threaded stems of the gates oiled or greased. Regular testing to ensure that the gates function properly is also required. During the design stage the following should be considered to assist with the maintenance:

- The access hole should be designed large enough to provide adequate access to the stop log. Removable concrete cover slabs can also be considered.
- Consider providing alternative diversion when the sluice gate is under repair
- Provide a bracket on the gate frame so that the gate can be raised, with for instance block and tackle, in case it breaks loose causing it to slide down.

6.4 Ventilation structures

Ventilation structures are required when force draft ventilation is required. An air blower can be used at ventilation stations although not always required. In the case of a siphon consider an airline jumper which connects the in- and outlet structures. At pump stations or treatment plants an air blower is usually provided. The fan belt will need to be replaced from time to time and the air fan bearing will require regular lubrication.

6.5 Silt/grit traps

Silt traps are designed to trap sand and grit. This is usually achieved by reducing the flow velocity and allowing enough time/distance for the particles to settle and remain in the trap. Depending on the anticipated volume of silt transported in the sewer system the sizing of the settling bay will in turn determine the number of times it needs to be emptied. During the design phase consider the following:

- Consider providing alternative diversion when the main trap area is being emptied

- The access to the trap should be designed large enough to provide adequate access. Removable concrete cover slabs can be considered or a sliding roof structure, as shown in **Figure 17**.

- Select a location where a dump truck or trailer can be brought into close proximity to the trap for ease of cleaning

- Preferably locate the silt trap some distance away from the residential areas for odour control

Figure 17: Sliding roof cover for silt trap (courtesy of BKS (Pty) (Ltd))

6.6 Flow-gauging structures

Flow-gauging structures are used for measuring wastewater flow for planning, design or monitoring purposes. The structure size and layout depend on the type of device such as a Parshall flume or Venturi flow-rate meter being used, and the degree of maintenance work that will be required. It also has a stilling well with water-level recorder and inlet pipe plus the instruments themselves. Maintenance work could include cleaning the clogged inlet pipe, sludge deposition in the stilling well or a corroded weir plate. Regular flushing of the stilling well and the connection pipe leading to the well is also required. Electronic measuring equipment used to measure the flow rate would also require regular inspection and cleaning. Downloading of information or ensuring that the telemetry system is operational may also be part of the required maintenance work.

7. CONVENTIONAL GRAVITY SEWER - PUMPING STATION OPERATION AND MAINTENANCE

The main function of a pump station, also sometimes called a lifting station, is to raise wastewater from a lower to a higher elevation. The ideal operation of a pump station would be when the discharge rate is almost equal to the inflow rate. This would occur with the highest use of equipment and energy efficiency possible and consequently operational and maintenance problems would be minimized.

Depending on the type, size, and capacity of the pump station the station may be fully-manned 24 h a day or operated unattended except for periodic visits. A fully-manned pump station has an operator always present who could take care of any breakdown whilst an unattended one poses potentially a maintenance problem. All unmanned pump stations should be equipped with secondary power and at least a basic telemetry system. Lift station operation is usually automated and does not require continuous on-site operator presence. However, frequent inspections are recommended to ensure normal functioning and to identify potential problems.

One rule that should be applied to all pump-station visits is that for safety precautions, there should always be two operators making a station visit. Safety precautions regarding the presence of hazardous gases apply not only to wet-well installations, but in the dry-well area of the pump station as well. This is especially applicable during off-duty hours when operators respond to pump-station telemetry alarms or complaints from local residents in the area.

Pump stations should have a sign-in log, indicating names, dates and time of arrival and departure of all visitors to allow for monitoring every activity that takes place in the pump station.

The following paragraphs outline the guidelines and procedures for developing an effective maintenance programme. Detailed instructions regarding the maintenance and repair of each individual piece of equipment are normally provided in the manufacturer's manual and are therefore not described here. A variety of equipment, ranging from the simplest mechanical, electrical to the most complex instrumentation and control, is present in a pump-station installation. Regular preventative maintenance is required to keep it in optimum operating condition.

A typical weekly pump-station inspection should include observations of the following (NEIWPCC (2003) and USEPA (2000)):

- *The components that make up the alarm system, i.e. wet-well controller and electrical system*
- *The pumps: observation of pump drives for unusual noise, vibration, heating and leakage, bearings, packing, seals, and monitoring of suction and discharge gauge pressures*
- *The pump motors: temperature, amperage and voltage, coupling alignment, vibration and noise*

- *Check pump suction and discharge lines for valve arrangement and leakage*
- *Valves, check, air and pressure relief*
- *Check control panel switches for proper position, monitoring of discharge pump rates and pump speed*
- *Oil levels and lubrication*
- *Belt wear and tightness (if applicable)*
- *Emergency generator*

The most labour-intensive task for pump stations is routine preventative maintenance. A well-planned maintenance programme for pump-station pumps prevents unnecessary equipment wear and downtime. Pump-station operators must maintain an inventory of critical spare parts. The number of spare parts in the inventory depends on the critical needs of the unit, the rate at which the part normally fails, and the availability of the part. The operator should tabulate each pumping element in the system and its recommended spare parts. This information is typically available from the operation and maintenance manuals provided with the pump station.

7.1 Pumps

The sewage pumps are probably the most important equipment in the sewage pumping station. A good understanding of the pump construction and operation is essential to provide proper maintenance. Regular inspection should be undertaken taking note of the following:

- *Bearings* – For low kilowatt pumps bearings are a major source of problems. A close-coupled pump has no bearings since the impellers are mounted directly to the end of the motor shaft. In the case of vertical open-shaft pumps, these pumps also do not have bearings. Noise is a tell-tale sign that there is a problem as well as unusual heat emanating from the bearings.

  The costs of the bearings are minimal compared to taking out the pump and overhauling it. Replacing the bearings every time the pump is being overhauled should therefore be considered.

- *Seals* – There are two types of seals in use, the packing-gland type and the mechanical type. Submersible pumps usually have mechanical-type seals. The packing of a pump is very important. Its function is to seal the pump whilst still allowing some shaft deflection. Packing-gland boxes are lubricated and cooled with small amounts of wastewater leaking through the packing gland or with an external source of clean water known as a water seal. These packing-gland boxes should be inspected for leakage of sealing water. If there is too much leakage or no leakage, the gland should be tightened or loosened as required.

Packing material should be regularly renewed to prevent scouring of the shaft or shaft sleeve.

An adequate supply of spare parts should be kept on hand, as mechanical breakdown is sometimes abrupt with no prior warning.

- *Lubrication* – This is definitely the most important function of a preventative maintenance programme. Pumps should be oiled and greased at predetermined intervals in strict accordance with the manufacturer's specifications.

Other less frequent inspections may include vibration analysis, infrared photography and internal inspection of pump components.

7.2 Mechanical

As indicated above the pumps are the most important piece of equipment in the pump station which requires a thorough inspection and regular maintenance to keep it operating as intended. Other mechanical equipment which requires regular inspection and confirmation that these are still all in a working condition includes: Pipe work on the pump suction and discharge lines as well as the valves (check air-pressure relief, isolating valve, etc.). The system should be checked to ensure that there are no leaks and the valves are still functional, i.e. air is being released from the air valve and flow is zero when isolating valve is closed, etc.

Identify any corrosion and/or damaged pipe sections or valves and have damaged items repaired.

7.3 Electrical equipment

There should be continuous preventative maintenance carried out on the electrical equipment.

Electrical control and protective devices tend to malfunction due to long periods of non-use and thus need to be checked regularly.

Electric motors are the machines most often used to convert electrical energy into mechanical energy. Modern electric motors are reliable and trouble-free pieces of equipment. An electric motor will yield a long service life if it is kept clean, free from moisture, lubricated and isolated from vibration.

7.4 Instrumentation and control

Pumping units should be supplied with running hour meters and there should be water-level sensors since these control the functioning of the pump station. The maintenance of the instrumentation and controls used in a pump station requires a specialized and trained technician.

Control floats can become clogged with grease or weighted down with rags and debris. The floats could also develop holes, fill up with water and sink. The control floats require frequent maintenance to remove grease and other debris which accumulate in the wet well. Other sensors such as the purged-air type can be maintained by simply checking the function from the dry well and draining condensate from the system. Ultrasonic level sensors are also popular since these are not in contact with the wastewater. If these units require maintenance it will require a high level of technical skills.

Alarms are used to alert the maintenance and operational personnel of some problem at the pump station. Remote unattended stations would require a telemetric and remote warning system whilst a manned station could simply have flashing lights and buzzers. There are a number of alarms signalling potential problems at a pump station due to some abnormal condition. These include:

- *Power failure* – power outage at the station
- *High water in wet well* – due to power failure, failure of automatic controls, obstruction in pump or piping system, improper arrangement of valves or hydraulic overloads due to excessive inflow into the pump sump
- *Water on dry well* – due to breakdown of sump pump, excessive bleed-off from pump packing or leaking from piping system or even from the wet well
- *Communication failure* – failure of the transmitting equipment due to power failure or physical damage
- *Devices cycling* – indication of the pump cycling on and off more than a specified number of times in a pre-set time period
- *Access alarm* – when access to the pump station is gained outside working hours

When any of these alarms are triggered a response procedure depending on the type of alarm received should be activated.

7.5 General plant structure

Not only the mechanical and electrical components of the pump station require maintenance; the plant appurtenances and the structure itself also need regular maintenance.

7.5.1 Wet well

One of the major problems in operation and maintenance of the wet well is the build-up of grit in the wet well. The grit build-up may result in a reduced flow as well as reduced wet-well capacity. The grit can be removed manually by use of buckets or by employing a bucket machine. Alternatively the grit can be flushed towards the pump's suction intake with high-pressure hoses and pumped away. However, this method could have a negative impact on the wear and tear of the pump impellers.

The design criteria for submersible pump wet-well sizing can lead to excessive grit deposition in the wet well due to initial low-flow conditions and a subsequent increase in maintenance requirements. The grit can result in serious odour problems and is difficult to remove. A solution for this could be the provision of temporary solid concrete block fillers in the wet-well areas subject to grit deposition or provide baffle walls to reduce the wet-well area during initial low-flow conditions. In the future when the flows approach the design flow rate, the blocks or baffle walls can be removed.

The wet well also requires regular cleaning since grease and other material usually accumulates causing odours and impairing the proper operation of the float controls. Cleaning of the wet well using a vacuum tanker is an effective method.

Cracks or leaking joints should be identified to prevent leakage into the pump-station structure. Cracks or joints in precast concrete manhole structures used to construct a pump station can result in groundwater leakage into the pump station which must be pumped to the treatment facility resulting in unnecessary costs and reduced capacity. It is often difficult to permanently seal such cracks or joints after construction is completed and the pump station is in service creating a confined space. This is especially true for deep pump stations. All-weather butyl joint sealant materials are available for effective sealing of precast concrete joints exposed to high groundwater pressures. Butyl sealants are rubber-based and exhibit physical properties such as rebound, compression, low- temperature and high-temperature flows that are all required for long-term sealing performance. Other methods of sealing the joints and concrete surfaces are also available including bentonite.

7.5.2 Screening devices and comminutors

Comminutors, shredding and screening devices are widely used in sewage pump stations to disintegrate wastewater solids. The two types of screening devices used are either manually or mechanically cleaned. Manually cleaned coarse screens would be the typical basket or bar-rack type (see **Figure 18**). This type of screening requires a high frequency of manual labour but may be cost-effective in small systems. Utilizing wheeled containers, steam cleaners or high-pressure water washers can assist in reducing the labour demand for this tedious maintenance job.

Mechanically-cleaned bar or basket screens are more common and are used in larger systems or where frequent cleaning is required; labour costs are reduced but these screens require more maintenance. Automatic controls such as timers or differential pressure sensors assist in reducing operational time. Regular inspection of the mechanical screens is required.

Figure 18: Manual screening with rake

A vertical perforated screen basket and a shafted auger in a vertical tube are shown in **Figure 19**. The wastewater flows through an inflow connection and a chamber into the screen basket. Within the screen basket the flights of the screw are equipped with wear-resistant brushes for effective cleaning of the screen. As the screenings are gradually elevated by the auger, they are dewatered. The compacted screenings are discharged into a container or onto a conveyer belt system thus eliminating odour nuisance (Huber, 2009). The mechanical screening device can be combined with a manual screening device as shown in **Figure 20**. The primary screening is done by means of the mechanical device with the manual screening required during maintenance of the mechanical equipment and or during failure of the mechanical device.

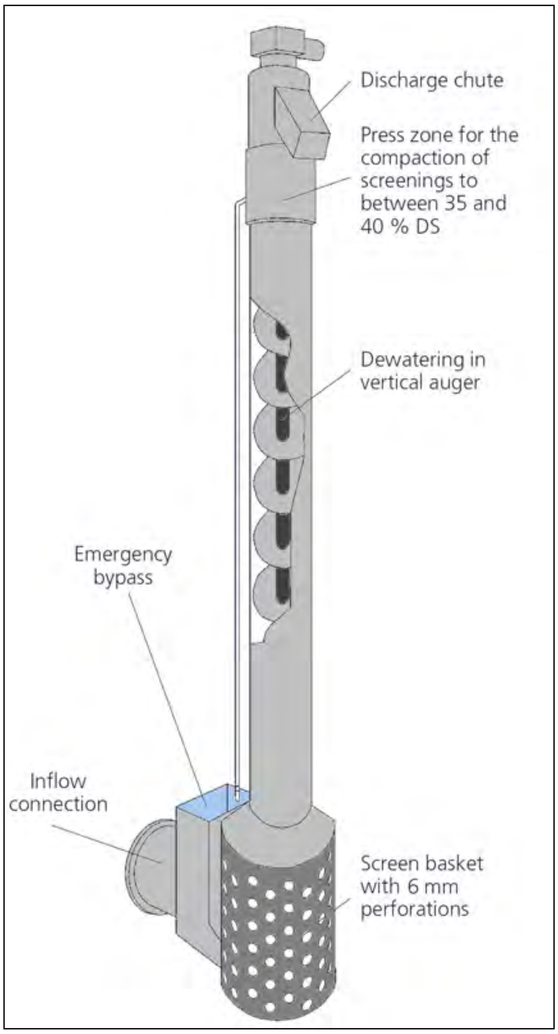

Figure 19: Mechanical screening device (Huber, 2009)

Figure 20: Combination of mechanical and manual screening devices (courtesy MVD Consulting Engineers Suid-Kaap)

The most common shredder is the comminutor. A continuous operation is preferred and comminutors perform screening and shredding in a single operation. Another advantage of comminutors is that screenings do not have to be removed. The maintenance required includes lubrication, cleaning the comminutor, its housing and basin at regular intervals. The grinder should also be inspected regularly with all cutting parts kept sharp.

Some of the older pump stations have the wastewater entering directly into the wet well and rely on the ability of the submersible pumps to pump a certain size solid. Some pump stations have a basket screen attached to the inlet pipe inside the wet well aimed at protecting the pumps from damage. However, the screens have to be manually lifted out of the wet well and cleaned by hand regularly to be effective. In this instance a comminutor vault preceding the wet well in pump stations should be considered. Raw wastewater entering the pump station flows through the comminutor vault influent channel which is equipped with a grinder. The grinder is a hydraulically driven horizontal screen and cutter assembly. The rotating screen directs solids toward and into the cutters where the influent solids are ground into fine particles to protect the downstream pumps. When the grinder has to be taken out of service, slide gates can be provided to direct comminutor vault flow to a bypass bar screen. Also, in the event of backflows occurring upstream of the grinder the inflow channel wall has an overflow notch just upstream of the bar screen. The bar screen is constructed of stainless steel bars and must be manually cleaned with a rake. Providing a ventilation fan on top of the comminutor vault could be considered.

If a pump station is equipped with grinder bar screens to remove coarse materials from the wastewater, these materials are collected in containers and disposed of to a sanitary landfill site as required. In pump stations where a scrubber system is utilized for odour control, chemicals are supplied and replenished typically every three months. In pump-station systems where chemicals are added for odour control upstream of the pump station, the chemical feed stations should be inspected weekly and chemicals replenished as needed.

7.5.3 Ventilation

If a pump station is fitted with a ventilation system it will require regular maintenance. Accumulated moisture can be drained off by providing a valve at low points in the duct work. Non-corrosive material should preferably be used for the fan and duct work.

7.5.4 Sump pumps

Dry wells usually have sump pumps to remove accumulated moisture. These sump pumps require regular maintenance work as well as the float that controls the on-and-off switching. The pump strainer and sump should be cleaned of debris. Unattended pump stations would require an alarm system to warn in case of failure of the sump pump and potential flooding of the dry well.

7.5.5 General housekeeping

General housekeeping will assist in keeping a pump station in a workable condition, reduce potential hazards and prolong the life of the structure. During the design phase it is thus important to take note of the requirements to perform general housekeeping tasks such as:

- Provide storage area for housekeeping supplies, electrical and mechanical supplies, spare parts and tools
- Provide ablution facilities. At larger pump stations provide a shower and toilet facilities.
- Provide first aid and emergency equipment
- Freshwater and electricity should be available at all stations
- Provide access road/driveway for delivery or removal of equipment

The general maintenance required to the structure exterior would include painting, attending to problems, as well as general landscaping, i.e., keeping the property clean and providing a workable environment.

7.6 Rehabilitation of pump stations

Even if pump stations are effectively maintained for years they will need to be rehabilitated at some stage. After a number of years of service parts are no longer available for electrical controls, and pumps and valves need to be replaced. Also, the building structures, roads and electrical service panels are often in need of replacement. The pump station must be maintained in continuous service through construction and thus constructability issues must be identified in the design process.

A pump station needs to be examined to determine the rehabilitation measures required. These could include:

- Pumps and valves and other mechanical equipment items may need to be replaced. Typically, dry pit submersible pumps are used to replace shaft pumps.
- New electrical controls may need to be installed
- Corrosion-resistant materials are installed to replace corroded materials or epoxy coatings are applied to existing surfaces
- Structural and architectural improvements need to be identified
- The construction phasing and temporary pumping requirements should be identified to allow for continuous operation of the pump station during the rehabilitation thereof

7.7 O&M manual for pump station

The City of Tshwane Metropolitan Municipality has compiled the following criteria for the consulting engineer responsible for designing a sewage pump station in terms of preparing an O&M manual (CTMM, 2007) for a sewage pump station:

The consulting engineer shall supply the Divisional Head: Water and Sanitation with three copies of the operating and maintenance manuals when the pump station is taken over and shall also be responsible for obtaining all manufacturers' manuals and operating instructions - which shall be assembled into an organised supplement to the Operation and Maintenance Manual.

The Operation and Maintenance Manual shall include the following information:

- *A flow diagram of the pump station showing all the components as well as the working pressures and flow rates, including updated information on the actual pumps installed.*
- *Detailed descriptions of all operating processes and sequence of operations including description of the operation and interaction of systems and subsystems during start-up and shutdown, operation in automatic mode, operation in manual mode, and operation with backup power. This includes, but is not limited to, equipment, pumps, piping, valves, HVAC, electrical, controls, and instrumentation.*

- *Design data for pumps, motors, force main, standby power, overflow point and elevation, telemetry (where applicable), and sulphide control system, as applicable.*
- *Pump curves with computed system curves showing design operating points.*
- *Analysis of critical safety issues and procedures, as well as a vulnerability analysis.*
- *Inventory of critical components, including nameplate data for pumps and motors, etc.*
- *A consolidated summary of required routine scheduled maintenance and scheduled preventative and predictive maintenance for all station equipment, along with references to the location within the manual where detailed information may be found. These will include lubrication, cleaning, inspection, oiling, adjusting, equipment condition monitoring, and rebuilding to factory specifications. Scheduled maintenance shall be triggered by frequencies (elapsed calendar days, run time, etc.) or on demand.*
- *A complete list of emergency spares to be kept in store.*
- *List of vendors and manufacturers of critical system components, including after-hour contacts, as well as name, location, and telephone number of nearest supplier and spare parts retailer, for all components used in the pump station, pipe work and rising main.*
- *Contingency plan, including redundancy considerations.*
- *Emergency plans and procedures.*
- *All safety related aspects.*
- *Required training and training plan far operation and maintenance teams.*
- *A complete set of the as built drawings, as well as electrical panel drawings.*
- *Description of the maintenance management system, including preventive and predictive maintenance.*

The following information shall be included in an equipment literature supplement to the O&M Manual:

- *Disassembly and reassembly instructions.*
- *Parts lists and information for all installed equipment - by generic title and identification number.*
- *Manufacturer's certifications, including calibration data sheets and specified calibration procedures and/or methods, for installed equipment.*
- *Warranty forms.*

When performing a pump-station inspection, special attention should be given to safety precautions. Toxic odours and slippery floors are examples of potential hazards to be mindful about. The inspection should cover the following items, the frequency of which is determined by its criticality (ASCE, 2004):

- *Standby generator;*
- *Pump and motor condition;*
- *Compressor condition;*
- *Valves condition;*
- *Belt condition;*
- *Oil level;*
- *Bearing condition;*
- *Wet well condition;*
- *Back flow preventer;*
- *Lighting and heating;*
- *SCADA system;*
- *Fire extinguisher;*
- *Condition of the building, vents, and louvers;*
- *Security of the pumping station and alarms;*
- *Electrical switches, circuit boards, and wiring conditions;*
- *Evidence of grease or oil leaking, and*
- *Evidence of equipment heating.*

8. VACUUM SEWERS – OPERATION AND MAINTENANCE

Early vacuum systems were often plagued with regular operational problems. Small-diameter vacuum mains, improperly planned vacuum main profiles, too large liquid slug volumes, and insufficient air all resulted in transport problems (PDH Engineering, 2009).

Several breakthroughs occurred in the 1980s that led to significant improvements in the sewer vacuum system technology. These included the introduction of the sawtooth profile design concept, an improved valve controller, the use of gasketed pipe and the use of larger pipe and vacuum pumps.

Significant operational improvements have been achieved through a better understanding of vacuum sewer hydraulics, improved system components, and cognizance of established operation and maintenance guidelines.

An asset management programme will show that normal and preventative maintenance is far better than emergency maintenance. Vacuum sewer systems operate and must be maintained throughout the entire year. Variations in operation and maintenance workloads occur, making it essential that preventative maintenance be performed. Inspection and maintenance involves time, personnel and equipment.

8.1 Vacuum station

Vacuum stations function as transfer facilities between a central collection point for all vacuum sewer lines and a pressurized line leading directly or indirectly to a treatment facility, see **Figure 21**. A correctly designed vacuum station will be equipped with a fault monitoring system, such as a telemetry system. This system will monitor the operation of both the vacuum station and the collection system, and automatically notify the operator of low vacuum pressure, high levels of sewage in the collection tank, and power outages.

Normal operation includes visiting each vacuum station daily. Some daily maintenance procedures include the recording of pump running hours and oil and block temperature checks. Once an operator is familiar with the operating characteristics of the system, a simple visual check of the gauges and the recorders in the station will provide an adequate alert of any problems. This visual check along with recording operating data generally takes about 30 min. Typical operation and maintenance tasks associated with the vacuum station and the frequency are shown in **Table 5**.

The vacuum vessel requires no maintenance other than external painting. For this reason, no standby vessel is offered or needed. The two vacuum pumps are each sized to be able individually to perform the duty required and in the event of one failing or being maintained, the other pump will operate the system. This also applies to the sewage discharge pumps. In general then, the vacuum station requires no more maintenance than a conventional pumping station.

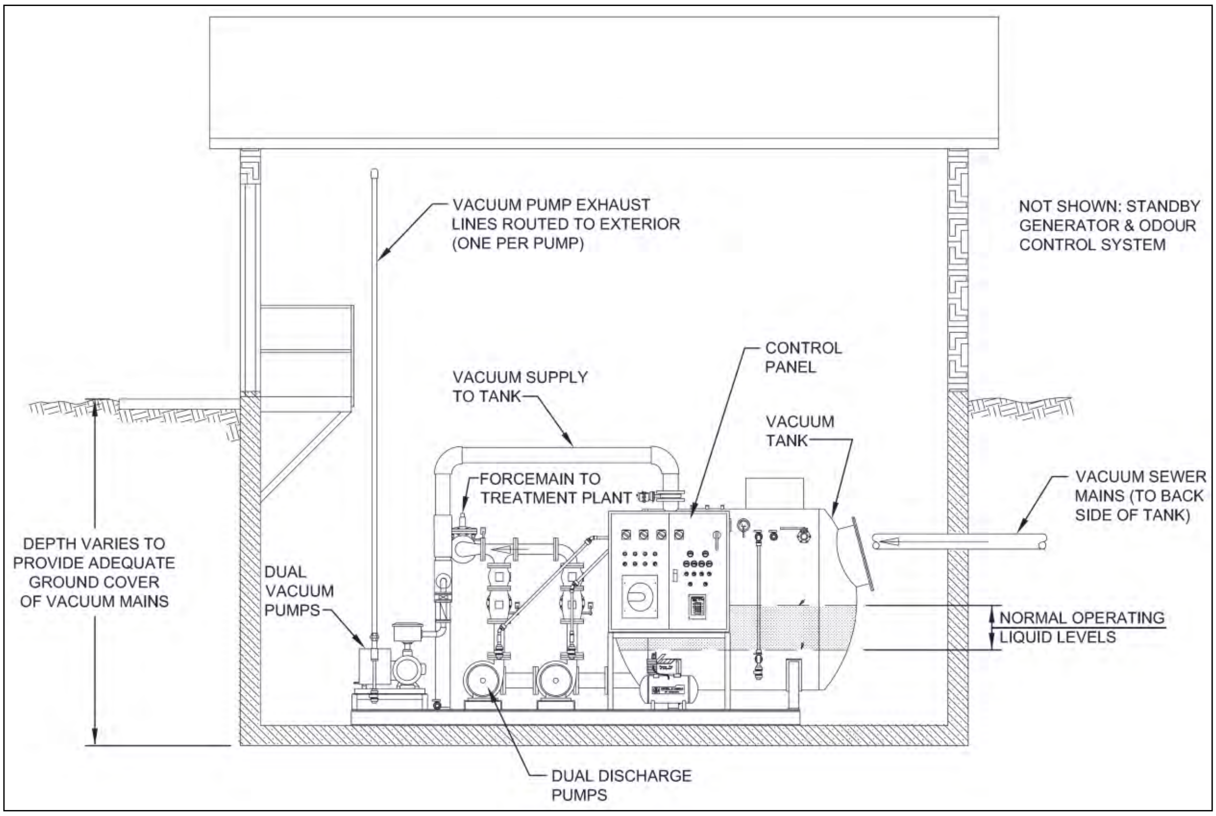

Figure 21: Typical vacuum station (WEF, 2008)

Table 5: Normal vacuum system O&M tasks and frequencies (WEF, 2008)

Frequency	Task
Daily	○ Record all pump run times ○ Check oil level in vacuum pump sight glass ○ Test-cycle the AIRVAC sump valve in station ○ Visually check gauges/charts/recorders
Weekly	○ Change chart on chart recorder ○ Exercise generator ○ Change oil and oil filters on vacuum pumps
Monthly	○ Remove and clean inlet filters on vacuum pumps ○ Test all alarm systems ○ Check all motor couplings and adjust if needed ○ Clean all sight glasses ○ Exercise all shut-off valves (vacuum station) ○ Exercise isolation valves (vacuum mains)
Semi-annually	○ Conduct external leak test on all vacuum valves ○ Check valve timing and adjust if needed
Annually	○ Preventative maintenance for the major equipment at the vacuum station should be done in accordance with manufacturers' recommendations ○ Removal from service and comprehensive inspection of check valves, plug valves, vacuum pumps, sewage pumps, generator, and the telemetry system

Malfunctions at the vacuum station which will require emergency maintenance are generally caused by pump, motor, or electrical control breakdowns. Redundancy of most components allows for the continued operation of the system when this occurs.

8.2 Collection system piping

Normally, the operators will not be required to visit the collection system. Normal conditions at the vacuum station are an indication that the collection system is functioning properly. Any scheduled maintenance on the collection piping should be minimal.

At least once a year, the division valves should be checked. This is done by moving the valve through the entire opening-and-closing cycle at least once. This procedure is known as 'exercising' and will keep valves in good operating condition (Water Environment Federation, 2008).

Assuming proper design and construction, there is very little physically that can go wrong in the piping system. Sometimes, a pipeline break will occur, due to excavation for other utilities or landslides, causing a loss of system vacuum. In the event of this happening, the telemetry alarm will be raised and the maintenance operative will quickly be able to isolate which line has been damaged. By closing and opening division valves in a logical sequence in key areas along the piping route, the operator can easily isolate the defective section.

Other potential problems include system water-logging or a complete loss of vacuum that results in the entire collection system failing. Fortunately, these instances are very rare and usually short-lived.

Blockages in vacuum sewers are an extremely rare occurrence. The sewage is moved through the vacuum sewers at high velocities; up to 6 m/s in the form of a foamed 'plug'. This makes the pipe work self-cleaning, and coupled with the fact that the system's vigorous action breaks up solids, means that blockages almost never occur.

Is the vacuum main prone to damage and if so, what procedures are to be followed to locate the fault?

In the unlikely event of a leak or blockage developing in a vacuum main from a cause other than excavation, then the method of locating the leak is as follows (Iseki-Redivac, 2010):

- *Each main is shut down in turn at the station so that the main on which the fault lies is quickly ascertained*
- *Next, by shutting the isolating valves it can be established on which branch of the main the fault lies*
- *Then, using the valve-monitoring system and a portable monitor, it is possible to determine between which two valves the fault has occurred. In practice, this distance is unlikely to be much more than about 50 m.*

The benefit of using the valve telemetry system in this diagnostic mode is that the number of isolation valves on the system can be kept to a minimum.

- *The precise location of a blockage is discovered by removing the downstream valve and inserting flexible rods to identify the point of blockage. After identifying this point, a repair can be carried out as is done in a conventional sewerage system, but this is simpler on a vacuum system because the depth of the main is minimal and polyethylene pipe is very easily and quickly repaired using electro-fusion couplings.*

- *Because the existence of a fault would be immediately brought to the attention of the maintenance authority via the telemetry, the fault could be quickly repaired and not remain undiscovered, leaking pollution into the surrounding soils as can happen with a conventional system.*

8.3 Valve pit and vacuum valve

Depending on a system's history of emergency valve-breakdown maintenance, some periodic inspection may be required. As with pressure sewer systems, certain on-lot units are prone to more problems than the rest of the system. Access to valves for maintenance reasons is gained by removing the manhole cover on the valve pit, see **Figure 22**. Routine maintenance is easily performed inside the standard valve pit from the ground surface. The only tools required are a manhole cover pick and a sensor pipe puller to drain any groundwater that may have accumulated in the valve pit.

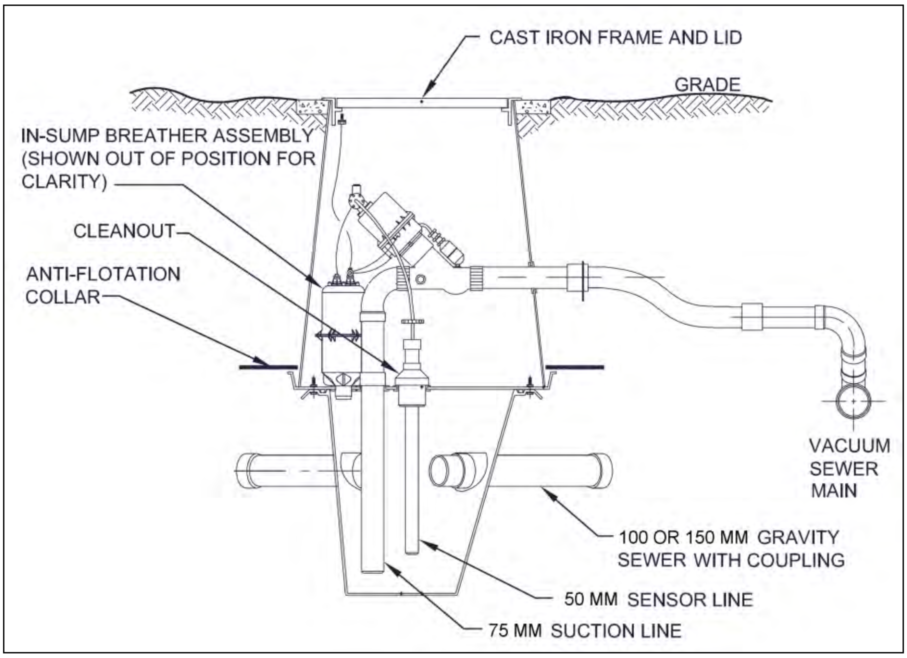

Figure 22: Valve pit and vacuum valve (WEF, 2008)

According to AIRVAC (2005b) all vacuum valves should be inspected at least once a year. The valves should be manually cycled to see that they are operating correctly. A comparison between the controller timing cycle and the original setting it had should be made. If required, the controller timing should be reset and recorded. The operator should check for dirt or water in the controller, valve or tubing.

The above-ground vent screens should also be checked to see if these are clean. AIRVAC also recommends that every 5 years, each controller should be removed and re-built, or valves that cycle more frequently, i.e. more than 500 000 cycles, should be replaced (AIRVAC, 2005b). Rebuilding of the controller would involve replacing the shaft seals, greasing the shaft, and cleaning all the various components. AIRVAC further recommends that every 10 years, each vacuum valve should be removed and replaced, and the old valve can then be refurbished checking for wear (AIRVAC, 2005b).

Emergency maintenance is usually related to malfunctioning vacuum valves. This is caused by either low system vacuum or extraneous water with the valve being generally in the open position when failing. This subsequently results in a loss of system vacuum as the system is then open to the atmosphere. If an interface valve should fail in the open position and thus cause the system vacuum to fall, the individual valve telemetry/monitoring system will register this and maintenance personnel/operator will instantly be able to locate the fault.

Other parts of the system could fail if a valve remains open or continuously cycles resulting in the system vacuum to drop. The consequence could be that the pumps are unable to cope with this vacuum loss resulting in insufficient vacuum to open other valves. Backups will form in the system and when the vacuum is restored this might result in a large amount of sewage, in relation to the amount of air, being introduced into the system which could cause water-logging. If the valve failing occurs with the valve in the closed position this will result in the users experiencing problems with toilet flushing or backup of sewage on the property.

8.4 Record keeping

Efficient operation of the system requires good record keeping. The records provide information that would assist with operating the system and troubleshooting procedures. Records of all normal, preventative and emergency maintenance procedures should be kept. The records should be preserved and made readily available to operating personnel. It would be ideal to store the records electronically and allow access to this prior to O&M personnel responding to a call-out.

According to WEF (2008), typical normal maintenance information that should be recorded on a daily basis includes:

- *Date & weather conditions*
- *Personnel on duty*
- *Routine duties performed*
- *Operating range of vacuum pumps*
- *Run-times of vacuum pumps, sewage discharge pumps & generator*
- *Flow data*

- *Complaints received and the remedies*
- *Facilities' visitors*
- *Accidents or injuries*
- *Unusual conditions*
- *Alterations to the system*

In addition to the records which should be kept on normal maintenance, information pertaining to preventative maintenance should also be recorded. As detailed in **Table 5**, information on the servicing of the major equipment at the vacuum station should be done in accordance with manufacturers' recommendations. Records should be kept of when the check valves, plug valves, vacuum pumps, sewage pumps, generator, and the telemetry system were inspected and serviced.

Efficient scheduling of maintenance tasks can be structured to avoid interference with other important aspects of system operation. Results of periodic inspections should be kept. This would include a list of all potential problems, the likely cause of these problems, the repairs necessary to solve the problem, and recommendations for future improvements to minimize recurrence.

Records should also be kept concerning all emergency maintenance. This includes (WEF, 2008):

- *Date and time of occurrence*
- *Person(s) responding to problem*
- *Description of problem*
- *Remedy of problem including total time to correct problem*
- *Parts and equipment used*
- *Recommendations for future improvements*

8.5 Operation and maintenance manual

To effectively operate a vacuum sewer system requires appropriate training. An operation and maintenance (O&M) manual is an imperative piece of this training process. It must, however, be highlighted that whilst an O&M manual is a valuable tool, it will not necessarily provide the answer to every problem. The efficiency of the system depends on the care and sense of responsibility of the system's operation and maintenance staff. Regular updating of the manual is essential to reflect new operational experience, updated equipment data, and previous problems and implemented solutions.

Typical information that should be contained in the O&M manual includes (WEF, 2008):

- *Design data*
- *Equipment manuals*
- *Shop drawings*
- *Permits & Standards*
- *Operation & Control information*
- *Personnel information*
- *Records*
- *Preventive maintenance schedules*
- *Emergency operating & response program*
- *Safety information*
- *Utility listings*

9. SMALL-BORE SEWERS – OPERATION AND MAINTENANCE

Small-bore systems or small-diameter gravity (SDG) sewers are also called septic tank effluent gravity (STEG) sewers, and these systems convey effluent by gravity from an interceptor tank (or septic tank) to a centralized treatment plant or pump station from where it is conveyed to another collection system. Another variation on this alternative sewer system is the septic tank effluent pumping (STEP) concept. All these systems utilize smaller-diameter pipes placed in shallow trenches following the natural contours of the area, thus reducing the capital cost of the pipe as well as excavation and construction costs.

Most of the suspended material is removed from the wastewater flow by the septic or interceptor tank reducing the risk of clogging to occur. The diameter of the sewer downstream of the tank, the lateral and the sewer main can thus be reduced. Cleanouts are used to provide an access point for flushing and manholes are rarely constructed. Air-release risers are required at summits in the sewer profile. Odour control is important since wastewater from the tank still has the potential to release odours.

Generally the operation and maintenance requirements of a small-bore system are low especially if there are no lifting stations. Most maintenance tasks are relatively simple when compared with those associated with conventional sewers and their associated lift stations.

An operation and maintenance manual is essential and it should assist in the location of components and services and provide typical drawings detailing the design and construction of each component. A manual should contain at least the following (WEF, 2008):

- *Description of the system.* A description of the system and each of its components such as the function, typical performance characteristics, design data, drawings, profiles of the collector mains, etc.
- *System operation description.* A description of the normal and emergency operation situations and procedures.
- *Testing, inspection, and monitoring of the system*. This should include a description of the methods, and schedule of all recommended testing, inspections, and monitoring.
- *Preventative maintenance.* A description of all preventative maintenance procedures is required.
- *Troubleshooting.* A description of typical operating problems, how to identify these and procedures to correct them will be extremely helpful to operation and maintenance personnel.
- *Safety.* The safety practices and precautions should be described to warn personnel of potential hazards and how to avoid them.
- *Recordkeeping*. Pro-forma recordkeeping forms and logs should be provided.
- *Equipment details.* Drawings and installation and maintenance manuals of all major equipment should be included. Supplier's details should be listed with contact names, addresses, and telephone numbers.

9.1 Staff and equipment requirements

Operation and maintenance requirements of small-bore systems are generally relatively simple, requiring a less demanding set of special qualifications for maintenance staff than what is required by conventional facilities. The operator's responsibilities will largely be to answer service calls, carry out routine operational inspections, new service connection inspections, and administrative duties. The maintenance requirements for the interceptor tank pumping are normally performed by an outside contractor.

The maintenance equipment needed is also limited. A vehicle with mounted centrifugal suction pump can be used to provide most of the emergency operation equipment needs. Some hand tools and a communication system are also standard equipment.

For small-bore systems where pumping is required replacement pumps, electric panel components, liquid-level sensors, a multimeter, and an amp probe are required.

9.2 Operator training

Training for STEG maintenance personnel is less difficult due to the simplicity of the components, but it is advantageous that the personnel are familiarized with the components and procedures to be used. General plumbing skills are useful and in the case of STEP systems, an understanding of pumps and electrical controls should be acquired through appropriate training.

It is extremely important that the personnel are aware of the dangers of exposure to sewer gases and avoid entry into confined spaces, unless properly protected. Good communication skills would also be helpful since a major portion of the system is located on the property of the residents.

9.3 Maintenance

The most important activity of small-bore sewer O&M programmes is to control infiltration and inflow. The maintenance requirements for STEP systems are usually related to electrical problems. **Table 6** lists typical operation and maintenance activities and frequencies of small-bore systems.

The maintenance required is usually limited to call-outs by users to report problems. The call-outs are normally a result of sewer line backups or odour problems. In nearly every case reported, the sewer backups occurred because of obstructions in the building sewer.

Odour complaints are very common. The cause is usually the defective venting in the building's plumbing. If the venting cannot solve the odour problems, the interceptor inlet vent can be sealed or running traps positioned in the service lateral to prevent the sewer main from venting through the service connection. Alternatively carbon filters can be affixed to vent outlets, although this is usually only a temporary measure. Preventative maintenance would include inspection and pumping of the interceptor tanks and inspection and servicing of any STEP units.

Table 6: Typical operation and maintenance duties and frequencies (EPRI, 2004)

Task	Description	Frequency performed
Survey system condition	Perform 'windshield' survey of system, looking for alarm lights, ponding wastewater, damaged tank riser covers, and signs of infiltration or inflow.	Continuously, while performing other tasks.
Monitor flows	Record STEG and STEP flows, as measured near system terminus; STEP pump event counters; and elapsed time meters, to identify any infiltration and inflow.	STEG lift stations (if exist): daily or weekly (minimum); STEP pump monitors: quarterly; Terminus flow: daily.
Monitor STEP mainline pressures	Measure and record operating pressures at designed cleanouts.	Semi-annually.

Table 6: Typical operation and maintenance duties and frequencies (EPRI, 2004) (continued)

Task	Description	Frequency performed
Oversee septage removal and treatment	Schedule septage removal by qualified waste transporter.	Residential: typically every 3 to 5 years (or as needed from regular inspections); Commercial: annually or as needed.
Clean interceptor tank outlet screens	Remove, flush with water, and replace.	Residential: annually; Commercial: quarterly or as needed.
Oversee installation of new services	Observe construction, document water-tightness testing, and prepare record drawings.	At time of installation.
Service mechanical equipment	Perform routine maintenance, as recommended by manufacturer.	As recommended by manufacturers (or annually).
Respond to service calls	Troubleshoot problem and respond appropriately.	As soon as is practical.
Implement emergency response procedures	Troubleshoot problem and respond appropriately.	Immediately.

9.3.1 Interceptor tanks

The interceptor tanks must be pumped periodically, to prevent solid matter from flowing into the collector mains. The prescribed emptying frequencies are typically 3 years to 5 years, but some operating experience indicates that a longer time between emptying (7 years to 10 years) could be sufficient. Other higher-use users such as restaurants could require more frequent emptying. Since grease removal would typically be done every 6 months to 12 months inspecting the interceptor tank during these visits would be convenient and practical.

The interceptor tank is normally inspected immediately after the tank has been emptied, to check for cracks, leaks, baffle integrity, and general condition of the tank. In some tanks additional screens are placed at the outlet of the tank and these must be inspected and cleaned during each visit by operation and maintenance personnel. Regular, at least once a year, inspection of these screens is recommended.

The septage/sludge which is removed would typically be discharged at a treatment plant and it must be ensured that this facility can handle the high concentration loads.

9.3.2 Collector mains

Inspection of the collector main pipes is only required if some or other event or accident causes it, and there are usually no preventative maintenance functions. Periodic flushing of low-velocity sections of the collector mains may be required. Hydraulic flushing is most often recommended for cleaning these mains, but no instances of these events have been documented in the United States experience for properly designed and installed systems (WEF, 2008).

The experience with STEG is that no noticeable solids accumulations have been noted in the collector mains (WEF, 2008). The recorded collector line obstructions were usually due to debris left in the system during construction.

The cleaning and testing of air vents and air-release valves should be done regularly.

9.3.3 Lift station units (STEP systems)

Individual STEP units are essentially simplified small lift stations. They are normally combination interceptor/ pressurization tank units constructed of polyethylene or fibreglass with a submersible pump controlled by mercury float switches, see **Figure 23**. Successful operation may be improved by using effluent screening before pumping.

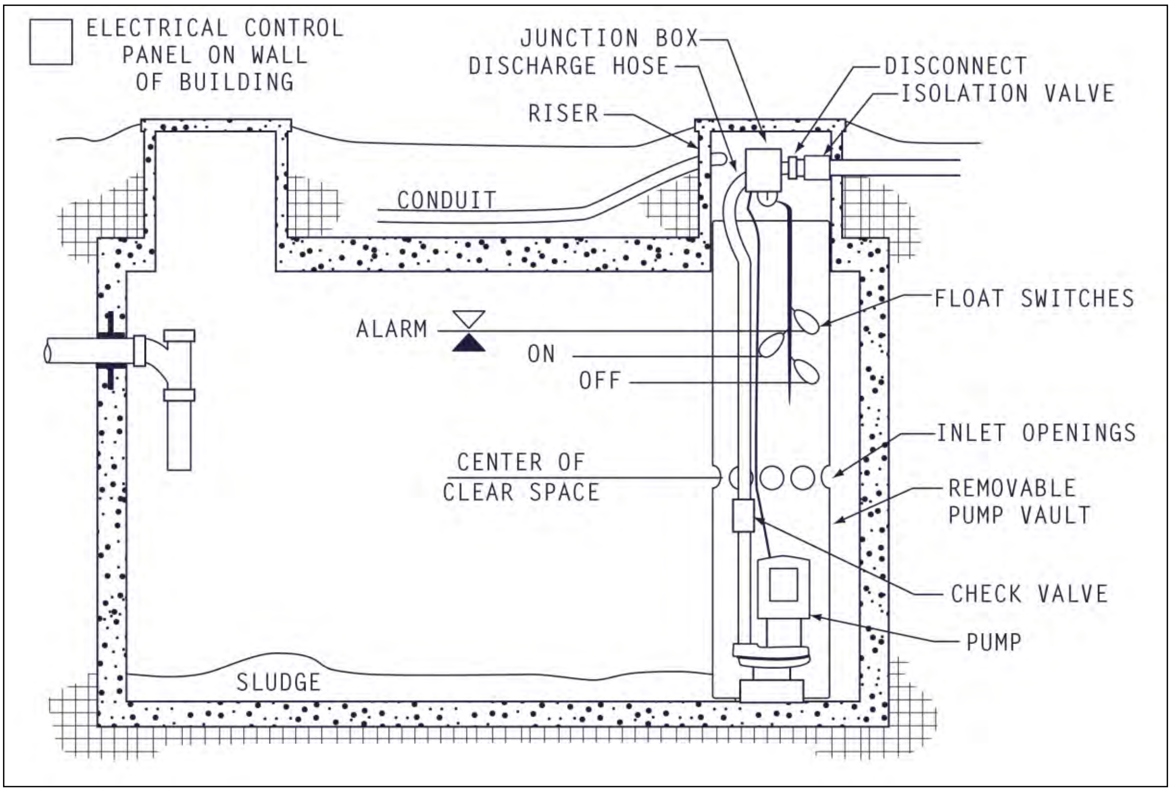

Figure 23: Typical interceptor-pressurization tank (WEF, 2008)

Routine inspection of the pressurization unit should include the following:

- Removing the pump from the tank, checking the pump intake for blockage, checking the body for corrosion and cleaning the entire pump
- Checking all valves for proper operation
- Cleaning the inlet openings
- Returning the pump to the tank and testing it
- Testing the alarm system

9.4 Recordkeeping

It is crucial to have a good set of records of all operation and maintenance performed (preventative maintenance and troubleshooting). Flows at the ends of mainlines should be measured and logged daily. These data will provide real-time indications when infiltration or inflow problems are evaluated. Records should also be kept of tank inspection and emptying actions performed by staff or contractors.

9.5 Troubleshooting

The problems most frequently experienced with small-bore systems are summarized in **Table 7**.

Table 7: Small-bore system problems

Problem	Description	Solution
Odours	Odours typically occur from erroneous house plumbing stack vents, particularly in homes located at higher elevations or the end of lines. Odours are most prominent where turbulence occurs since this causes the release of noxious gases dissolved in the wastewater. Odours at individual connections often begin in the collection main. When a sanitary tee or baffle is used at the interceptor tank inlet and outlet, a straight path for sewer gases to the house plumbing stack vent is provided.	Repair the vents. In the interceptor tank the top of the inlet tee can be sealed or capped to prevent the gases escaping into the building sewer and stack. P-traps or running traps on the service lateral can be used in the service lateral, to prevent gases from reaching the tank. If the problem is occurring at the most upstream service, extension of the main terminus to a location further upslope with venting to a subsurface soil filter can be considered.

Table 7: Small-bore system problems (continued)

Problem	Description	Solution
Corrosion	This is a problem that is normally most evident at the discharge end of the system (treatment plant or conventional sewer manhole).	Concrete manholes must be coated with corrosion-resistant materials. If the effluent sewer discharges directly to a treatment facility or manhole, the transition must be made with a minimum of turbulence (i.e. ensure it is submerged).
Infiltration and inflow	Clear water infiltration and inflow was a common problem with earlier STEG systems that used a high percentage of existing septic tanks for interceptor tanks. Leaking tanks and building sewers with illegal connections are the primary entry points of clear water. The control of infiltration and inflow has the biggest effect on the performance of STEP and STEG sewers. Backups occur when the collection system capacity is insufficient to handle the domestic flow and infiltration and inflows. High infiltration and inflow and/or too small pipe sizes can result in numerous pumps running simultaneously in STEP systems and some pumps then being unable to meet pumping head requirements resulting in subsequent failures.	Where new systems have been installed and the interceptor tanks have been pressure-tested, few infiltration and inflow problems occur. Replacement of the existing effluent sewer mains with larger pipe sizes to prevent backup from occurring is not usually done. The only practical solution is to control infiltration and inflow. Good recordkeeping and monitoring should be done to enable comparison and analysis of flows and thus enable the detection of increases in infiltration and inflow in the effluent sewer.

9.6 O&M costing

O&M basically covers the annual cost of operating and maintaining a selected design technology; this includes maintenance of equipment as well as labour. Additional O&M costs other than pump power consumption and tank pumping include scheduled and unscheduled call-outs, mainline cleaning, and valve maintenance.

There is a significant difference in the expense models between small-bore systems and conventional gravity systems. O&M expenses for gravity sewers are generally anticipated to be relatively low per customer served. The costs for conventional gravity sewers are more associated with the length of pipe in service than the number of customers served. Accordingly, O&M costs are highly variable with respect to erf density. Initial O&M costs could be very high, relative to the actual number of customers served.

By comparison, small-bore sewer systems' O&M costs are generally linked to on-site O&M costs. O&M costs for the collection main are very low.

Since on-site components of the system are not installed until a customer is being served, O&M expenses tend to be more aligned with the number of paying users. The cost of O&M should be presented as an optimized balance of preventative and reactive maintenance and this is especially true on STEP systems.

Gravity sewer systems are often operated for long periods of time with little or no preventative maintenance. While the system is in good condition, the O&M costs will appear artificially low. Low initial operating costs will ultimately result in higher long-term operating costs as elements such as inflow and infiltration and sewer overflows become more common.

10. SIMPLIFIED SEWERAGE – OPERATION AND MAINTENANCE

For successful operation of a simplified sewerage scheme, there must be an effective partnership between the community served and the sewerage authority (Watson, 1995). It is extremely important that each party clearly understand their duties and responsibilities. This means that at an early stage in a simplified sewerage project's planning stage, public community meetings should be held to explain to the community how the system would work, and how responsibilities for operation and maintenance are to be allocated between the community and the local authority. This basically means that the community would be responsible for operation and maintenance of the in-block sewer, and the local authority would be responsible for the collector sewers and wastewater treatment.

As described by Mara et al. (2000), the community usually allocates each block resident the responsibility for sewer O&M for the length of sewer passing through his or her land, and this includes the O&M of any junction boxes, and the clearance of any blockages. According to Watson (1995) this is not successful and the appointment of a small local contractor who is contacted directly by the residents when maintenance is required is more effective. The willingness of the community to be involved in the management and maintenance of the local sewerage facility should not be assumed! Community management has obvious advantages, in terms both of the users taking 'ownership' of the sewerage system and making use of the limited resources, and it should always be considered as early on in the project cycle as possible.

10.1 Staff and equipment requirements

The local sewerage facility connects to a higher order facility which is usually operated by the local authority. Staffing and equipment requirements would thus be similar for the higher order system whether this is a conventional gravity sewer or something else.

Operation and maintenance requirements of the local sewerage facility are relatively simple, requiring no specialized qualifications or training. The maintenance requirements for the system could be performed by the users/owners themselves or as indicated above a small local contractor could be utilized.

The maintenance equipment needed is also limited. Some hand tools and rodding equipment are all that is needed. The disposal of the trash/grease causing the blockage may require hauling it to a WWTW.

10.2 Operator training

Training of maintenance personnel is less difficult due to the simplicity of the system. General plumbing skills are useful. Education of the users and operators to make them aware of the dangers of exposure to sewer gases and avoiding entry into confined spaces, unless properly protected, is important.

10.3 Maintenance

In the simplified design, a 600 mm square or circular connection (or inspection) box is placed between the residential building and the service line. All sewers or drains from the house or building convey the wastewater to this connection box or just a cleanout point. These connection boxes should be cleaned when required, i.e. when there is a blockage.

In some areas where the risk of obstruction is believed to be high baffled boxes have been added downstream of each building sewer, in addition to the connection or inspection box. Their function is to prevent trash and other large settleable solids from entering the sewer. Their maintenance is usually the responsibility of the homeowner.

The sewer pipes are laid in shallow trenches and thus if there is a failure such as a collapsed pipe then repairing this could be done by the residents themselves. A spare length of sewer pipe with couplings could be useful to keep in supply.

Rodding of the sewers should be sufficient to remove blockages in the local sewerage network. Jetting could also be employed although access might be problematic.

11. CONDITION ASSESSMENT AND MONITORING OF SEWERS

Condition assessment is a critical component of an effective programme to resolve sewer overflows. Decisions regarding the maintenance, operation, and rehabilitation of the sewage collection system to eliminate sewer overflows can be based on the results of a condition assessment of the system. Condition assessment may address the structural and/or infiltration/inflow conditions.

The condition assessment is typically based on inspections by closed circuit television (CCTV), Sewer Scanning Evaluation Technology (SSET), manhole inspections, smoke testing, dyed water flooding or other evaluation means as appropriate. For structural assessment, particular attention is paid to defects such as pipe breaks, cracks, displaced joints, missing pipe pieces, sags, corrosion activity and manhole structural defects. Inflow and infiltration condition assessment is performed by utilizing a combination of methods such as manhole inspection, CCTV inspection of sewer lines, and flow monitoring.

The identification of the most likely location of sewer overflows and evaluation of the causes of sewer overflows should be a part of a comprehensive preventative maintenance programme and capital expenditure plan.

There are several techniques for identifying the locations where sewer overflows may occur; these include:

- Performing sewer inspections by CCTV monitoring
- Analysing sewage indicators in nearby streams and storm drains
- Monitoring of flow as well as hydraulic modelling of the system
- Standard system inspections which includes manholes, pumping stations and smoke or dye testing
- Reviewing the customer complaints and/or the maintenance records
- Assessing the structural integrity of the sewer system

Sewer-evaluation activities include those activities that are used to quantify flows, assess the structural and the inflow and infiltration condition of the system pipes, manholes, and other structures and facilities (see **Table 8**).

Table 8: Sewer-evaluation activities (adapted from ASCE, 2004)

Activity	Description
Flow & rainfall monitoring	 Flow monitoring is used to quantify wastewater and infiltration and inflow in the sewage collection system. This information could be used for the hydraulic evaluation of the sewer system, calibration of hydraulic models, assessment of infiltration and inflow, and assessment of effectiveness of rehabilitation measures. Flow monitors are typically installed at strategic locations in the sewer system and measurements take place at regular intervals (±15 min). Various flow meters which could be used include, flumes, weirs, velocity-measuring devices (Doppler and ultrasonic) and depth-measuring devices (ultrasonic, bubbler and transducers). In areas where wet-weather flows are of concern rain gauges should also be installed and monitored.

Table 8: Sewer-evaluation activities – continued (adapted from ASCE, 2004)

Activity	Description
Flow isolation	 Flow isolation and measurements are used to quantify localized infiltration levels into the sewer system. This typically involves isolating one or more sewer section and measuring the flow manually during the early morning hours of low domestic activity, such as from 24:00 to 04:00. It is recommended that this is performed during high groundwater conditions. During the flow isolation, the upstream sewer line is blocked/plugged and flow is measured with one of the flow-metering methods described above in a manhole downstream of the blocked sewer section.
Direct visual inspection	 Visual inspection involves a sewer inspection team walking through large-diameter pipelines and tunnels (900 mm diameter and larger) to check for cracks, pipe or joint separations, corrosion, root intrusion, obstruction, and other pipeline defects not normally visible from on-surface inspection. Photographs should be taken of any observed defects to assess the extent of corrosion activity, and field measurements of, for example, pH, dissolved oxygen, ambient hydrogen, etc., should be taken. Due to the hazardous conditions in the sewer line and confined space extreme care should be taken to provide adequate safety measures as discussed in **Paragraph 12**. Inspectors can use manually operated cameras for detailed pictures or illustrations for reports, instructions, or maintenance work. The inspection should be carried out by at least two persons and they should have constant communication with personnel outside the sewer line.
Smoke testing	 The purpose of smoke testing is to locate rainfall-dependent inflow and infiltration sources, which could lead to a sewer overflow during a storm event. Specific sources detected include roof, erf and area drain connections, catch basins, area drains, and broken main and service lines. The procedure consists of blowing a non-toxic, non-staining low-pressure smoke in large volumes through the sewer lines. The smoke follows the path of the intruding water in a reverse to the surface pattern, which indicates the defect in manholes, sewer lines and sewer laterals or the source of the problem. It is very important to notify the public if smoke testing is going to be conducted since there is the potential that smoke may appear in and around buildings.

Table 8: Sewer-evaluation activities – continued (adapted from ASCE, 2004)

Activity	Description
Dyed water testing	 Dyed water testing includes dye tracing or flooding which is done to determine potential sources of inflow such as drains suspected of being linked to the sewer line or sources of rainfall-induced inflow/infiltration (I/I) which indirectly add to the flow in the sewer. A manhole downstream of the test area is monitored to see if the dyed water, which contains the non-toxic indicator, injected in an outside source such as a downpipe, has found its way into the sewer system. Verification for major sources (such as stormwater catch basins) is achieved by evaluating the flows at the downstream manhole before and during testing. The test methods typically include: - Pouring the dyed water into the suspect inflow source - Flooding the storm sewer catch basins or channel with dyed water - Injecting the areas around suspected underground sources with dyed water A sufficiently detailed schematic drawing is required to ensure that the path of the observed dye can be traced. Typical applications of the dye testing include the following: - Buildings that may not show smoke at vents during the smoke test due to dips or traps in the service connection pipes - Where an erf drain or storm drain is suspected of being tied to the building sewer or a lateral sewer - Any suspected surface inflow to the wastewater collection system - Testing for infiltration and exfiltration - Flow-velocity measurements
Closed Circuit Television Inspection (CCTV)	 Since most of the collection system is non-man entry due to small-diameter sewers, it can only be inspected by CCTV. CCTV is regularly performed on selected defective sewer lines identified through other less costly preliminary inspection techniques. CCTV inspection is performed by pulling the camera through the sewer line or alternatively the camera may be installed on tractor transporters which travel through the sewer line by motorized tracks or tyres. Most CCTV equipment available on the market has controllable colour cameras with tilting, zooming and panning capabilities. The observations are usually summarized in field logs which are prepared and narrated by an operator. Still photographs of specific defects and interesting other features are also taken. The recorded images and field logs provide a visual and audio-record of problem areas along the sewer line. The CCTV records will help identify structural problems, locate leaking joints and non-structural cracks, blockages, and identify areas of root intrusion. The analysis and interpretation of the CCTV data is as important as its collection. A standard method of interpretation should be applied for characterizing the identified defects.

Table 8: Sewer-evaluation activities – continued (adapted from ASCE, 2004)

Activity	Description
Sewer scanner and evaluation technology surveys	 SSET is an inspection pipeline technology which is an effective tool in performing condition assessment of sewer systems. An important feature of this technology is the possibility of measuring the rate of deterioration of the sewer system. This can be achieved by comparing the SSET images taken at certain times and comparing them with images taken at a later date. The SSET system consists of a scanner, a CCTV, and three-axis mechanical gyroscopes. The gyroscope is used to measure inclination and meander. The images of SSET are of higher quality than CCTV images. The high-angle 'fish eye' lens provides a simultaneous 360° side scan and forward-looking images. The interpretation of the recorded data is performed in the office by an engineer and not in the field by the technician. The scanned image is digitized and a colour-coded computer image is produced. SSET is applicable in pipes ranging from 200 mm to 600 mm in diameter and is appropriate for all pipe types except dark-coloured HDPE and iron pipes.
Sonar and laser technology	 As advances in electronics continue to improve, so will the techniques used to collect information on the condition of sanitary sewers. Two of the lesser-known technologies include sonar and laser scanning. Sonar is used to identify problems below the flow line of a sewer and lasers are used to evaluate sewers above the flow line. Sonar units emit a sound wave that travels until it hits a solid object (pipe wall or debris line) and returns back to the unit. The sound wave outlines the shape of whatever it bounces off. The information can be used to identify things such as the level of debris in a siphon or if the invert of a pipe is losing structural integrity, as well as providing information on silt level, grease accumulation, pipe deformation, offsets, and blockages. Laser scanning is a relatively new technique used to evaluate sewers and works by emitting up to a million points at a time. These laser points enable the pipe and any other attribute within the pipe to be outlined and a 3-D model to be constructed. The advantage of this technology is that accurate measurements are generated without the presence of light finding the smallest defects in the interior surface of the pipe. While this technology is useful for all pipe sizes, it is probably the most beneficial for the evaluation of large-diameter sewers. Reports can then be generated using integrated software that displays the following: millimetres of debris build-up; increased areas of internal/external pressure; misalignment of joints; ovality; capacity; and inclination. However, laser profiling can only be used in pipes above the flow line.

Table 8: Sewer-evaluation activities – continued (adapted from ASCE, 2004)

Activity	Description
Line lamping (Visual inspection)	 Lamping consists of visually inspecting the interior of the sewer lines connected to the manhole by using a remote halogen or flash light and mirror (mirror telescope rod) while standing above or in the manhole. Line lamping is used to obtain information on the physical condition of the pipe and to determine whether a section of pipe is straight and clean. Line lamping is also used to determine the size and flow characteristics through the manhole. The data generated from lamping are also used to identify sewer-pipe defects and provide a basis for selecting sewers for television inspection. Information generated by line lamping includes observations of the pipe, flow, depth, and deposition or debris present. Alternatively a pole-mounted digital camera could be used which is then lowered into the manhole and a digital picture is taken of the sewer line.
Manhole inspection	 Manhole inspections are performed to confirm the physical layout and mapping of the sewer system, to determine the physical condition of the sanitary sewer manholes, and to locate sources of inflow and infiltration. During inspection, evidence of surcharging may be observed in the form of high-water marks on the walls of manholes. The manhole inspections identify defects that can be used to estimate the inflow and infiltration flows attributable to each manhole (inspection form included in **Appendix A**).
Pump station inspection	 The failure of a pump station can lead to significant sewer overflow problems. The pump station should therefore be inspected frequently to ensure that it is operating as intended. The frequency of the inspection may vary from once a day to once a month and depends on factors such as size of the station, criticality of the station, and reliance on real-time monitoring of the station. Inspection trips can be performed in conjunction with routine maintenance activities such as lubricating equipment. A typical inspection form is included in **Appendix A**.

Table 8: Sewer-evaluation activities – continued (adapted from ASCE, 2004)

Activity	Description
Internal corrosion monitoring	 The environment of a sewer line is conducive to the generation of hydrogen sulphide, which can cause various problems such as unwanted odours, potentially lethal toxic conditions, and corrosion of unprotected sewer pipes. The inside pipe wall above the wastewater flow line will be the principal area of corrosion. At points of high turbulence, such as drops, manholes, junctions and other structures, hydrogen sulphide is released very rapidly and can result in severe corrosion, leading to loss of structural integrity and subsequent collapse of the sewer line. Typical locations to monitor for the existence of corrosion involve areas where wastewater has had the opportunity to go septic (in interceptors or where there are lengthy travel times). Internal corrosion monitoring involves field measurement of parameters such as ambient and dissolved oxygen, ambient and dissolved hydrogen sulphide, pH, and temperature from which the potential corrosivity of the wastewater flow can then be determined. Direct measurements of wall thickness change and CCTV images also provide supplementary information.
External corrosion monitoring	 The long-term performance and expected life of the sewer line is dependent on the environment in which it is installed. Factors such as the pipeline material, soil type, moisture and free oxygen levels will influence external corrosion. PVC and VC pipes are usually unaffected by the environment and do not corrode. However, cast-iron pipe, ductile iron pipe, and steel rebars in the reinforced concrete pipe can corrode. In most cases fine-grained soils (silts and clays), are more corrosive than coarse-grained soils (sand and gravel). A number of methods are available for external corrosion monitoring (ASCE, 2004): - *Measurement of the acidity of the environment;* - *Measurement of the electrical resistivity of the pipeline;* - *Measurement of stray currents;* - *Measurements of potentials between pipeline and environment (potential survey);* - *Measurement of the effective electrical resistance of coating; and* - *Determination of conditions suitable for anaerobic bacteria.*

Table 8: Sewer-evaluation activities – continued (adapted from ASCE, 2004)

Activity	Description
Rising main inspection	 Visual inspection conducted along the profile of the rising main is a common method to detect obvious problems. These problems include construction-related damages, faulty air valves and exposed rising mains at stream crossings. Regular monitoring of pressure and flow at pump stations can also provide information of potential problems in rising mains. Cast-iron, ductile iron and steel rising mains are susceptible to corrosion. The failure of a rising main can lead to the discharge of a large quantity of wastewater/raw sewage into the environment and thus it is important that a condition assessment is conducted in order to take proactive steps to prevent failure. Useful information can also be gathered from rising main failures which should be investigated fully to minimize the potential for recurrence of failures.

12. SAFETY MEASURES AND PRACTICES

The physical, chemical, and biological hazards are a constant threat and occur with regularity. It is only through the adoption of an effective safety programme and training that these may be minimized. The reasons for development of a safety programme should be obvious for any collection system owner or operator. The purpose of the programme is to define the principles under which the work is to be accomplished, to make the employees aware of safe working procedures, and to establish and enforce specific regulations and procedures.

The purpose of safety training is to stress the importance of safety to employees. Safety training can be accomplished through the use of manuals, meetings, posters, and a safety suggestion programme. One of the most common reasons for injury and fatalities in wastewater collection systems is the failure of victims to recognize hazards. Safety training cuts across all job descriptions and should emphasize the need to recognize and address hazardous situations. Safety programmes should be in place for the following areas (USEPA, 2005):

- *Confined spaces;*
- *Chemical handling;*
- *Trenching and excavations;*
- *Biological hazards in wastewater;*
- *Traffic control and work site safety;*
- *Electrical and mechanical safety; and*
- *Pneumatic or hydraulic systems safety.*

The collection system owner or operator should have written procedures which address all of the above issues and are made available to employees. In addition to training, safety programmes should incorporate procedures to enforce the programme.

The local authority should recognize its responsibility to provide a safe and healthful working environment for all its employees. To achieve this objective, the following procedures should be established:

- Eliminate unsafe acts of individuals or unsafe structures, installations, shops, facilities, and working conditions

- Organize and supervise a programme of safety information and training concerning:
    - The correct use of tools and equipment
    - Safe work methods
    - Safety precautions
    - Application of safety rules for accident prevention
    - Safety orientation of new employees

- Maintain records of accidents and safety performance. Investigate and analyse all accidents, prepare reports for management and submit recommendations for preventative measures.

12.1 Risks

The design engineer should be aware of the various types of hazards encountered by the wastewater collection system operation and maintenance personnel. The workers are exposed to them, whether they are working in manholes, pump stations, or large-diameter sewers. They include the following:

- Physical injuries

- Bodily infection

- Dangers from noxious gases or vapours, explosive gases, or oxygen deficiency

- Chlorine gas from defective equipment

- Commercial and industrial chemicals

- Medical hazards

- Electrical hazards

12.2 Incorporating safety measures in the design

The role of the design engineer in providing a safe working environment for the sewage collection system cannot be over-emphasized. Many of the potential hazards can be minimized, if not totally eliminated, right at the design stage by incorporating appropriate safety features in the design of the sewer system.

Some of the safety measures that should be considered by a design engineer are (Bureau of Engineering, 2007):

- *Provide adequate ventilation for sewer collection system facilities against hazardous gases. Such facilities include the following:*
    - *All large trunk sewers;*
    - *Sewers located in the vicinity of gas mains and gasoline storage tanks;*
    - *Sewers on flat grades where solids may settle and decompose;*
    - *Sewers where pressure manholes covers are used and the houses connected thereto have sewer traps preventing ventilation through house stacks;*
    - *All manholes more than 1,5 m deep, or excavations where the sewer is more than 1,5 m deep;*
    - *Deep tanks and pump station wet wells; and*
    - *Sewers located in heavily industrialized areas, regardless of depth.*
- *Require contractors to provide safety barricades and other traffic safety control during construction.*
- *Specify shoring requirements for deep excavations and/or unstable soil condition.*
- *Specify a portable ladder for use in entering manholes where permanent steps are not provided.*
- *Provide guard railing around all open basins, and for stairs at other openings into which a worker could fall.*
- *Provide adequate lighting at points where maintenance or repair work is required, or at any point where good visibility is necessary.*
- *Provide safety guards for all moving parts, particularly for drive couplings and universal joints.*

12.3 Safety and rescue equipment

The owner or operator should maintain all of the safety equipment necessary for system staff to perform their daily activities and also undertake any emergency repairs. This equipment should include, at minimum:

- Atmospheric gas testing equipment
- Respirators and/or self-contained breathing apparatus

- Full-body harness
- Tripods or non-entry rescue equipment
- Hard hats
- Safety glasses
- Rubber boots
- Rubber and/or disposable gloves
- Antibacterial soap
- First-aid kit
- Protective clothing
- Confined space ventilation equipment
- Traffic and/or public access control equipment
- Hazardous gas meter

Each maintenance team vehicle should have adequate health and safety supplies.

12.4 Safety programme

The development of a safety programme is a necessity for any local authority that is responsible for collecting sewage. The purpose of a safety programme is to define the principles under which the work is to be accomplished, to make workers aware of safe working procedures, and to establish and enforce specific regulations and procedures. Safety training cuts across all job descriptions and should emphasize the need to recognize and address hazardous situations as listed in **Paragraph 13.1**.

The safety programme should explicitly state the organization's safety policy. According to the New England Interstate Water Pollution Control Commission (NEIWPCC, 2003) the safety policy should:

- *Define the goals and objectives of the program.*
- *Identify the person's responsibilities for each element of the program.*
- *Affirm management's intent to enforce safety regulations.*
- *Describe the disciplinary actions that will be taken to enforce safe work practices.*

The manager/superintendent is the key to any safety program. Implementation and enforcement of the program is the responsibility of the manager. The manager/superintendent should:

- *Ensure that all employees are trained and periodically retrained in proper safe work practices and safety equipment.*
- *Ensure that proper safety practices are implemented and continued as long as the policy is in effect.*
- *Provide adequate safety equipment.*
- *Investigate all accidents and injuries to determine their cause.*
- *Institute corrective measures where unsafe conditions or work methods exist.*
- *Ensure that equipment, tools, and the work area are maintained to comply with established safety standards.*

The sewage collection system operators are the direct benefactors of a safety program. The operators share the responsibility to:

- *Observe prescribed work procedures with respect to personal safety and that of their co-workers.*
- *Report any detected hazard to a manager immediately.*
- *Report all accidents, even those that cause minor injuries.*
- *Report near-miss accidents so that hazards can be removed or procedures changed to avoid problems in the future.*
- *Correctly use all protective devices and safety equipment supplied to reduce the possibility of injury.*

Included in **Appendix C** are examples of safe work procedures which can be adapted to fit specific needs.

13. PREVENTATIVE SEWER MAINTENANCE

Maintenance classified as preventative is proactive and is defined by a programmed, systematic approach to maintenance activities. System performance will always be improved if this type of maintenance is performed unless the maintenance is required as a result of bad design and/or construction. Proactive maintenance is performed on a periodic (preventative) basis or an as-needed (predictive) basis.

Preventative maintenance can be scheduled on the basis of specific criteria such as known problem areas (old neighbourhood with large trees causing regular clogging or area with high sediment load), equipment operating time since the last maintenance was performed, or on a calendar basis.

The major elements of a good preventative and predictive maintenance programme include the following:

- Planning and scheduling (establishment of schedules and procedures for routine inspections)
- System mapping/GIS
- Computerized maintenance programme
- Records management (use of an organized record-keeping system to schedule tests and document inspections)
- Asset inventory and management
- Spare parts management (especially spare parts for equipment that needs frequent repairs)
- Identification of equipment or systems that may malfunction and cause blockages or leaks, or may otherwise result in overflows
- Periodic testing of plant equipment for structural soundness
- Prompt repair or replacement of defective equipment found during inspection and testing
- Cost and budget control
- Emergency repair procedures
- Training programme

Some benefits of taking a preventative maintenance approach are:

- Maintenance can be planned and scheduled
- Work backlog can be identified
- Adequate resources necessary to support the maintenance programme can be budgeted for
- Capital improvement programme (CIP) items can be identified and budgeted for
- Human and material resources can be used effectively

The goal of managing maintenance is to minimize investment in labour, materials, money, and equipment. In other words, human and material resources are to be managed as effectively as possible, while delivering a high level of service to customers.

The benefits of an effective operation and maintenance programme are as follows:

- Ensuring the availability of facilities and equipment as intended
- Maintaining the reliability of the equipment and facilities as designed. Utility systems are required to operate 24 h/d, 7 d/week and 365 d/yr.
- Maintaining the value of the investment. Collection systems represent major capital investments for communities and are major capital assets of the community. If maintenance of the system is not managed, equipment and facilities will deteriorate through normal usage and age. Maintaining the value of the capital asset is one of the major responsibilities of the utility manager. Accomplishing this goal requires on-going investment to maintain existing facilities and equipment and to extend the life of the system, and establishing a comprehensive O&M programme.
- Obtaining full use of the system throughout its useful life
- Collecting accurate information and data on which to base the operation and maintenance of the system and justify requests for the financial resources necessary to support it
- Costs: Planned maintenance and repairs are much more cost-effective both in the long and short term because the work can be done with the proper materials during normal working hours and under preferred working conditions.

The primary limitations of implementing a preventative maintenance programme include:

- Cost
- Availability of trained preventative maintenance staff technicians
- Management direction and staff motivation in expanding the preventative maintenance programme

Preventative maintenance procedures and activities are applicable to almost all components of the sewer system. This concept should be part of a general good housekeeping programme designed to maintain a clean and orderly work environment. Often the most effective first step towards preventing sewer-system problems is to improve the system's preventative maintenance and general good housekeeping methods.

13.1 Proactive maintenance

A good preventative maintenance programme is one of the best ways to keep a system in good working order and prevent service interruptions and system failures which can result in overflows and/or backups. Furthermore it protects the asset, i.e. the capital investment made (NEIWPCC, 2003).

According to NEIWPCC (2003) preventative maintenance activities should ensure that the local authority:

- *Routinely inspects the collection system, including pump stations, and addresses defects or other problems.*
- *Investigates complaints and promptly corrects faulty conditions.*
- *Provides maintenance records, an adequate workforce and appropriate equipment in working order.*
- *Maintains and updates a schedule of planned activities.*

Preventative maintenance activities typically address (NEIWPCC, 2003):

- *Planned, systematic, and scheduled inspections to determine current conditions and plan for maintenance and repairs.*
- *Planned, systematic, and scheduled cleaning and repairs of the system based on past history.*
- *Proper sealing and/or maintenance of manholes.*
- *Regular repair of deteriorating sewer lines.*
- *Remediation of poor construction.*
- *Inspection and maintenance of pump stations and other appurtenances.*
- *A program to ensure that new sewers and connections are properly designed, inspected and constructed and new connections of inflow sources are prohibited.*
- *A program to oversee lateral and private collection system installations that tie in to public wastewater collection systems.*
- *A program to eliminate existing illegal inflow sources and a strategy for informing and educating the public about such sources.*

A maintenance management system (MMS) can significantly simplify the scheduling of proactive maintenance activities. Major industries throughout the world have recognized the cost-saving trend toward a maintenance programme that targets the root causes of wear and failure.

While collection system management differs fundamentally from other commercial enterprises, there are lessons to be learnt by the sewer industry (ASCE, 2004). The accepted methods currently being used to combat sewer degradation are based on either detecting the warning signs of failure once they have already begun (predictive) or regular maintenance according to a schedule, rather than being based on the sewer's true condition (proactive).

Proactive maintenance addresses sewer degradation by concentrating on the causes of, rather than the symptoms of, wear. Proactive maintenance is being recognized worldwide as the single most important means of achieving savings unsurpassed by conventional maintenance techniques. Low-cost maintenance is a consequence of good maintenance practice.

13.2 Predictive maintenance

Predictive maintenance, which is also proactive, is a method of establishing baseline performance data, monitoring performance criteria over a period of time, and observing changes in performance so that failure can be predicted and maintenance can be performed on a planned, scheduled basis.

System performance is frequently a reliable indicator of how the system is operated and maintained. Local authorities that historically relied primarily on corrective maintenance as their method of operating and maintaining the system are never able to focus on preventative and predictive maintenance since most of their resources are directed at corrective maintenance activities and it is difficult to free up these resources to begin developing preventative maintenance programmes.

As an example, analysis of historical data of the number of sewer blockages related to the length of the sewer network per suburb taking causes into account and then rating these suburbs to determine their rank in terms of sewer maintenance 'hotspots' can be done.

Utilizing a maintenance management system (as described in **Paragraph 14.3**) provides the ability to analyse data trends. The heart of a planning and monitoring system is prediction and trend analysis based on reliable performance information.

Within a trend analysis, it is important to look for patterns in three different meanings of the term (ASCE, 2004):

- *Recurring themes and motifs that are common across a whole range of cases at different times and places;*
- *A particular design or a particular distribution of events that is either repeated in regular ways or represents an anomaly or deviation; and*
- *A dominant form of activity that shifts over time and is replaced by another dominant form. It is also useful to distinguish between internal patterns that are, in effect, intrinsic to the activity, and external patterns that increasingly characterize a large portion of the activity.*

In Johannesburg such a system confirmed that most overflows occur within collector sewers and that tree roots were the main cause of blockage (see **Figure 24**).

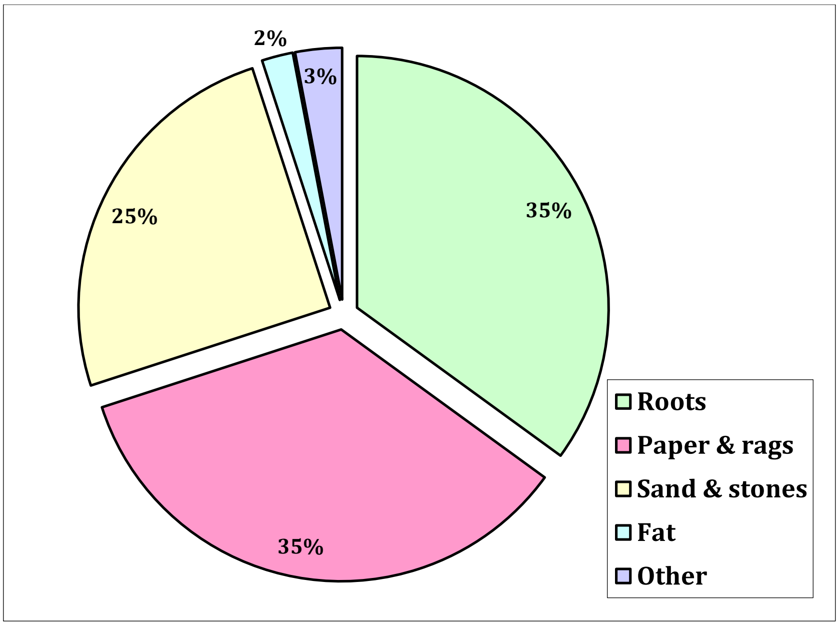

Figure 24: Causes of blockages (Johannesburg Water, 2008)

13.3 Maintenance management system (MMS)

A maintenance management system (MMS) is a tool to deliver effective customer service, to resolve collection system problems, and to provide the basis for developing a proactive maintenance programme. Nowadays this is all computerized and allows the creation of work orders and importing or exporting of data to other modules in a relational database. The maintenance data within an MMS can be mapped, analysed, and coordinated with other condition assessment information to yield solutions to stoppages, overflows and backups.

An effective MMS is also vital for compliance with the proposed CMOM (capacity, management, operation, and maintenance) requirements (see **Appendix B**). The MOM portion of the proposed sewer overflows rule incorporates record-keeping and performance objectives, measures, and self-audits to enable utilities to further reduce sewer overflows and backups.

The MMS will enable the utility to measure and track performance trends, optimize MOM practices, and enable the utility to move from being reactive to being proactive in stabilizing and reducing sewer overflows and backups. Historical records of emergency maintenance, preventative maintenance, and corrective actions yield the basis for developing proactive strategies to preclude the problem from occurring in the future.

The key to the proper implementation and tracking of a preventative maintenance programme is through the continual updating of maintenance records. Update records immediately after performing preventative maintenance or repairing an item and review them annually to evaluate the overall effectiveness of the programme. The preventative maintenance programme can then be refined.

14. SEWAGE DISPOSAL EDUCATION

The users of the waterborne sanitation sewer system have a major impact on the effective functioning of the system. Durban Metro Water Services (DMWS, 2010) has pioneered and implemented a Sewage Disposal Education Programme (SDEP) which arose out of the need to curb high levels of sewage pollution and maintenance costs incurred through the abuse and misuse of sewer systems in the Durban Metropolitan Area. Indirectly, this education programme has become a medium of broader social reconstruction and development. It involves public / private partnerships, and aims to establish a climate of civic responsibility, calling on communities to support their local government and businesses in the construction and development of their living environments.

Many previously disadvantaged communities are without basic facilities and, where water and sewerage services are provided to these communities, the previous service providers often neglected the maintenance and management of these services. Consequently, communities placed little value on the proper use and maintenance of sewer systems. The SDEP was launched to inform people that the provision of improved services must be accompanied by corresponding responsibilities.

The main objective of Durban's Sewage Disposal Education Programme is to create a better understanding of the workings of the sewer system amongst communities, especially first-time users of these services (DMWS, 2010). This is done through a number of innovative educational interventions, which encourage interactive and participative learning. Educational resources and toolkits have been designed for use in schools and at informal education settings, such as clinics. Road-show and street-theatre performances are presented at informal settings to a broad spectrum of the community, reaching out to less literate members of communities, see **Figure 25**.

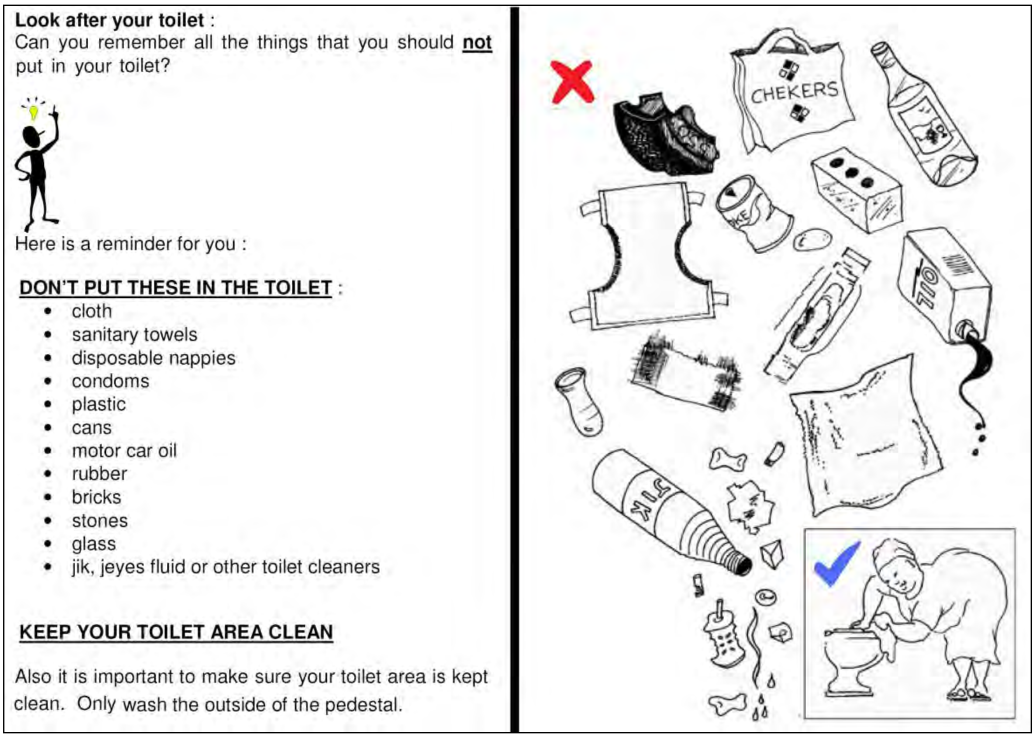

Figure 25: Educational material (DMWS, 2003)

The education programme by the Ethekwini Municipality has made a quantitative impact; for example, over a period of about one and a half to two years the number of blockages have been reduced from approximately 1 300 per month to 300 to 400 per month in particular areas. An attitudinal and behavioural shift has occurred as a result of this on-going educational programme.

According to the Durban Metro Water Services, rewarding public/private partnerships have resulted from the SDEP programme, with buy-in from industry (DMWS, 2010). Emphasis has been placed on community capacity building and skills development, and the employment of women has been encouraged. By-laws have been passed and formalised in the form of a Legal Framework for Pollution Management.

A similar educational drive by DWEA, for example, produced the sticker (**Figure 26**) which is attached to each toilet cubicle door, the use of which has resulted in a remarkable reduction in blockages.

Figure 26: Educational material distributed by the Department of Water and Environmental Affairs

A properly designed and constructed sewer system can provide long-term and effective wastewater conveyance if it is maintained properly. The correct use of the waterborne sanitation system can have a significant impact on the required maintenance.

As shown in **Figures 25** and **26** there are numerous items that do not belong in a waterborne sanitation system. However, problems in sewer systems are not only caused by unwanted and unauthorised items flushed down the toilet.

Excessive inflows also cause severe problems – illegally connecting French drains, roof gutters, sump pumps and other flood-control systems to the sewer system causes sewer overflows as the supply of wastewater to be carried is greater than the hydraulic capacity of the pipes to carry the flow.

- Infiltration

Extensive studies on sewers in the U.S. found that the greatest contribution of inflow comes from private property. General inflow sources include direct connections from rain gutter downpipes, outdoor drains, and pool overflow pipes connected to the sewer lines. Uncapped cleanouts and broken house sewer laterals also cause excessive amounts of rainwater to enter the sewer system.

Although these inflow connections at the homes may alleviate the inconvenience of the property flooding, they have a significant impact on the sewer system and public health. The individual sewer user therefore can play a big role in minimizing sewer maintenance (costs), promoting proper functioning of the sewer system (reducing spills), and protecting the environment, **Figure 27**.

Figure 27: Overflowing manhole due to excessive inflow

It is extremely difficult and costly to determine the actual private property leakage rate for any specific collection system. The lack of legal authorities and the private property issues involved in the investigation and elimination of the extraneous flow inhibit widespread pursuit of this element of infiltration/inflow. In a typical residential collection system, the length of lateral pipe is roughly equal to the length of the mainline sewer.

Not only does the structural deterioration of the lateral pipe and the connection appurtenance play a role in leakiness of the lateral sewers; the local authorities' plumbing codes that may have permitted downpipes, foundation drains, areaway drains, and other groundwater or stormwater discharges to the sewer system are significant factors in the overall infiltration/inflow problem.

- Clothes, sanitary towels, disposable nappies, condoms, etc.

The toilet and sewer system are only designed to dispose of human wastes and toilet paper (which quickly breaks down). Indiscriminate disposal of sanitary items, nappies, etc., to the sewers can cause problems, including flooding in the residents' own home or someone else's. It is a huge '*out of sight, out of mind'* problem because people hardly ever see the mess sewer overflows cause and the problems that sewer workers need to deal with! Domestic sewer pipes are typically only 100 mm in diameter, and even local public sewers will rarely be wider than 150 mm in diameter. It is thus not surprising that blockages will occur if these pipes are misused. Almost anything other than human wastes and toilet paper may restrict sewage flow, clog sewers, and cause sewage overflows.

The following items should **not** be going down the toilet and kitchen sinks:

- Paper (paper towels, facial tissue (Kleenex), paper napkins, wrappers, etc.). Only toilet tissue can be used!
- Plastics (bags, wrappers, bottles, cotton-tip shafts)
- Rubber (gloves, condoms, underwear elastic, etc.)
- Cloth and fibres (cotton balls, tampons, cigarette filters, stockings, rags, etc.)
- Food scraps (greasy items are the worst but non-greasy items can also be problematic. Try to keep out even smaller food items such as tea-leaves, coffee grounds or eggshells. Garbage grinders/macerators help but it is better not to use these where possible – rather compost what you can and dispose of the rest in the trash.)
- Toys, cans, sticks, pebbles and sand, and pretty much all other solids except for human wastes and toilet tissue

Rubbish and other objects often combine with hair, grease and other debris to cause clogging of the sewer system. Even something as small as a cotton-tip swab with other attached debris can cause a blockage in sewer pipes. Rags and stringy material can clog sewage pumps. Malfunctioning sewage pumps, like clogged pipes, prevent sewage from flowing through the system and are a cause of spills. Unauthorised items dumped in toilets and sinks at home, work, schools, shopping centres, movie theatres, or even parks can contribute to sewage spills.

- Fats, oil and grease (FOG)

Fats, oil and grease are major contributors to wastewater collection system maintenance costs throughout the country. FOG clogs the collection system leading to sewer overflows, fouls pumping station screens and force mains, and with excessive accumulation at treatment facilities, can lead to bypass of contaminants, see **Figure 28**.

Figure 28: Grease in sewer

FOG has both commercial and residential sources. According to the American Society of Consulting Engineers (2004) the problem is not just the grease alone, but the interaction of the FOG with the pipe material and the existing defects within the pipe. Some sewer pipes, such as PVC, are oleophilic, meaning oily substances are naturally attracted to the pipe material. The naturally sticky surface of FOG builds on the pipe wall and upon itself, resulting in increasing masses of FOG material in locations where it gathers and accumulates. Furthermore the grease combined with roots also creates a difficult maintenance problem that limits cleaning options for both problems. The roots occupy the same pipe headspace as surface-floating FOG. The roots themselves pose one problem and also serve as a catalyst for a more significant stoppage potential by providing a surface upon which the grease can cling and build.

Figure 29: Sample grease control educational material (ASCE, 2004)

Figure 30: Example of educational material (USEPA, 2002)

A comprehensive education and outreach programme is vital to achieving success with any regulation. The information is primarily intended to inform and educate users in order to achieve compliance with local ordinances. The most effective education outreach is performed in coordination with other government departments (health, environment). Direct mailings, workshops, web information and other audio and/or visual presentations can effectively convey the message; see **Figures 29** and **30**. In addition to the traditional educational mediums, bill inserts, newspaper articles and community events are also used to reach the customer base. The message can be reinforced by reporting the scope of the problems in the collection system, and highlighting the impact on cost and inconvenience to neighbours affected by backups and overflows, and the level of effort within the water utility to control the problems. Active enforcement and promotion of the enforcement penalties are the final step in encouraging the public to change behaviours that contribute to the problems in sewers.

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Appendix A

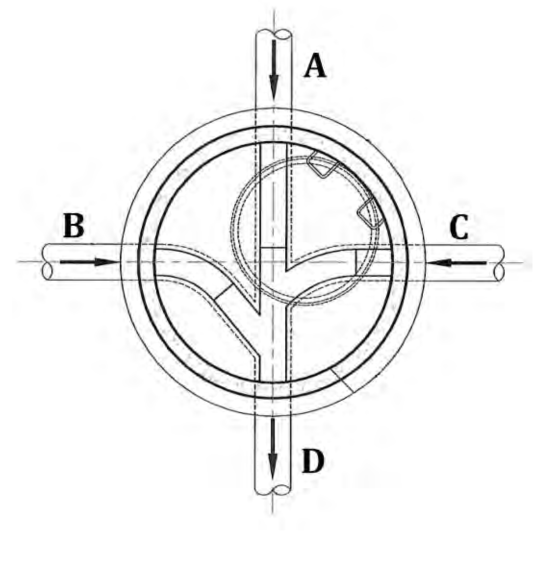
Inspection forms

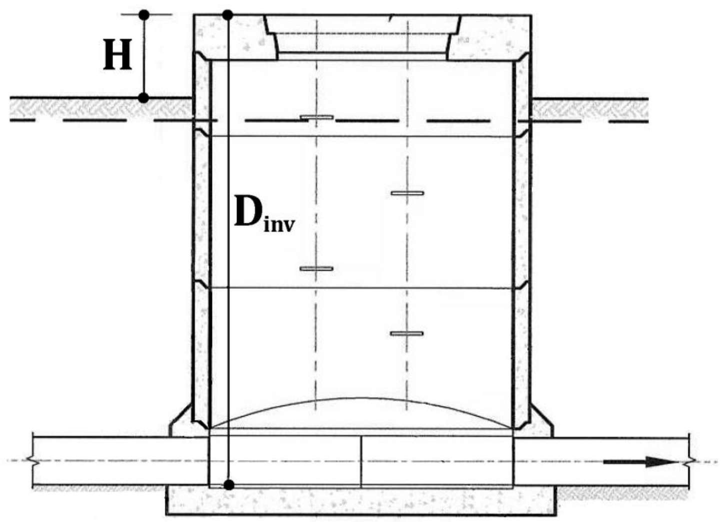
This appendix contains examples of inspection forms. These forms can be adapted to fit specific inspection and data-collection needs.

A1

Manhole inspection report

Section number					
Drawing No.					
Date		Time of inspection			
Inspector name					
Manhole No.					
GPS coordinates	X:	Y:			
Depth to invert (D_{inv}) (mm)					
Cleanliness					
Type of construction					
Street reference					
Gas meter readings	O_2:		LEL:		H_2S:
Manhole cover type					
Manhole cover condition	Loose:	Tight:	Sealed:	Bolted:	Buried:
Frame and cover status	Raise:	Lower:	OK:	Comment:	
Manhole interior construction	Brick:	Concrete:	Other:		
Root intrusion (y/n):		Grit depth:		mm	
Infiltration into manhole	Low:	Medium:	High:	None:	
Water level in manhole (mm)		Signs of spillage			





	Pipe size (mm)	Length (m)	To manhole No.	Height above lowest invert (mm)	Estimated flow (ℓ/s)	Type of flow
A						
B						
C						
D						

General remarks on any defects (cover, frame, grout, steps, pipes. etc.):

1.	
2.	

A2

Pump-station standard operation inspection

General

In addition to the continuous monitoring, each pump station should be inspected on a regular schedule. The frequency of these inspections is determined on a station-by-station basis, and is based on factors such as age, operating history, size and potential for negative environmental impact.

Inspection schedule for pump stations

Name of station			**1/5**
Inspector		**Date**	
Mechanical			
Inspection task	**Description**	**Frequency**	**Remarks/Signature**
Pump	Check for leaking packing, excessive heat, vibration or noise. Operate it in manual mode and perform other checks.	Weekly	
Pump efficiency test	The pumps should be checked to verify their efficiency.	Every 3 years	
Motor condition assessment	The condition of the motors should be checked with preventative maintenance carried out if required.	Every 3 years	
Impeller	Inspection of the impeller should be performed when motor hours are not within 10% of each other. The inspections would assure that the impeller is free of debris.	Quarterly	
Seals/glands	Leakage during pumping	Monthly	
	Replace seals and repack glands.	Annually	
Belt	Slackness and signs of slip (hardened and cracked).	Monthly	
Bearing	Increased noise or heat on bearings.	Monthly	
Motor	Take motor voltage and ampere readings while units are running.	Weekly	
Pipe work and fittings	Check for leaks or deterioration and record on O&M record.	Monthly	

Name of station			**2/5**
Inspector		**Date**	

Mechanical			
Inspection task	**Description**	**Frequency**	**Remarks/Signature**
Compressor	Check compressor and pressure-relief valve. Check air delivery rate, on/off settings, oil level, belts and guards.	Monthly	
Valves	Check for leaky valves. Inspection of the check valves should be performed, to ensure proper working order and to prevent backflow from the force main to the wet well. Exercise all gate and butterfly valves.	Weekly/ biannually	
Couplings	Check for alignment and signs of leaks.	Quarterly	
Base plates	Check all hold-down bolts for tightness and also check alignment.	Quarterly	
Power generator	Inspect and test generator. Check fluid levels (fuel, oil and water), batteries and charger. Inspect hoses and belts and piping for leaks. Check that the generator is warm. Check the generator control panel for generator fault lights.	Weekly	
Wet-well float switches	Cleaning and inspections of floats to assure proper performance. The build-up of grease prevents floats from working properly.	Quarterly	
Electrical and communication			
Electrical equipment	Test and inspect electrical equipment as per OHASA.	Annually	
Heating	Inspect to check working for cold weather.	Weekly	
Communication (telephone)	Inspect communication system (for larger stations).	Weekly	
Electrical switches	Test any 'push to test' lights.	Weekly	
Circuit boards	Check seal failure light. Ensure that all breakers are on.	Weekly	

Name of station			3/5
Inspector		Date	
Electrical and communication			
Inspection task	**Description**	**Frequency**	**Remarks/Signature**
Communication (SCADA)	Periodic service and calibration of all instrumentation, such as flow meters, level sensors, alarms, elapsed time meters and telemetry equipment.	Weekly	
Wiring conditions	Visually inspect control-panel wiring for obvious signs of electrical problems, such as burnt wiring, wire off terminal, and burn spots on cabinet.	Monthly	
Alarms	Check operation of all the alarms (security and malfunctions).	Weekly	
Data recording	Periodic service and calibration of all instrumentation, such as flow meters, level sensors, alarms and data loggers.	Weekly	
Ventilation system	Exhaust fans (warm weather) should be inspected.	Weekly	
Recording devices	Amp and vibration readings on each motor. If the readings do not meet the manufacturer's specifications, indications are that debris is lodged in the propeller within the motor, or that water has entered the motor housing or the wiring.	Monthly	
	Hour meter on each motor will give an accurate record of how often each motor is cycling; and hence, the amount of water being pumped through the system. The pumps should be alternated.	Weekly	
	Flow meter on each pump will give an accurate record of how much flow is being processed through the system.	Weekly	

Name of station			4/5
Inspector		**Date**	

Civil and miscellaneous			
Inspection task	**Description**	**Frequency**	**Remarks/Signature**
General housekeeping - interior	Clean floor, equipment, etc. – do not leave rags, paper, cans, and parts lying on floor or stairway. Wipe down station as needed. Store spare parts, etc., on shelving or in cabinets.	Twice weekly	
General housekeeping - outside	Keep free of weeds, debris, trim bushes, etc.	Twice weekly	
Building	Check building for structural integrity, vandalism.	Annually	
Roof structure	Check roof for structural integrity and ensure that it is waterproof.	Annually	
Drainage	Ensure that drainage system is clean and will function as intended.	Annually	
Vents and louvers	Should be clean and open.	Annually	
Noise levels	Potential of loose connections on services and malfunctioning of system components.	Monthly	
Lighting	Check that all bulbs and switches are working.	Monthly	
Plinths	Check to see that these are not cracked.	Monthly	
Signage	Ensure that all safety signage is visible.	Yearly	
Hoist and mechanism	Test the hoist motors and railing as per OHASA.	Yearly	
Dry well	Check for any signs of leakage. Check that cabling is secure. Sound founding of pumps. Check alignment of pump and motors.	Yearly	
	Check cover over rotating parts.	Monthly	
Security and alarms	Check and release intrusion alarm switch.	Weekly	
Fire extinguisher	Check that it is charged and accessible.	Monthly	

Name of station			5/5
Inspector		Date	
Civil and miscellaneous			
Inspection task	**Description**	**Frequency**	**Remarks/Signature**
Wet well	Check wet well for turbulence, unusual noise and obvious visual problems in the wet well (grease and debris). Check floats by tilting and holding the high-level float upside down for 30 s. Pump out and clean the well to prevent solids and grease build-up. Build-up of solids can create odours and damage to the pump. Inspect interior coating (cracks, blisters, loose material, exposed concrete, etc.). Inspect exterior coating. Inspect concrete penetrations (discharge piping, conduits, etc.). Check and verify opening of hatch to accommodate pump extraction. Inspect alignment of discharge piping.	Monthly	

Appendix B

Checklists

This appendix contains information developed by EPA Region IV for evaluating Operation and Maintenance Programmes for collection systems. This checklist can be used to evaluate collection-system operation and maintenance programmes and to highlight programme areas needing improvement (USEPA, 2005).

Checklist for conducting evaluations of municipal wastewater collection-system Operation and Maintenance (O&M) Programmes

Question	Response	Documentation available	
		Yes	No
GENERAL INFORMATION			
Collection-System Description			
Size of service area (ha)			
Population of service (ha)			
Number of pump stations			
Length of sewer (km)			
Age of system (e.g., 30% over 30 years, 20% over 50 years, etc.)			
OPERATION			
Collection-System Operation: Water Quality Monitoring			
Is there a water quality monitoring programme in the service areas?			
If so, who performs the monitoring?			
How many locations are monitored?			
What parameters are monitored and how often?			
Is water quality monitored after an SSO event?			
Are there written standard sampling procedures available?			
Is analysis performed in-house or by a contract laboratory?			
Collection-System Operation: Hydrogen Sulphide Monitoring and Control			
Are odours a frequent source of complaints? How many?			
Are the locations of the frequent odour complaints documented?			
What is the typical sewer slope? Does the owner or operator take hydrogen sulphide corrosion into consideration when designing sewers?			
Does the collection-system owner or operator have a hydrogen sulphide problem, and if so, does it have in place corrosion control programmes? What are the major elements of the programme?			
Does the owner or operator have written procedures for the application of chemical dosages?			
Are chemical dosages, dates, and locations documented?			
Does the owner or operator have a programme in place for renewing or replacing severely corroded sewer lines to prevent collapse?			
Are the following methods used for hydrogen sulphide control: □ aeration; □ iron salts, G enzymes; □ activated charcoal canisters; □ chlorine; □ sodium hydroxide; □ hydrogen peroxide, G potassium permanganate; □ biofiltration; □ others?			
Does the system contain air-relief valves at the high points of the force main system?			
How often are the valves maintained and inspected (weekly, monthly, etc.)?			

Question	Response	Documentation available	
		Yes	No
Does the owner or operator enforce pre-treatment requirements?			
Collection-System Operation: Safety			
Is there a documented safety programme supported by the top administration official?			
Is there a Safety Department that provides training, equipment, and an evaluation of procedures?			
If not, who provides safety training?			
Does the owner or operator have written procedures for the following: □ lockout/tag-out; □ MSDS; □ chemical handling; □ confined spaces permit programme;□ trenching and excavations; □ biological hazards in wastewater; □ traffic control and work site safety; □ electrical and mechanical systems; □ pneumatic and hydraulic systems safety?			
What is the agency's lost-time injury rate (in per cent or in hours)?			
Is there a permit required and confined space entry procedure for manholes, wet wells, etc.? Are confined spaces clearly marked?			
Are the following equipment items available and in adequate supply: □ rubber/disposable gloves; □ confined space ventilation equipment; □ hard hats; □ safety glasses; □ rubber boots; □ antibacterial soap and first aid kit; □ tripods or non-entry rescue equipment; □ fire extinguishers; □ equipment to enter manholes; □ portable crane/hoist; □ atmospheric testing equipment and gas detectors; □ oxygen sensors; □ H_2S monitors; □ full body harness; □ protective clothing; □ traffic/public access control equipment; □ 5-minute escape breathing devices; □ life preservers for lagoons; □ safety buoy at activated sludge plants; □ fibreglass or wooden ladders for electrical work; □ respirators and/or self-contained breathing apparatus; □ methane gas or OVA analyser; □ LEL metering?			
Are safety monitors clearly identified?			
How often are safety procedures reviewed and revised?			
Are workplace accidents investigated?			
How does the administration department communicate with field personnel on safety procedures: memo, direct communication, video, etc.?			
Is there a Safety Committee with participation by O&M staff? How often does it meet?			
Is there a formal Safety Training Programme? Are records of training maintained?			
Collection-System Operation: Emergency Preparedness and Response			
Does the owner or operator have an emergency response plan? A contingency plan?			
How often is the plan reviewed and updated? What is the date on which it was last updated?			

Question	Response	Documentation available	
		Yes	No
Does the plan take into consideration vulnerable points in the system, severe natural events, failure of critical system components, vandalism or other third-party events, and a root-cause analysis protocol?			
Are staff trained and drilled to respond to emergency situations? Are responsibilities detailed for all personnel who respond to emergencies?			
Are there emergency operation procedures for equipment and processes?			
Does the owner or operator have standard procedures for notifying state agencies, local health departments, the regulatory authority, and drinking water authorities of significant overflow events?			
Does the procedure include an up-to-date list of the names, titles, phone numbers, and responsibilities of all personnel involved?			
Do work crews have immediate access to tools and equipment during emergencies?			
Is there a public notification plan? If so, does it cover both regular business hours and after-hours?			
Does the owner or operator have procedures to limit public access to and contact with areas affected with SSOs?			
Does the owner or operator use containment techniques to protect the storm drainage systems?			
Do the overflow records include the following information: □ date and time; □ cause(s); □ names of affected receiving water(s);□ location; □ how it was stopped; □ any remediation efforts; □ estimated flow/volume discharged; □ duration of overflow?			
Does the owner or operator have signage to keep the public from entering affected areas?			
Is there a hazard classification system? Where is it located?			
Does the owner or operator conduct vulnerability analyses?			
Are risk assessments performed? How often?			
Collection-System Operation: Modelling			
Does the owner or operator have a hydraulic model of the collection system including pump stations? What model is used?			
What uses does the model serve (predicting flow capacity, peak flows, force main pressures, etc.)?			
Does the model produce results consistent with observed conditions?			
Is the model kept up to date with respect to new construction and repairs that may affect hydraulic capacity?			
Collection-System Operation: Engineering - System Mapping and As-Built Plans (Record Drawings)			
What type of mapping/inventory system is used?			

Question	Response	Documentation available	
		Yes	No
Is the mapping tied to a GPS system?			
Are ‘as-built’ plans (record drawings) or maps available for use by field crews in the office and in the field?			
Do field crews record changes or inaccuracies and is there a process in place to update ‘as built’ plans (record drawings)?			
Do the maps show the date the map was drafted and the date of the last revision?			
Do the sewer line maps include the following: ☐ scale; ☐ north arrow; ☐ date the map was drafted; ☐ date of the last revision; ☐ service area boundaries; ☐ property lines; ☐ other landmarks; ☐ manhole and other access points; ☐ location of building laterals; ☐ street names; ☐ SSOs/CSOs; ☐ flow monitors; ☐ force mains; ☐ pump stations; ☐ lined sewers; ☐ main, trunk, and interceptor sewers; ☐ easement lines and dimensions; ☐ pipe material; ☐ pipe diameter; ☐ pipe diameter; ☐ installation date; ☐ slope; ☐ manhole rim elevation; ☐ manhole coordinates; ☐ manhole invert elevation; ☐ distance between manholes?			
Are the following sewer attributes recorded: ☐ size; ☐ shape; ☐ invert elevation; ☐ material; ☐ separate/combined sewer; ☐ installation date?			
Are the following manhole attributes recorded: ☐ shape; ☐ type;☐ depth; ☐ age; ☐ material?			
Is there a systematic numbering and identification method/system established to identify sewer system manhole, sewer lines, and other items (pump stations, etc.)?			
Collection-System Operation: Engineering - Design			
Is there a document which details design criteria and standard construction details?			
Is life-cycle cost analysis performed as part of the design process?			
Is there a document that describes the procedures that the owner or operator follows in conducting design reviews? Are there any standard forms that are used as a guide?			
Are O&M staff involved in the design review process?			
Does the owner or operator have documentation on private service lateral design and inspection standards?			
Does the owner or operator attempt to standardize equipment and sewer system components?			
Collection-System Operation: Engineering - Capacity			
What procedures are used in determining whether the capacity of existing gravity sewer system, pump stations and force mains are adequate for new connections?			
Is any metering of flow performed prior to allowing new connections?			

Question	Response	Documentation available	
		Yes	No
Is a hydraulic model of the system used to predict the effects of new connections?			
Any certification as to the adequacy of the sewer system to carry additional flow from new connections required?			
Collection-System Operation: Engineering - Construction			
Who constructs new sewers?			
If other than the owner or operator, does the owner or operator review and approve the design?			
Is there a document that describes the procedures that the owner or operator follows in conducting their construction inspection and testing programme?			
Are there any standard forms that guide the owner or operator in conducting their construction inspection and testing programme?			
Is new construction inspected by the owner or operator or others? What are the qualifications of the inspector(s)?			
What percentage of time is a construction inspector on site?			
Is inspection supervision provided by a registered professional engineer?			
How is the new gravity sewer construction tested? (Air, water, weirs, etc.)			
Are new manholes tested for inflow and infiltration?			
Are new gravity sewers televised?			
What tests are performed on pump stations?			
What tests are performed on force mains?			
Is new construction built to standard specifications established by the owner or operator and/or the State?			
Is there a warranty for new construction? If so, is there a warranty inspection done at the end of this period?			
Collection-System Operation: Pump Stations - Operation			
How many pump stations are in the system?			
How many have backup power sources?			
Are enough trained personnel assigned to properly maintain pump stations?			
Are these personnel assigned full-time or part-time to pump station duties?			
Are there manned and un-manned pump stations in the system? How many of each?			
Is there a procedure for manipulating pump operations (manually or automatically) during wet weather to increase in-line storage of wet-weather flows?			
Are well-operating levels set to limit pump starts/stops? Are the lead, lag, and back-up pumps rotated regularly?			
Collection-System Operation: Pump Stations - Inspection			
How often are pump stations inspected?			
What work is accomplished during inspections?			
Is there a checklist?			
Are records maintained for each inspection?			

Question	Response	Documentation available	
		Yes	No
What are the average annual labour hours spent on pump station inspections?			
Are there Standard Operating Procedures (SOPs) and Standard Maintenance Procedures (SMPs) for each station?			
What are the critical operating characteristics maintained for each station? Are the stations maintained within these criteria?			
Collection-System Operation: Pump Stations – Emergencies			
Is there an Emergency Operating Procedure for each pump station?			
Is there sufficient redundancy of equipment in all pump stations?			
Who responds to lift station failures and overflows? How are they notified?			
How is loss of power at a station dealt with? (i.e. on-site electrical generators, alternate power source, portable electric generator(s))			
What equipment is available for pump-station bypass?			
What process is used to investigate the cause of pump-station failure and take necessary action to prevent future failures?			
Collection-System Operation: Pump Stations – Emergency Response and Monitoring			
How are lift stations monitored?			
If a SCADA system is used, what parameters are monitored?			
Collection-System Operation: Pump Stations – Recordkeeping			
Are operation logs maintained for all pump stations?			
Are manufacturer's specifications and equipment manuals available for all equipment?			
Are pump run times maintained for all pumps?			
Are elapsed time meters used to assess performance?			
Collection-System Operation: Pump Stations – Force Mains and Air/Vacuum Valves			
Does the owner or operator regularly inspect the route of force mains?			
Does the owner or operator have a programme to regularly assess force main condition?			
Is there a process in place to investigate the cause of force main failures?			
Does the owner or operator have a regular maintenance/inspection programme for air/vacuum valves?			
Have force main failures been caused by water hammer?			

Question	Response	Documentation available	
		Yes	No
MAINTENANCE			
Equipment and Collection-System Maintenance: Maintenance Budgeting			
How does the collection-system owner or operator track yearly maintenance costs?			
Is there a maintenance cost-control system?			
Are maintenance costs developed from past cost records?			
How does the owner or operator categorize costs? Preventative? Corrective?			
Projected costs? Projected repair?			
How does the owner or operator control expenditures?			
Equipment and Collection-System Maintenance: Planned Maintenance			
Are preventative maintenance tasks and frequencies established for all pump stations and equipment?			
How were preventative maintenance frequencies established?			
What percentage of the operator's time is devoted to planned as opposed to unplanned maintenance?			
What predictive maintenance techniques are used as part of PM programme?			
Is there a formal procedure to repair or replace pump stations and equipment when useful life is reached?			
Has an energy audit been performed on pump station electrical usage?			
Is an adequate parts inventory kept for all equipment?			
Are there sufficient numbers of trained personnel to properly maintain all stations?			
Who performs mechanical and electrical maintenance?			
Are there Standard Maintenance Procedures (SMPs) for each station?			
Equipment and Collection-System Maintenance: Maintenance Scheduling			
Does the owner or operator plan and schedule preventative and corrective maintenance activities?			
Is there an established priority system? Who sets priorities for maintenance?			
Is a maintenance card or record kept for each piece of mechanical equipment within the collection system?			
Do equipment maintenance records include the following information: □ maintenance recommendations; □ instructions on conducting the maintenance activity; □ other observations on the equipment; □ maintenance schedule; □ a record of maintenance on the equipment to date?			
Are dated tags used to show out-of-service equipment?			
Is maintenance backlog tracked?			
How is O&M performance tracked and measured?			
What percentage of repair funds is spent on emergency repairs?			
Are corrective repair work orders backlogged more than six months?			

Question	Response	Documentation available	
		Yes	No
Is maintenance performed for other public works divisions?			
How are priorities determined for this work?			
How is this work funded?			
Are maintenance logs maintained for all pump stations?			
Equipment and Collection-System Maintenance: Sewer Cleaning			
Is there a routine schedule for cleaning sewer lines on a system- wide basis, e.g., at the rate of once every seven to twelve years or at a rate of between 8% and 14% per year?			
What are the owner's/operator's goals for annual system cleaning?			
What percentage of the sewer lines are cleaned, even high/repeat cleaning trouble spots, during the past year?			
Is there a programme to identify sewer line segments that have chronic problems and should be cleaned on a more frequent schedule?			
What is the average number of stoppages experienced per mile of sewer pipe per year?			
Has the number of stoppages increased, decreased, or stayed the same over the past five years?			
Are stoppages diagnosed to determine the cause?			
Are stoppages plotted on maps and correlated with other data such as pipe size and material, or location?			
Do the sewer cleaning records include the following information: ☐ date and time; ☐ cause of stoppage; ☐ method of cleaning, location of stoppage or routine cleaning activity; ☐ identity of cleaning crew; ☐ further actions necessary/initiated?			
If sewer cleaning is done by a contractor, are videos taken of before and after cleaning?			
Equipment and Collection-System Maintenance: Sewer Cleaning - Cleaning Equipment			
What type of cleaning equipment does the owner or operator use?			
How many cleaning units of each type does the owner or operator have? What is the age of each?			
How many cleaning crews and shifts does the owner or operator employ?			
How many cleaning crews are dedicated to preventative maintenance cleaning?			
How many cleaning crews are dedicated to corrective maintenance cleaning?			
What has the owner's or operator's experience been regarding pipe damage caused by mechanical equipment?			
Where is the cleaning equipment stationed?			
Equipment and Collection-System Maintenance: Sewer Cleaning - Chemical Cleaning and Root Removal			
Does the owner/operator have a root-control programme?			
Does the owner or operator have a FOG programme?			
Are chemical cleaners used?			

Question	Response	Documentation available	
		Yes	No
What types of chemical cleaners are used?			
How often are they applied?			
How are the chemical cleaners applied?			
What results are achieved through the use of chemical cleaners?			
Equipment and Collection-System Maintenance: Parts Inventory			
Does the owner or operator have a central location for the storage of spare parts?			
Have critical spare parts been identified?			
Are adequate supplies on hand to allow for two point repairs in any part if the system?			
Is there a parts standardization policy in place?			
Does the owner or operator maintain a stock of spare parts on its maintenance vehicles?			
What method(s) does the owner or operator employ to keep track of the location, usage, and ordering of spare parts? Are parts logged out when taken by maintenance personnel for use?			
Does the owner or operator salvage specific equipment parts when equipment is placed out-of-service and not replaced?			
How often does the owner or operator conduct a check of the inventory of parts to ensure that their tracking system is working?			
Who has the responsibility of tracking the inventory?			
For those parts which are not kept in an inventory, does the owner or operator have a readily available source or supplier?			

Appendix C

Work procedures

This appendix contains examples of work procedures which can be adapted to meet specific needs.

C1

Work in restricted spaces

This is an example of a work procedure as issued by the Public Works and Infrastructure Development Department - Water and Sanitation -Waste Water Collection of the City of Tshwane Metropolitan Municipality

INTRODUCTION

The information in this document must be read together with the stipulations of General Safety Regulation No 5 of the Machinery and Occupational Safety Act, 1983 (Act 6 of 1983).

The unscheduled and unauthorised entry of restricted spaces is often fatal for workers in the industrial sector. By pointing out the possible hazards of restricted spaces to workers and by implementing safe work procedures this sector can avoid fatalities and accidents.

GENERAL

A restricted space can be defined as any area with limited exits, which causes toxic, harmful and flammable gases to accumulate there, or a lack of oxygen as a result of poor or non-existent natural and/or mechanical ventilation. Restricted spaces include the following: storage tanks, production containers, silos, refuse containers, boilers, sewage manholes and networks, vaults, tunnels, outlet pipes, inspection holes, storage dams and valve chambers.

Employers must compile mandatory work procedures that are acceptable and consistent for each restricted space that is entered by workers periodically or regularly. The minimum requirements are as follows:

1. Test the atmosphere

Workers may under no circumstances be allowed to enter a restricted space before it has been established that the atmosphere in the space can sustain life, that is, is not flammable or explosive.

The procedure below must always be followed:

Let the prescribed pipe down to about 1 m from the bottom of the restricted work space (eg a manhole) and take readings with the monitor. If the manhole is deeper than 2,5 m, a reading must be taken for every metre. Keep the pipe on each level for about one minute before taking the reading. Only once the readings indicate that it is safe, may the workers climb into the manhole. The monitor must always be strapped to the worker in the manhole. The worker in the manhole must also wear a safety harness with a lifeline and a communication line at all times. Should the alarm of the monitor go off, the manhole must be evacuated immediately.

If the atmosphere in any work space is unsafe for entry, the test apparatus will give an audible alarm and a light will flash. Should the testing indicate an unsafe atmosphere, the space must be ventilated until the apparatus registers a safe reading. After entry the space should be checked continuously for safety.

The work space can be ventilated with the use of extractor fans.

Should the atmosphere in the work space not be rendered safe with the aid of ventilation, and work must be done in the work space, the persons who enter the work space must use breathing equipment, as well as a harness with a lifeline and a communication line.

The tests must be conducted by trained persons who are fully acquainted with the instruments and test procedure. The instruments should be calibrated at regular intervals. Field test results must be recorded on the job cards. Instrument calibration must be recorded on the calibration register of every instrument.

2. Ventilation

Sufficient mechanical extraction ventilation must be provided to ensure that the atmosphere is consistently safe. Should the ventilation occur at street level, sufficient warning signs must be put up that will be read before manhole covers or vault doors are opened. The whole work area must also be fenced off adequately.

NB: Never use oxygen to ventilate a restricted space!

3. Number of workers

There must always be at least two workers, and at least one must be on duty outside the restricted space at all times.

4. Safety equipment

Under no circumstances may any worker enter a restricted space without an approved safety harness with a lifeline. The lifeline must be under the control of at least one person outside the space. As soon as the atmosphere is safe, the harness can be removed and more workers can enter the restricted space. The harness and lifeline must be kept in the work space for an emergency.

If falling objects pose a hazard in the work space, hard hats must be worn. Safety boots must also be worn at all times, except when the presence of water requires the wearing of Wellingtons (and then preferably those with capped toes).

C2

Trench excavations

This is an example of a work procedure as issued by the Public Works and Infrastructure Development Department - Water and Sanitation -Waste Water Collection of the City of Tshwane Metropolitan Municipality

The following must be read with the provisions of Regulation 13 of the General Safety Regulations published under the Occupational Health and Safety Act, 1993 (Act 85 of 1993).

The walls of an excavation can collapse if there is no timber supporting the walls, or if the supporting timber is not strong enough or not erected properly. This problem can prove fatal and cannot be afforded.

The employer must institute an acceptable compulsory entry procedure for occasions when a worker must enter a trench that is deeper than 1,5 m, and this procedure must be adhered to throughout.

The following are relevant information and minimum requirements:

1. CAUSES OF COLLAPSE

- *Ground usually gives way mechanically when it cannot bear its own weight.*
- *Ground is weakened by dampness (usually after heavy rains).*
- *Vibration of vehicles/machinery in the immediate vicinity may cause a collapse.*
- *The weight of loads of sand/material that are placed near the excavation may cause a collapse.*

2. EXCAVATION AT AN ANGLE

The trench must be excavated at a safe angle once the excavation has reached the depth where workers (who possibly have to work in a crouching or stooped position) may become trapped or buried should the trench collapse.

3. TIMBERING FOR EXCAVATIONS

The only correct way of preventing a collapse if the walls of an excavation cannot be excavated at a safe angle is by providing timbering and shoring. The shoring must be used once the excavation has reached a depth at which workers would be injured should a collapse occur.

The following method of timbering must be used:

Adjustable frame
The frame is set at a width slightly less than that of the excavation, then lowered into the excavation and tightened against the walls by means of a spoked wheel. The spoked wheel can be turned with an extension pipe from outside the excavation. The adjustable frame supports the walls while other timbering is put into place.

4. ERECTION OF TIMBERING

If timbering is needed, the timbering must be made ready before workers enter the excavations so that the timbering can protect them while they work. Care must be taken that the work does not progress faster than the timbering can be erected. Timbering must be erected at the one end of the excavation to protect the workers while they are erecting the next section of timbering.

5. SAFETY EQUIPMENT AND COMMUNICATION

Under no circumstances may a worker enter an excavation without there being communication by means of direct observation from outside the excavation. The worker erecting the timbering must wear an approved harness with a life-line attached to it.

6. PERSONAL PROTECTIVE EQUIPMENT

A worker may under no circumstances enter an excavation without wearing the following personal protective equipment:

- *Steel-tipped safety shoes or steel-tipped gumboots*
- *Hard hat*
- *Overall.*

C3

Lifting manhole covers

This is an example of a work procedure as issued by the Public Works and Infrastructure Development Department - Water and Sanitation -Waste Water Collection of the City of Tshwane Metropolitan Municipality

PROCEDURE FOR LIFTING MAN-HOLE COVERS

Only a pick or purpose-made tool may be used to lift a man-hole cover from the frame or to lower a man-hole cover into the frame. Under no circumstances may a worker use his or hands for this purpose.

After the cover has been lifted from the frame, a wooden or metal object must be placed between the cover and the frame for support. Only then may a worker use his or hands to lift the cover further or to remove the cover.

When putting the cover back, the same procedure must be followed. Before the cover is lifted from the ground, a wooden or metal object must be placed on the frame so that the cover rests on the frame and the object. A pick or purpose-made tool must be used to lift the cover over the frame. The support must then be removed and the cover lowered into the frame.