Water supply

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SCOPE

These guidelines cover aspects that need to be considered when planning and implementing water supply projects for existing residential areas and developing communities. The guidelines will also be of assistance where a Water Services Authority compiles a Water Services Development Plan (the latter forms part of a municipality's Integrated Development Plan).

The guidelines assist in determining and setting objectives, developing a strategy and identifying the required planning activities for implementing water services. Technical guidelines are given for use in feasibility studies and the detailed design of water supply elements.

The guidelines form part of a planned series of management guidelines intended for use by decision-makers. The series of guidelines is shown in Table 9.1.

INTRODUCTION

Water services (i.e. water supply and sanitation) in South Africa are controlled by the Water Services Act (Act 108 of 1997) and the National Water Act (Act 36 of 1998). The Water Services Act deals with water services provision to consumers, while the National Water Act deals with water in its natural state.

Central to the supply of water to a community is the Water Services Development Plan of the relevant Water Services Authority, which is required in terms of the Water Services Act. The Water Services Development Plan defines the minimum as well as the desired level of water service for communities, which must be adhered to by a Water Services Provider in its area of jurisdiction. It describes the arrangements for water service provision in an area, both present and future. Water services are also to be provided in accordance with by-laws made in terms of the Water Services Act.

Engineers and other decision-makers within a Water Services Authority, and those working for and on behalf of the Water Services Authority, should be aware of the social and organisational constraints in the provision of potable water. The issues relating to these constraints must be addressed in the objectives of any water supply project, keeping in mind that the sanitation arrangements for a community are inextricably bound to the process (see Chapter 10).

The principles of sustainability, affordability, effectiveness, efficiency and appropriateness should be kept uppermost in supplying water to a community. These and other important issues are dealt with under the relevant headings in this chapter.

Table 9.1: Management guidelines for water service providers (Palmer Development Group 1994)

NAME	TYPE	AUTHOR
URBAN SERVICE PROVIDERS		
Organisational arrangements for service providers	Institutional	PDG
Consumer profile and demand for services	Economic	PDG
Preparation of a water services development plan	Planning	PDG
Water supply tariff setting	Finance	PDG
Sanitation tariff setting	Finance	PDG
Reporting	Management	PDG
Guidelines for private sector participation	Institutional	Pybus
RURAL SERVICE PROVIDERS		
Establishing effective service providers	Institutional	
IMPLEMENTING AGENTS		
Guidelines for local authorities and developers (urban)	Planning	PDG
Series of guidelines for rural areas	Technical	CSIR
DESIGNERS		
Red Book	Technical	CSIR
COMMUNITY LEADERS		
Guidelines for community leaders (urban)	General	PDG
Guidelines for community leaders (rural)	General	CSIR

THE IMPORTANCE OF HYGIENE PROMOTION IN WATER SUPPLY AND SANITATION

Introduction

The principal purpose of programmes to improve water supply and sanitation is to improve health. On the other hand, the mere provision of water and sanitation infrastructure will not, in itself, improve health. To get the maximum benefit out of an improved water supply and sanitation infrastructure, people need to be supported with information that will enhance these benefits. This form of information, and the imparting of skills, is called hygiene education. Hygiene promotion and education provides people with information that they can use to change their behavioural patterns in order to improve their health. Changes in behaviour do not come automatically, but also have a motivational component. In many instances incentives are necessary to induce a change in behaviour, the major incentive being the benefit derived from changed behaviour.

An important lesson learnt during the International Drinking Water Supply and Sanitation Decade is that good coverage – providing a large number of people with access to facilities – does not equal success or sustainability. Because water supply and sanitation facilities are subject to misuse, non-use, or breakdown, international donors and national governments alike have come to recognise that the sustainability of systems is of critical importance. Apart from a sense of ownership of the facilities, it also means that communities should adopt hygiene practices that will help them realise the health benefits of water supply and sanitation improvements. Hygiene promotion and education is a key component of the effort to achieve these health benefits.

To achieve sustainable water supply and sanitation development requires effective complementary inputs such as community participation, community capacity-building and community training. International trends and research have indicated that hygiene promotion and education plays a major role in breaking down the transmission of diseases that are affecting many rural communities in the developing world.

In South Africa it is essential to understand the attitudes and behaviours of developing communities towards water, sanitation and hygiene. Most developing communities rely on the government to make sure that their water supply and sanitation projects are sustainable, but it is necessary for the community itself to contribute to the sustainability of its projects, as well as to the development of an appropriate hygiene-promotion and education programme. It is at community level that real decisions on hygiene promotion and education should be made, but these communities need information to be able to make decisions reflecting their aspirations, desires and needs.

For guidelines on implementing a project with the above elements, see Appendix A of Chapter 10.

What is hygiene promotion and education?

Hygiene promotion and education is not about coercion, but about bringing change in the behaviour patterns of people, to make them aware of the diseases related to unhygienic practices, poor water supply and improper sanitation. It forms an integral part of any water and sanitation development programme.

Hygiene promotion and education comprises a broad range of activities aimed at changing attitudes and behaviours, to break the chain of disease transmission associated with inadequate water supply and sanitation. It is the process of imparting knowledge regarding the links between health, water and sanitation, and seeking to provide people with information that they can use to change their behavioural patterns so that they can improve their health. It is about keeping well, about a better quality of life and about recognising that the majority of illnesses that kill children can be associated with poor sanitation practices and inadequate or unsafe water supplies. It is a primary intervention that, like immunisation but much more cheaply, aims at preventing illness or minimising the risk of infection.

A definition of hygiene promotion and education that emphasises activities aimed at changing attitudes and behaviours must recognise that behavioural change cannot be effected from outside the communities. The individuals in the community must want to change, and only they can effect sustainable change. The role of the external agent can be only that of a catalyst and of providing (or broadening) awareness. Furthermore, the role of women cannot be overemphasised. Women are the latent forces for change in local communities, and their empowerment and involvement are prerequisites to the success of a community-based health or hygiene education and awareness programme or campaign.

It is now recognised worldwide that hygiene promotion and education is an important channel to link newly installed facilities to improved health. Improved water supply and sanitation systems will reduce the persistence and prevalence of diseases.

PLANNING: OVERVIEW

General

The provision of water to a community has to follow the same route as any other project, in that it has to go through a series of distinct stages between the initial conceptualisation and the time when the project is completed. These stages, shown in Figure 9.1, can be summarised as follows:

- *Identification and preparation* comprise the pre-investment planning stages.
- *Approval* is the stage at which decision-makers, including financiers, determine whether or not a project will become a reality.
- *Implementation* is the stage at which detailed designs are completed and the project facilities are built and commissioned; supporting activities such as staff training are also undertaken.
- *Operation* is the stage during which the project facilities are integrated with the existing system to provide improved services.
- *Evaluation*, the final stage, determines what lessons have been learned so that future projects can be improved accordingly.

It is important that the project be undertaken within a framework of clear objectives, aimed at ensuring maximum operational effectiveness, as well as sustainability on completion.

Technical guidelines should be assessed in the context of the operational goals set for the water supply, and adjustments made to take into account factors such as levels of income, availability of funds and the ability of the community to operate and maintain the service. Sustainability of the service is the most important criterion that must be addressed in the planning phase.

The planning process should produce reports that define the purpose and objectives of the water supply and set the broad strategy for reaching the objectives. These reports act as overall guidelines and assist in the generation and selection of the alternative technologies that could be used in the provision of the water supply. The community to be served should be involved in the planning process.

Where the upgrading or rehabilitation of an existing water supply scheme is contemplated, a thorough investigation of existing supply arrangements is required. Eliminating water theft, reducing unaccounted-for water and improving recovery mechanisms could render capital works unnecessary, or postpone them.

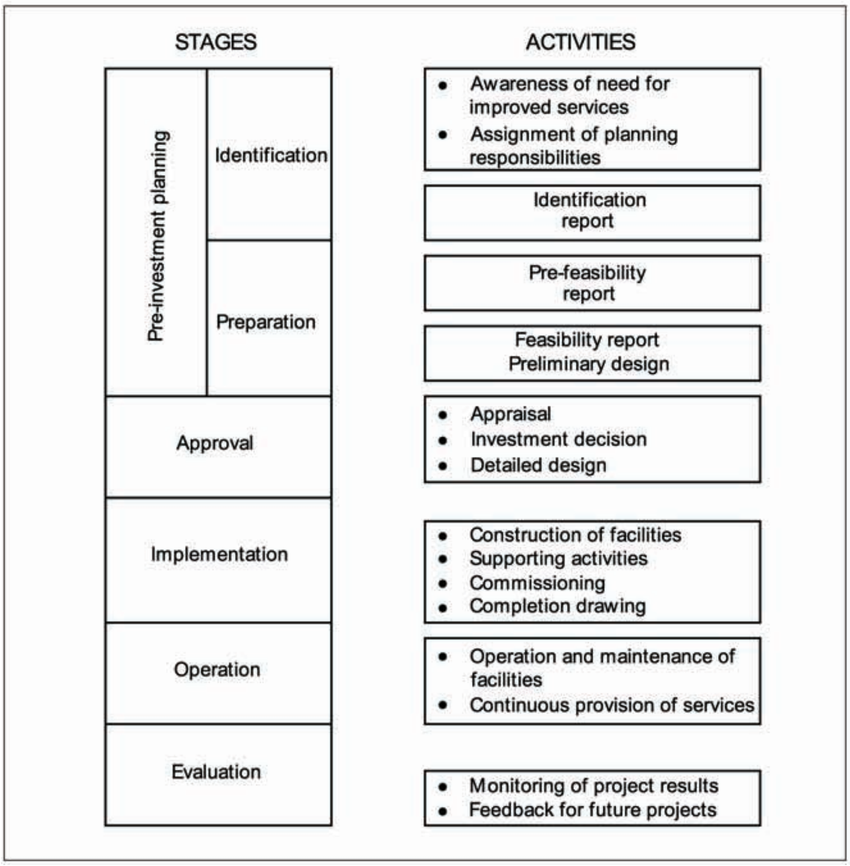


Figure 9.1: Development stages for water supply and sanitation projects

Purpose of the water supply

Establish the purpose of the water supply. Why is the water supply needed? Who will use the water and for what activities? What is the problem with the current situation and how will the proposed water supply project alleviate the problem?

Objectives

Set broad objectives, or goals, first for the operational phase and then for the project phase. It is important to look at operational objectives first, and use these to establish the objectives for the project phase, otherwise there is a risk that the water supply system will operate inefficiently, even if the project phase was completed successfully.

The objectives of a water supply project should include the following:

- the provision of water for domestic consumption and personal hygiene in terms of the Water Services Authority's by-laws (government policy requires that a minimum of 25 litres per person per day be provided);
- the improvement of the quality of the existing supplies (protection of the sources being the first consideration);
- the improvement of the availability of water to the community (both reliability and accessibility);
- community involvement (acceptability) and commitment;
- the improvement of public health;
- the improvement of the living standards of the community;
- the development of local technical, financial and administrative skills; and
- the improvement of the economic potential of the community (e.g. small-scale agriculture and industries).

Strategies

An overall strategy is needed to guide the project through various stages into the operational phase.

By-laws

Note should be taken of the by-laws of the Water Services Authority. The following aspects are of particular importance where Water Services Development Plans are incomplete or unclear:

Administration

The community should be involved in the planning, implementation and maintenance phases of the project (preferably through an independent committee of community representatives).

Finance

Subsidisation of the scheme by bodies outside the community is restricted to the provision of the basic level of service prescribed in government policy documents. The community must also be able to bear the operational costs involved. There are, however, exceptions to the rule, which can be found in the policy documents.

No water supply system should be planned in the absence of a tariff structure and expense-recovery mechanism, agreed to by the client community. The client community must be able to pay for its basic operation and maintenance, with due regard to the free basic water policy of the National Government.

Development impact

Maximum use should be made of local manpower and materials, with training given where appropriate. Where possible, local contractors and entrepreneurs should be employed. However, the technologies employed – including labour-based construction methods – should be cost-effective.

Health

The improvement of the quality of services should be driven by increased community awareness of health-related problems and their causes. For example, improvements in living standards and public health in a community may be impossible to achieve unless hygiene education is provided and sanitation improvements are made concurrently with an improvement in water supply.

Planning activities

The objectives, strategy and policies must provide sound guidelines for formulating and executing the activities, tasks and sub-tasks required to reach the given set of objectives.

The completion of an activity should result in an objective being met. For example, an objective could be the commissioning of a single element of the water supply that is needed to achieve the overall purpose of the whole scheme.

PLANNING: REPORTS

Project reports

In the absence of other guidelines on a project report, the format and contents of the reports should follow the following format.

Feasibility reports

Feasibility reports should cover any factors that could be relevant to the detailed planning and design of a new water supply scheme, or the upgrading of an existing one. Some analyses that should be considered in the feasibility study are given in the documents referred to in Table 9.1.

Water demand

Future water demand is one of the key issues in water supply planning. The following important points regarding the demographic and economic situations determining future water demand should correspond with the contents of the Water Services Development Plan.

The demographic and service information required includes:

- the current population;
- the number of households;
- the number of residential consumer units;
- the incomes related to these consumer units;
- the number and type of non-residential consumer units;
- current levels of water service;
- current consumption; and
- the demand for services, in terms of willingness to pay for the services desired.

The information required to make proper projections of future requirements includes:

- population growth;
- economic growth;
- growth in number of consumer units;
- level of service provided to residential consumer units;
- changes in income levels of residential consumer units;
- changes in consumption per consumer unit;
- effects of water-metering programmes; and
- weather patterns and climate.

Water conservation and demand management (DWAF 2002)

One of major impediments to the implementation of water conservation and demand management at a local level is the lack of social awareness and understanding about these topics among both consumers and water service institutions/authorities. If not implemented in an integrated, targeted and strategic manner, social awareness campaigns will have limited success in achieving the desired behaviour change in water use patterns. Social awareness campaigns need time, energy and resources, and those promoting water demand awareness need to adopt a single, consistent message.

Attempts to implement water conservation and demand management have generally focused on narrow, technical solutions. However, successful implementation is as much about raising awareness as it is about technical interventions. As social awareness is often implemented in conjunction with other measures, gauging its impact on consumer demand is not easy, making it a less attractive option compared to those that provide quick, clear and good results. Awareness-raising is also perceived either as difficult to implement, or simply about making posters or pamphlets. Those involved in raising awareness about water issues do not approach it from the type of marketing perspective needed to sell a product or a concept.

Raising awareness about water demand has to be approached in a strategic manner. Changing the mindsets and behaviour of both water users and managers is a fundamental component of water conservation and water demand management. It is one of the first steps that must be taken in an integrated water demand management strategy in order to achieve the acceptability and buy-in necessary for more technical measures to succeed. Water users and consumers should not be the only targets of education and awareness campaigns; rather, campaigns should be specifically targeted at all stakeholders, including water services institutions, local government, etc.

Raising awareness about water conservation and water demand management issues facilitates changes in behaviour, as knowledge about the subject increases through the education of stakeholders. The effectiveness of any awareness campaign is ultimately measured by the results of the implemented water conservation and water demand measures.

To be successful, any awareness/education campaign has to be *integrated*, *ongoing*, *relevant* and *targeted*. Preliminary research is therefore necessary to develop an understanding of the characteristics, conditions and dynamics of the context/community in which awareness raising needs to be conducted. The Knowledge, Attitudes and Practices (KAP) survey tool provides a model for facilitating change on an individual basis, to incorporate new practices that are being introduced.

General

Several methods may be used to predict the future population. It is important to note that conditions in this country differ to a great extent from those in other countries, and population growth is influenced by a host of demographic factors, which include migration and urbanisation. It is therefore considered important to consult demographers and town planners, as they are best equipped to deal with the issues of socio-economic planning and hence the future population of a given area. Designers should take note of the consequences of accepting an excessive growth rate, but cognisance should also be taken of the characteristics of the study area. Factors like employment opportunities, available residential area, infrastructural services and HIV/Aids can have a significant effect on growth rates.

Water demand figures adopted for design purposes should be based on a projected value for, say, 20 years hence.

Design periods for the integral components (i.e. purification works, reservoirs, pumps and mechanical components, electrical components and main pipelines – outside reticulation) should not exceed 10 years.

Design water demand values for communities are given under the section "Design Criteria for Water Distribution and Storage Systems" in this chapter. These are average daily figures and the design demand should be based on the peak daily demand at the end of the economic design life of the project (i.e. the point where more capital will be required to expand the facilities).

Designers should note that, in adopting water demand figures for a specific design, cognisance should be taken of local factors such as income level, climate and water charges, when interpolating between the upper and lower limits given in this chapter.

Wastewater disposal

It should be borne in mind that increasing the quantity of water supplied to an area also increases the quantity of wastewater for disposal. It is therefore imperative, in the planning stage, that present wastewater disposal practices be evaluated to assess whether these methods can cope with an increased load arising from increased water usage. This aspect is dealt with in Chapter 10 (Sanitation). The recycling of wastewater can reduce the demand on water significantly and could be implemented where feasible and where human health will not be compromised.

A broad approach to the contents of project reports is given in Table 9.2.

Project business plans

The business plan of a project describes a strategic programme-based approach to water service delivery by:

- giving details of the project;
- demonstrating how it will conform to national policy;
- describing how it will be implemented and managed;
- showing how progress will be measured against goals specified; and
- discussing a funding strategy and sustainability.

Business plans normally have the following components:

- an introduction, describing the purpose of the business plan;
- a description of the management structure;
- a project description, which should include the technical details;
- the details of conformity with national policy and other guidelines of funders;
- a table of cost estimates; and
- time plans.

The format and content of business plans is usually prescribed by funding agencies and government departments.

WATER QUALITY

General

Water quality refers to the presence of living organisms or substances suspended or dissolved in water. Water used for domestic purposes needs to be of an acceptable quality and should have a certain amount of dissolved salts present, both for taste and

Table 9.2: Broad approach to contents of planning reports

TOPIC	PRESENT SITUATION
Climate	Rainfall, evaporation, seasonal changes.
Hydrology	Sources of uncontaminated water. Depth of water table. Recharging of groundwater. Presence of streams, rivers, dams.
Geology	Prevalent rock and soil types. Likely existence of impervious and pervious layers. Geological faults. Potential for boreholes. Dam sites.
Population	Existing distribution and numbers. Horizontal and vertical distances from water sources. Migrant labour practices. Age distribution.
Prevalent diseases	Water-related (typhoid, cholera, gastro-enteritis, scabies, bilharzia, malaria). Nutrition-related (malnutrition, kwashiorkor).
Financial resources	Average expenditure per household. Savings.
Institutional structures	Leadership (chief, councillors, government officials). Committees and clubs; household heads. Fieldworkers (agricultural, health). Responsibility for water supply, sanitation, health. Role of women and youth.
Existing water supply and distribution	Springs, pumps, water vendors, tanks, boreholes. Reliability and demand. Costs. Type and age of piping. Present consumption.
TOPIC	FUTURE DEVELOPMENTS
Population	Expected rate of increase and controlling factors. Informal settlements (urbanisation). Age distribution. Migrant labour practices.
Public facilities	Schools; clinics, hospitals; transport; recreation centres.
Commercial and Industrial	Factories, shops, offices, restaurants.
Financial prospects	Improved per capita income. Savings.
TOPIC	COMMUNITY VALUES, ATTITUDES, NEEDS AND SKILLS IN RESPECT OF:
Water supply	Quality; distance; quantity (expected consumption after upgrading).
Sanitation facilities	Toilets, disposal systems; washing hands; disease transmission.
Expertise and skills	Administrative; technical; financial; leadership.
Need priorities	Domestic water; sanitation; public facilities; commercial enterprises; industrialisation.
Education and training needs	Health; water supply schemes; maintenance.

to minimise the corrosive potential of the water. Furthermore, it has been estimated that only one out of every 20 000 strains of bacteria is pathogenic, and the mere presence of bacteria in drinking water is not necessarily a cause for concern. The approach to water quality control in water supply projects should therefore include the following steps:

- the protection of all components (including the source, storage units and pipelines) against possible contamination by pathogenic organisms;
- the improvement of the existing water quality to ensure aesthetic acceptability (removal of turbidity and unpleasant taste); and
- the education of consumers regarding basic precautions for the collection, storage and use of water.

Aspects of water quality that have a bearing on these requirements are discussed in the following sections.

Diseases associated with water

Water development projects are intended to improve the quality of the human environment. However, unless well planned, designed and implemented, a water project may bring about a decrease in one type of disease but cause an increase in a more severe type. This may be especially true of projects designed to improve local agriculture.

Hence, one of the chief concerns of water quality control is the spread of diseases where water acts as a vehicle. The World Health Organisation (WHO) estimates that 80% of illnesses in developing countries are related to waterborne diseases.

Information on water related diseases is available in various textbooks.

In order to minimise water related diseases the following should be observed:

- the disinfection of domestic water supplies;
- the provision of well-designed and -constructed toilets;
- an increased quantity of water for domestic use;
- the provision of laundry facilities, thereby reducing contact with open water bodies; and
- the provision of adequate drainage and the disposal of wastewater.

Water quality

Water for human consumption must comply with the requirements of SABS 241. This standard provides for a Class 0 or Class 1 water – the two classes intended for lifetime consumption – and a Class 2 water, intended for short-term consumption, in relation to the physical, organic and chemical requirements as specified. All classes of water must comply with the specified microbiological requirements.

Stability of water supplies

Water that is put into distribution pipelines should be neither corrosive nor scale-forming in nature. Corrosive water may lead to corrosion of the pipelines, fittings and storage tanks, resulting in costly maintenance, and/or the presence of anti-corrosion products in the final water being delivered to the consumer.

WATER SOURCES

When planning a water supply scheme for an area, the potential sources of water should first be assessed. Consideration should be given to the quantity of water available to meet present and future needs in the supply area, as well as to the quality of the water. Water that is unfit for human consumption will need to be treated before being distributed.

Water for human settlements can be obtained from one or more of the following sources:

- springs;
- wells and boreholes;
- rainwater;
- surface water – rivers and dams;
- bulk-supply pipelines; and
- a combination of the above.

Springs

A spring is a visible outlet from a natural underground water system. Management and protection of the whole system, including the unseen underground part, is essential if the spring is to be used for water supply. The seepage area can be identified by visual inspection of the topography, and the identification of plant species associated with saturated ground conditions. The area can be fenced off, surrounded by a hedge, or just left under natural bush and marsh vegetation. Gardens and trees can be safely planted some distance downstream of the spring, but not within the seepage area above the eye of the spring. The conservation of wetlands or spring seepage areas is an extremely important and integral part of spring water development and management.

Generally, springs fall into three broad categories. These are:

- *Open springs*: occurring as pools in open country. Some form of sump or central collection point from which an outlet pipe can be led is all that is required. It may sometimes be necessary to protect the eye of the spring.

- *Closed springs*: the more common form of spring found in rolling or steep topography. In this case a "spring chamber" is constructed around the eye of the spring, completely enclosing it. Some form of manhole should be provided so that desilting, routine maintenance, and inspection of the pipe intake can be undertaken. It should not be the function of the spring chamber (cut-off wall, spring box or V-box) to store water, since a rise in the chamber's water level above the eye of the spring can result in the underground flow of water finding additional outlets or eyes.

  The spring chamber in Figure 9.2 should be designed according to the principles of underground filters. Provide a graded filter or filter cloth between the in-situ material and the outlet pipe.

- *Seepage field*: where the spring has several eyes or seeps out over a large area. In this case, infiltration trenches are dug and subsoil drains constructed. The drains feed the spring water to a central collector pipe. Subsoil drains can be made of stone, gravel, brushwood, tiles, river sand, slotted pipes, filter material or a combination of the above.

The outlet pipe from a protected spring is usually fed to a storage tank, which keeps the water available for use. The storage tank should have an overflow pipe that is below the level of the spring outlet in the case of gravity feed.

The area immediately above and around the spring outlet or protection works (see Figure 9.3) should be fenced, to prevent faecal contamination by humans and animals. A furrow and berm should be dug on the upstream side of the outlet, to prevent the direct ingress of surface water into the spring after rains.

The reliable yield from a spring is estimated by measuring the outlet flow rate during the driest months of the year (August/September in summer rainfall areas, February/March in winter rainfall areas). The reliable yield is then calculated by multiplying this flow rate by a factor. This factor (see Table 9.3)

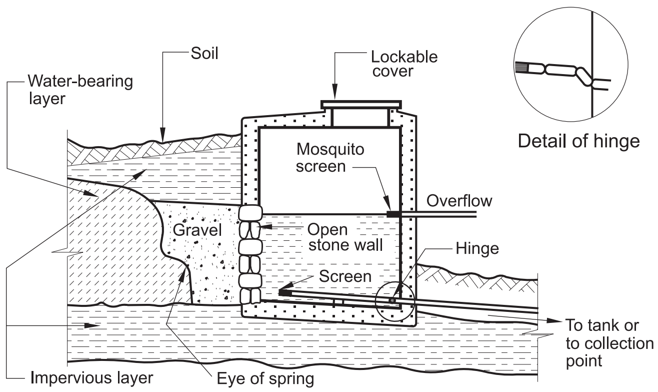


Figure 9.2: Details of spring chamber (Cairncross and Feachem 1978)

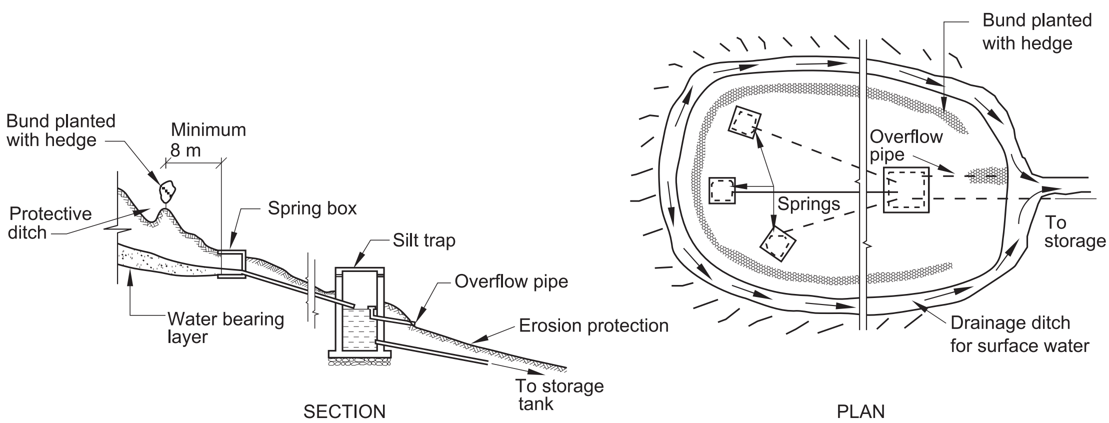


Figure 9.3: Layout of spring protection works for multiple spring eyes (Cairnross and Feachem 1978)

Table 9.3: Factors for obtaining reliable yield estimates of spring water

RAINFALL DURING PREVIOUS WET SEASON	FACTOR
Above average, extending into normally dry season	0,25
Above average	0,35
Average	0,50
Below average	0,65
Below average, longer than usual dry period	0,80

depends on a number of variables, including geology, soil types, land use, and hydrological characteristics. As a first approximation the following factors may be used, but it is advisable to try to obtain additional information where possible.

Usually, the local populace can provide information on whether the spring ever dries up, or how many containers can be filled in an hour for the worst drought years.

It is also reasonable to assume some level of risk, especially since during at least 90% of the year better flow conditions than the reliable yield can be expected.

Wells

Where the underground water does not emerge above the natural surface of the ground, this water can be accessed by digging a well in the case of shallow depths, or drilling a borehole when the water level is deep (i.e. greater than 15 m).

Hand-dug wells

A well is a shaft that is excavated vertically to a suitable depth below the free-standing surface of the underground water. It is usually dug with hand tools, and consists of a well head (the part visible above ground), a shaft section and the intake (the area where water infiltrates).

The well head's construction will depend on local conditions but must be built in a way that contributes to hygiene and cleanliness. The well lining should extend above the ground surface, to prevent contaminated surface water from running down into the well. For this reason, and to prevent subsidence, the space between the lining and the side of the shaft should be backfilled and compacted. A concrete apron, sloping away from the well, should preferably be cast around the well.

It is necessary to provide some form of lining to prevent the walls of the shaft collapsing, both during and after construction. Types of linings used include:

- reinforced concrete rings (caissons);
- curved concrete blocks;
- masonry (bricks, blocks or stone);
- cast-in-situ ferrocement;
- curved galvanised iron sections; and
- wicker work (saplings, reeds, bamboo, etc).

The well must be sunk sufficiently deep below the free-standing surface of the groundwater to form a sump in order to provide adequate water storage, to increase the infiltration capacity into the well, and to accommodate seasonal fluctuations in the depth of the water table. The larger the diameter of the hole, the faster it will recharge, depending on the characteristics of the aquifer. Joints between the linings can be sealed with mortar or bitumen above the water table, but left open below it.

The intake section is that part of the shaft in contact with the aquifer. Joints in this section must be left open. It is advisable to cover the bottom of the well with a gravel or stone layer to prevent silt from being stirred up as the water percolates upwards, or as the water is disturbed by the bucket or pump used for abstraction.

The well should be covered with a slab and equipped with a suitable pump or bucket and a lifting mechanism.

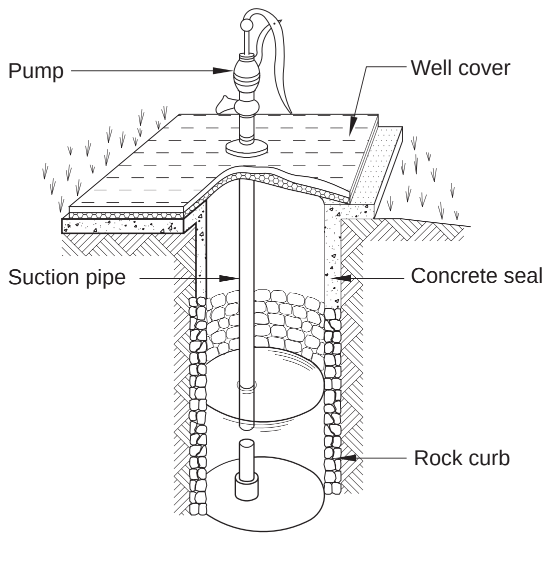


Figure 9.4: Hand-dug well (IRC 1980 & 1983)

Tube wells (also called bored wells)

In sandy soils, the hand-digging of wells is problematic and expensive since loose sands tend to collapse. Therefore hand-digging in sandy soils is not recommended as cheaper, more efficient methods are available. These methods include jetting, hand-drilling and augering of small-diameter holes (50 to 500 mm). The holes are lined using uPVC or mild steel casings to prevent collapse. The section below the water table is fitted with some form of well screen to allow for filtration of the groundwater while preventing the ingress of silt.

As with hand-dug wells, the tube well should be covered with a slab and equipped with a suitable pump and concrete apron. Specially designed buckets that can fit into the tubes and be winched down to the water level are still commonly used in tube wells. Certain designs of bucket eliminate the need for handling and, hence, the possibility of polluting the well water with germs, etc, from unwashed hands.

Boreholes

Generally, underground water is of a better quality, in terms of bacteria and suspended solids, than surface sources, and its supply is often more reliable. For these reasons human settlements throughout history have shown a preference for underground water, when available, for domestic water supplies. In all cases, groundwater should be analysed to determine its fitness for human consumption as well as its possible effect on pipe systems.

When the water table occurs at a great depth and/or in rock formations that do not facilitate the construction of hand-dug wells, a relatively small hole can be drilled using mechanical equipment. With the proper equipment, such boreholes can be sunk to depths of 100 m or more, if required.

The borehole should be drilled by a reputable drilling contractor registered with the Borehole Water Association of South Africa. The drilling should also be executed in terms of accepted procedures and standards, e.g. the Association's publication *Minimum Code of Practice for Borehole Construction and Pump Installation.*

The diameter of the hole should suit the size of the casing to be installed, plus any temporary casing required to keep the hole open during drilling and gravel-packing. For most hand-pump installations a casing diameter of 100 to 110 mm is adequate, while submersible pumps normally require a minimum diameter of 120 mm, and preferably at least 150 mm.

As with hand-dug wells and tube wells, it is important to prevent surface water entering the borehole, and to drain any excess water from the borehole site. If necessary, a concrete apron or collar should be provided. The installation of a sanitary seal provides effective protection against aquifer pollution via the borehole annulus. Wherever possible, a local resident should be trained to maintain the borehole and borehole pump and to alert the appropriate authorities when major breakdowns occur. Water level measurements should be taken regularly and recorded, to ensure the pump is submerged at all times and provide early warning of source depletion.

Siting of wells and boreholes

The presence, amount and depth of deep underground water cannot normally be predicted beforehand with a high degree of accuracy. Boreholes and wells previously sunk in the area could give valuable information as to the depth and amount of water available. Trained geoscientists (e.g. hydrogeologists or geophysicists) are able to establish the most favourable sites by using techniques such as aerial photograph interpretation and geophysical exploration – e.g. electrical resistivity, magnetic, seismic and gravimetric measurements. National and regional groundwater maps providing synoptic and visual information on South Africa's groundwater resources are available from the Water Research Commission and the Department of Water Affairs & Forestry. These maps are not site-specific and cannot be used for borehole siting or any site-specific groundwater conditions, but are an aid in determining borehole prospects and other groundwater related information such as quality.

Groundwater is vulnerable to pollution. All boreholes not correctly equipped should be properly closed. As a minimum guideline, boreholes for domestic use should be at least 30-50 m away from potential pollution sources such as on-site toilets, cattle kraals or cemeteries; however, this general rule must be considered against site-specific conditions and circumstances.

Determination of yield

Once a successful borehole has been established, it is important to carry out tests to estimate the yield likely from that borehole. The type of test and its duration must be chosen to suit the level of reliability required. Recommendations in this regard are given in Table 9.4. These recommendations represent the minimum requirements, and can be altered to suit the situation (extract from *Test pumping standards for South Africa* published by the Ground Water Division of the Geological Society of South Africa).

All the aspects addressed above are covered in a document *Minimum standards and guidelines for groundwater resource development for the community water supply and sanitation programme* published by the Department of

Table 9.4: Recommended test and duration to estimate subsurface water yield

USE OF WATER	TEST	DURATION	RECOVERY TEST
Stock or domestic	Extended step	Total 6 hours	Up to 3 hours
Hand pump	Extended step	Total 6 hours	Up to 3 hours
Town water supply Low-yield borehole	Step Constant discharge	4 x 1 hour 24 hours	- Complete
Town water supply High-yield or main borehole	Step Constant discharge	4 x 1 hour 72 hours or more	- Complete

Water Affairs & Forestry (1997). More recently, the South African Bureau of Standards embarked on the development of a set of South African Standard Codes of Practice (SABS 0299 series) for the development, maintenance and management of groundwater resources.

Rainwater

Rainwater can be collected and stored. The harvesting of rainwater from roof runoff can supplement domestic supplies, even in semi-arid areas. In particular, rainwater can be harvested not only for domestic use, but also to provide water at remote public institutions like schools and clinics, as well as resorts. Usually the limit is not the amount of rainfall that can be collected, but the size of the storage tank that will provide a sustained supply during periods of little or no rainfall. It should, however, be considered a supplementary supply for non-potable use since it could pose a health risk.

Rainwater collection from roofs constructed from corrugated iron, asbestos sheeting or tiles is simple. Guttering is available in asbestos cement, galvanised iron, uPVC, plastic or aluminium. The guttering and downpipes can be attached directly to the ends of rafters or trusses, and to fascia boards.

Because the first water to run off a roof can contain a significant amount of debris and dirt that has accumulated on the roof or in the gutter, some mechanism (such as that in Figure 9.5) to discard the first flush is desirable. In addition, the inlet to the storage tank should be protected with a gauze screen to keep out debris, as well as mosquitoes and other insects or rodents.

Materials commonly used for rainwater tanks include corrugated iron, glass fibre, asbestos cement, high-density polyethylene (all prefabricated types) or ferrocement, concrete blocks, masonry, reinforced concrete, and precast concrete rings (tank constructed in-situ). Subject to the availability of a suitable mould, ferrocement construction is one of the most economical options at present. Ferrocement construction without the use of a mould is also possible, however.

Larger quantities of rainwater may be collected from specially prepared ground surfaces. Surface preparations to make the ground less permeable include compaction and chemical treatment, or covering with impermeable materials such as plastic, rubber, corrugated iron, bitumen or concrete. In the case of ground-level rainwater harvesting, the storage tank will normally need to be located underground. The catchment area should also be protected (fenced off) to minimise the risk of possible faecal contamination.

The average quantity of water available from a rainwater catchment area is found by multiplying the area (in plan) with the mean annual rainfall in that area, and adjusting by an efficiency factor (average rainwater (litres) = catchment area (m^2) x mean rainfall (mm) x efficiency, where efficiency, has a value between 0 and 1,0). For roofs an efficiency of 0,8 is usual.

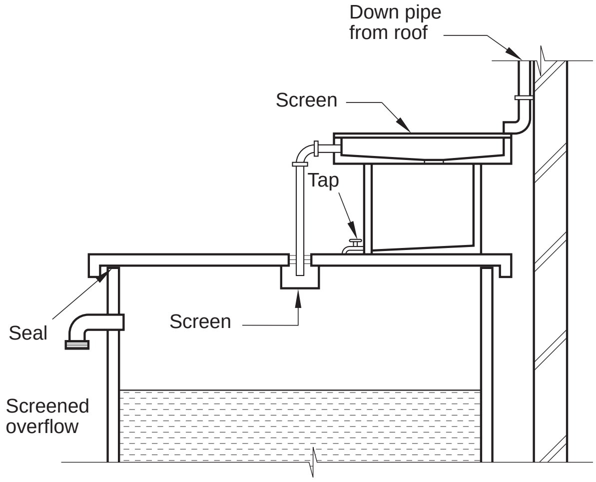


Figure 9.5: Arrangement for diverting the "first foul flush" (IRC 1980)

Fog harvesting

Fog harvesting is limited in application and confined to particular geographical areas. A number of pilot projects are currently being undertaken at Cape Columbine, Pampoenvlei, Lamberts Bay, Brand se Baai, Kalkbaken se Kop and Kleinsee. The publication *Fog harvesting along the west coast of South Africa: a feasibility study* by J. Olivier (Water SA, vol 28 no 4, October 2000) can be referred to in this regard.

The technique is fairly simple – nets spanned between poles. Fog condenses on the nets and runs down into an open chute for collection in a storage facility.

The findings of a number of test sites are currently awaited.

Surface water

The Catchment Management Agency or the Department of Water Affairs and Forestry's Regional Office should be consulted where surface water is used as source. Surface water sources, such as streams, rivers, lakes, pans and dams, will always contain suspended solids (turbidity) and microbiological pollutants. In addition, the quantity of water that can be abstracted from these sources is dependent upon droughts and floods, unless sufficient storage is available or can be provided. The following aspects should therefore be taken into account when relying on surface water to supply a community:

- The water should be treated for the removal or destruction of pathogenic organisms (e.g. bacteria, viruses, protozoa), as well as for turbidity.
- Where deemed necessary, a back-up source (e.g. a borehole) should be provided for times of shortage and drought, to ensure a minimum supply for domestic use.
- A pump station or other water extraction facility should be protected from possible damage by floods or vandalism.

The water supply intake may be sited at any point where the surface water can be withdrawn in sufficient quantities. In some situations where the gradient is steep enough, the water to be used may be diverted directly into a canal or pipeline, without the need for pumps.

In the case of a small stream or river it may be necessary to construct a weir across the river bed to provide enough depth for intake and to maintain the water level within a fairly narrow range. A weir may be constructed with concrete, cement blocks, or rocks covered with impermeable plastic sheeting. The type of construction selected will depend on economics and on the flood conditions expected.

The river or dam's intake point should be selected to abstract the best quality of water from the source. For example, a float intake (see Figure 9.6b) may be selected to withdraw water just below the surface. This may be desirable as the surface water may be clearer than the water at deeper levels. Alternatively, an intake placed below the bed of a river (see Figure 9.6d) would result in the water being partially filtered as it passes through the sand of the bed. While this may appear to be the most desirable, it is important to ensure that any such filtered-intake system is firmly fixed in place because, when the river floods, the river bed tends to become unstable.

In a stationary body of water like a dam or lake, it may be desirable to withdraw water well below the surface to minimise the amount of algae in the water extracted. However, if the water is extracted from too deep a level, the quality of this water may show a marked difference from the surface water. This is because of the possible thermal stratification of the lake in the warm summer months, when the oxygen levels in the deeper waters could be depleted, causing deterioration in quality.

Bulk-supply pipelines

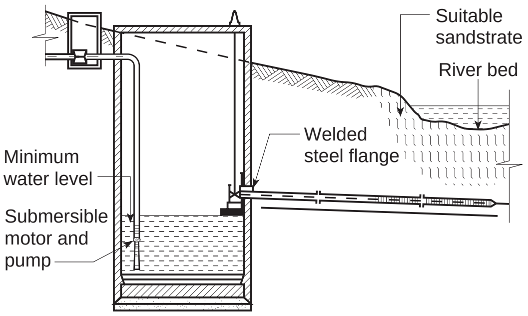
The storage and distribution system, often comprising the major expense, must be appropriate for the area in terms of cost, complexity and operational requirements.

When a developing area is located alongside an already developed area, it may be possible to purchase water directly from the authority supplying water to the developed area. In many cases, the existing water pipelines will be able to support the additional requirement of the developing area. If the pipeline is situated close to the developing area, this position could be highly cost-effective. A storage reservoir may be required to ensure a continuous supply where excess water is only available during off-peak periods. If the water in the pipeline is untreated, some treatment will be required to ensure that the water is safe for domestic use. The authority responsible for the pipeline will require payment for the water withdrawn from the pipeline, and hence it will be necessary to meter the connection.

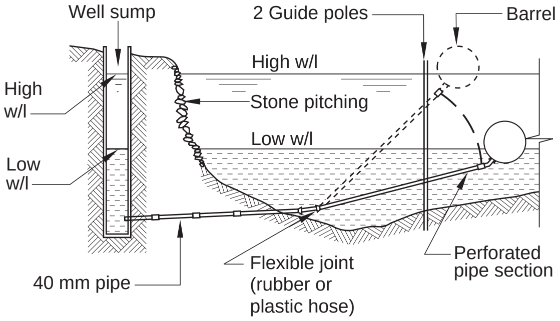
WATER TREATMENT

General

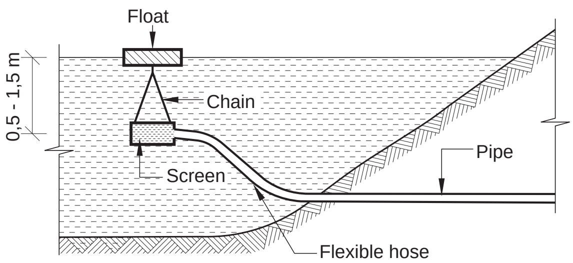
Water treatment is considered a specialised subject. This section therefore gives a broad background only and does not attempt to give guidance to the design engineer. Specialists should be consulted where water purification is considered.



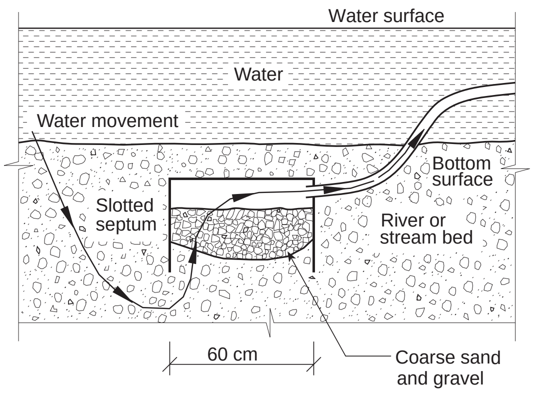
(a) River bank intake using infiltration drains



(b) Float intake



(c) Simple water intake structure



(d) The S.W.S. filter

Figure 9.6: Various surface water intake configurations

In many cases, water obtained from a particular source will require some treatment before being distributed for domestic use. Water obtained from boreholes, protected wells, protected springs and harvested rainfall often requires little or no treatment. However, as a precautionary measure and to minimise biological activity in the storage reservoirs and pipelines, even such waters should be chlorinated before distribution.

Most surface waters will require treatment, both to remove turbidity and for disinfection.

Certain surface waters and groundwaters will require additional treatment for the removal of organic and/or inorganic contaminants. Many groundwaters in southern Africa are highly saline and, unless a suitable alternative source of water can economically be located, they will require partial desalination to make them suitable for domestic use.

Unfortunately, there is no such thing as a universal, simple and reliable water treatment process suitable for small community water supplies. Treatment should be affordable and reliably operated. Okun and Schultz (1983) suggest that under all circumstances groundwater is the preferred choice for community supplies, as it generally does not require treatment. When treatment is required, this will be determined by the extent of contamination and by the characteristics of the raw water.

A simple approach for the selection of a treatment system is given by Thanh and Hettiaratchi (1982) (see Table 9.5). The emphasis on slow sand filtration is valid for areas where skilled personnel may not be permanently available to operate the plant, where chemical shortages may occur, where space is available at low cost, and where supervision may be irregular. Marx and Johannes (1988) found slow sand filtration to be an economical and successful option for water treatment plants in developing areas of South Africa.

Where sufficient money and skilled operators are available, standard water treatment plants (e.g. chemical flocculation, radial settler, rapid sand filtration and chlorination) have worked well under most circumstances.

Package water treatment plants

Package water treatment plants (see glossary) for smaller communities in rural areas have potential and could fulfil the need for potable water. Attention should, however, be given to operation and maintenance requirements as well as to backup from suppliers.

More information can be obtained from a Water Research Commission (1997) publication entitled *Package water treatment plant selection.*

Table 9.5: Treatment selection criteria (Thanh and Hettiaratchi 1982)

RAW WATER QUALITY	TREATMENT SUGGESTED
Turbidity 0-5 NTU Faecal coliform 0/100 mℓ Guinea worm or schistosomiasis not endemic	No treatment
Turbidity 0-5 NTU Faecal coliform 0/100 mℓ Guinea worm or schistosomiasis endemic	Slow sand filtration
Turbidity 0-20 NTU Faecal coliform 1-500/100 mℓ	Slow sand filtration Chlorination if possible
Turbidity 20-30 NTU Up to 30 NTU for a few days only Faecal coliform 1-500/100 mℓ	Pre-treatment advantageous Slow sand filtration Chlorination if possible
Turbidity 20-30 NTU Up to 30 NTU for several weeks Faecal coliform 1-500/100 mℓ	Pre-treatment advisable Slow sand filtration Chlorination if possible
Turbidity 20-150 NTU Faecal coliform 500-5 000/100 mℓ	Pre-treatment Slow sand filtration Chlorination if possible
Turbidity 30-150 NTU Faecal coliform >5 000/100 mℓ	Pre-treatment Slow sand filtration Chlorination
Turbidity >150 NTU	Detailed investigation (and possible pilot-plant study)

WATER SUPPLY OPTIONS

Selection of water supply terminals

Water supply terminals are divided into public (or communal) and private installations. Public or communal installations are those installations to which the public and the community have access. Private installations are those that render water to individual households.

The selection of terminals for a community depends on a number of factors, the most important being

- affordability of the system (by agency/users);
- selected method of cost recovery;
- unit cost to end-user; and
- long-term maintenance requirements.

With regard to water for domestic use, the relative importance of these factors for each terminal is given in Table 9.6. The value judgements in this table are subjective and a number of other factors may influence the final selection, or the validity of the judgement for a particular situation.

If possible, individual connections should be provided to schools, clinics and possibly some businesses, no matter which option is selected.

Public or communal water supply terminals

Rudimentary systems fall within the category of public or communal water supply terminals. These systems normally comprise a source or consumer terminal where water is collected in containers or buckets. Walking distance is usually between 200 and 500 metres. A minimum of water is provided – between 5

Table 9.6: Selection criteria for water supply terminals

TYPE OF SUPPLY	RELATIVE CAPITAL COST OF SUPPLY SCHEME	COST RECOVERY	MAINTENANCE NEEDS	UNIT COST
Public standpipes	medium	flat rate or per amount used	medium	low
Water kiosks	medium	per amount used	low	high
Tanker supply to tank	medium	flat rate	medium to high	medium to high
Vendors	low	per amount used	low	medium to high
Yard tank	low	per amount used	low	low
Roof tank	medium	per amount used	low	low
Metered yard tap	high	per amount used	low	low
Metered house connection	high	per amount used	low	low
Handpump	medium/low	flat rate	medium	medium
Spring supply to tank	low	flat rate	low	low

and 15 ℓ/c/d, mainly for drinking and cooking.

The most basic systems are run-of-river abstraction, rainwater harvesting, unprotected springs and open wells. The systems are often augmented by hand pumps, spring protection, a windmill, solar pump or some storage tanks. All systems require home treatment.

Communal street tap: Ordinary type

The system comprises a water reticulation system with standpipes in open areas or in road reserves. The Department of Water Affairs and Forestry's White Paper of 1994 defined basic water as access to 25 litres of potable water per person (capita) per day at a communal street tap which is within 200 metres of the dwelling, with 98% reliability and a 10 ℓ/min flow rate. Provision is usually made in the design for upgrading.

The design of the standpipe installation requires careful planning, and special attention should be given to drainage of excess water and avoiding wastage, in order to minimise health risks. A typical example is shown in Figure 9.7.

In the case of communal standpipes serving dwelling houses, the following criteria should be satisfied (payment arrangements may influence these considerations):

- one tap required per 25-50 dwellings;
- maximum number of people served per water point: 300;
- maximum number of people served per tap: 150;
- maximum walking distance from a dwelling to a standpipe: 200 m.

An acceptable discharge capacity from a standpipe is about 10 ℓ/min per tap. For commonly used taps the calculated discharge range, at an assumed efficiency of 80%, is given in Table 9.7.

These flow rates should be considered only as a guide; the actual flow rate depends on the type of tap used. The high discharge rates indicated for a 60 m head will normally be reduced by the limitations of the pipework. In practice, measured flow rates to single dwelling houses seldom exceed 40 ℓ/min.

In order to reduce water wastage, and to prolong the life of the tap washers, pressures should be limited.

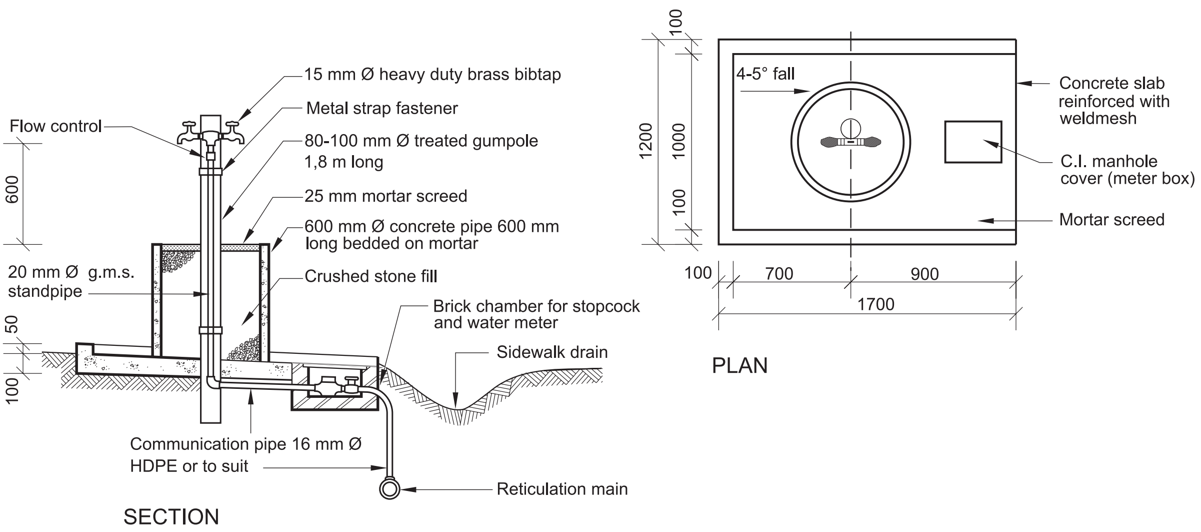


Figure 9.7: Typical standpipe detail

Table 9.7: Typical discharge rates for taps (assumed efficiency rate 80%)

TAP DIAMETER	DISCHARGE		
	5 m head	10 m head	60 m head
15 mm	16 ℓ/min	23 ℓ/min	54 ℓ/min
20 mm	22 ℓ/min	31 ℓ/min	70 ℓ/min

Access for physically disabled persons:
Barriers that prevent access to water and sanitation facilities for disabled people tend to fall into the following categories (WEDC, 2002):

- Environmental: barriers in the physical environment and infrastructure;
- Individual: functional limitations of the individual disabled person;
- Social: negative attitudes and behaviour of the community and society; and
- Institutional: discriminatory legislation, policies, and organisational practices.

Involvement of disabled people at all stages of project planning and implementation will improve both effectiveness and sustainability.

The provision of communal street taps should take cognisance of the requirements of physically disabled persons. Taps should be situated on smooth, even pathways, and ramps should be provided in lieu of steps. Ramps should be not less than 1100 mm wide with a slope not exceeding 1:12.

Communal street tap: Prepaid type

The basic (RDP) standard (25 ℓ/c/d within 200m at 98% reliability and 10 ℓ/min flow), with the addition of prepaid meters at street taps.

Water kiosks

Water kiosks are being used in developing areas where urbanisation has caused the rapid growth of settlements. The sale of water at kiosks provides an effective means of recovering costs, which is especially relevant in places where community management structures are not yet in place.

Due to their higher cost and the relatively large number of users required to make individual units commercially viable, kiosks are usually spaced further apart than standpipes would normally be. For the system to be viable, individual kiosks should supply at least 100 dwellings.

Facilities for accurately measuring and dispensing the standard purchase volume (usually 20 to 25 litres) should be provided. The structures should be sturdy, and have lockable facilities.

Water tanks with taps

Water tanks with taps may be the first level of supply improvement before any distribution piping is installed. Water may be supplied by gravity flow from a spring, from a borehole equipped with an engine-driven pump, by rainwater, or from a small treatment plant. People may need to walk long distances to the tanks to collect this water. However, its quality is usually good, and it may often be the only source of water available to a community.

The size and design of the tanks should be in accordance with the design principles given elsewhere in this chapter.

Handpump installations

The following criteria are considered important for effective water supply to areas using handpumps:

- The handpump chosen should take into account corrosiveness of the environment, together with suitable riser pipe material for the pumping head.
- The community should be consulted in the choice of the handpump; this selection should be made from a well-informed position.
- The pump should be installed professionally.
- The site should also be free from contamination by animals and humans, and generally be distant from sources of possible pollution.
- The pump should be taken care of by selected, motivated community members in order to facilitate maintenance tasks.
- It should not be expected of communities to be completely self-sufficient; adequate spares and maintenance should be available.

Private water supply terminals

Yard connections and house connections fall within the category of private water supply terminals.

Yard connections

Ordinary type
Water is provided, at pressure, at a tap on the boundary just within the stand. No storage facilities are provided on site and there is no supply to the house. However, an outside toilet may be supplied with a hand-washing facility or washtub.

Yard tank (or ground tank): low-pressure, trickle feed
Water is provided at full pressure up to specially manufactured yard tanks. The tank inlet has a flow regulator (trickle feed), which is sized to give a predetermined volume (mostly 25 ℓ/c/d) to the household. A ball valve inside the tank prevents it from overflowing. Supply can be shut off if required.

Yard tank (or ground tank): low-pressure, manually operated
This is similar to the Durban tank (Figure 9.8). Water is provided at full pressure into yard tanks. The volume of supply is either manually controlled by a bailiff who, on a daily basis, opens the supply at a control node, or electronically controlled to fill each tank where the monthly flat rate has been paid. The supply volume can be adjusted by changing the tank size and increasing the monthly flat rate. A ball valve inside the tank prevents it from overflowing. Supply can be shut off if required.

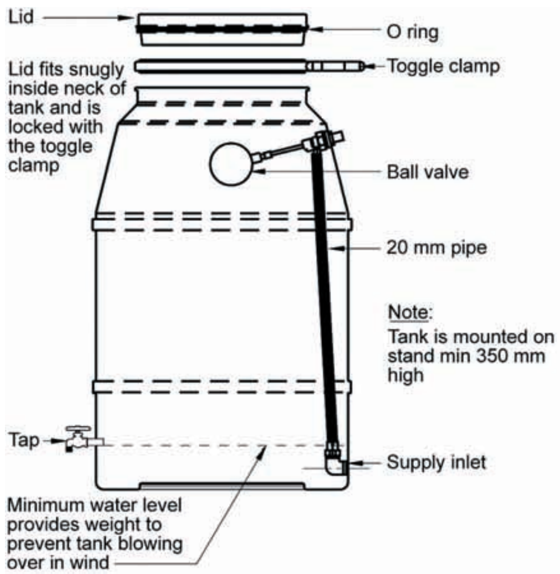


Figure 9.8: The Durban yard tank

Yard tank (or ground tank): low-pressure, regulated
Water is provided at regulated pressure and flow rate into yard tanks. Volume and pressure of supply is regulated by "equity" valves at control nodes located on the RDP pipe network. A ball valve inside the tank prevents it from overflowing. Bailiffs can shut off supply if required. Volume of supply can easily be adjusted by changing the size of the equity valve.

Roof tank: medium-pressure, manually operated
Water is provided at full pressure into a roof tank either in or on top of the roof of the house. The water supply is sometimes throttled to discourage excessive use. Water use in the house is at roof-height pressure. A ball valve inside the tank prevents it from overflowing. The volume of supply is unlimited and metered conventionally.

Customers are regularly invoiced for water consumed.

Roof tank: medium-pressured, regulated
Water is provided at high pressure to reticulation nodes, and at reduced pressure into a roof tank either in or on top of the house. The water supply is sometimes throttled to discourage excessive use. Water used in the house is at roof-height pressure.

The volume of supply is regulated by the "equity" valve at the node, and can be changed to upgrade or downgrade the level of water use. The volume of supply is unlimited and metered conventionally. Customers are regularly invoiced for water consumed.

House connections

Full-pressure conventional house connection
Water is provided at high pressure into the house, and all water use is at full pressure and unregulated flow. Water use is metered conventionally. Customers are regularly invoiced for water consumed.

The communication pipes for erf connections for dwelling houses (Residential zone 1) should be sized according to Tables 9.8 and 9.9.

For developments other than dwelling units metered individually, the communication pipe should be sized according to the specific demand.

House connection: full-pressure, prepaid
Water is provided at high pressure into the house, and all water use is at full pressure, and available with prior payment (prepayment tokens) activating the prepayment meter. These tokens can be bought at central vending offices. No monthly meter reading and billing is required.

DESIGN CRITERIA FOR WATER DISTRIBUTION AND STORAGE SYSTEMS

General

Water distribution and storage are, in most instances, the most costly parts of a water supply scheme. Hence savings in these areas through good design can often result in significant savings for a whole project.

The elements of a water distribution and -storage system include some or all of the following:

- bulk water transmission systems;
- bulk-storage reservoirs;
- intermediate-storage reservoirs;
- distribution networks; and
- terminal consumer installations.

This section deals with water demand and is presented in two parts. The first part deals with water demand in *developing areas* and the second part deals with *developed areas*. It does not therefore mean that the guidelines given are applicable only to a particular area – the designer should always be aware of the dynamics within a community that could influence the development of an area.

Table 9.8: Communication pipes across roads for house connections

INCOME LEVEL	MINIMUM ACTUAL INTERNAL DIAMETER (mm)	
	SERVING TWO ERVEN	SERVING ONE ERF
Higher	40, branching to 2 x 20	25, reducing to 20 at erf
Middle	40, branching to 2 x 20	25, reducing to 20 at erf
Lower	20, branching to 2 x 15	15

Table 9.9: Communication pipes on near side of road for house connections

INCOME LEVEL	MINIMUM ACTUAL INTERNAL DIAMETER (mm)	
	SERVING TWO ERVEN	SERVING ONE ERF
Higher	40, branching to 2 x 20	20
Middle	40, branching to 2 x 20	20
Lower	20, branching to 2 x 15*	15*

* The communication pipe may be reduced to 15 mm nominal diameter, provided the minimum head in the reticulation main at the take-off point for the erf connection under instantaneous peak demand is not less than 30 m.

Developing areas are considered to be those areas where the level of services to be installed may be subject to future upgrading to a higher level.

Developed areas are considered to be those areas where the services installed are already at their highest level and will therefore not require future upgrading.

Water demand

Water demand is usually based on historical consumption. Where water consumption records are not available, present consumption per capita can be estimated by consulting the residents. However, once the supply system has been upgraded, consumption is likely to change and Tables 9.10 and 9.11 may be used to estimate typical consumption. An improved estimate could be obtained by studying existing water supply systems in the same area. It has also been shown that extensive education programmes could have a positive influence on water demand.

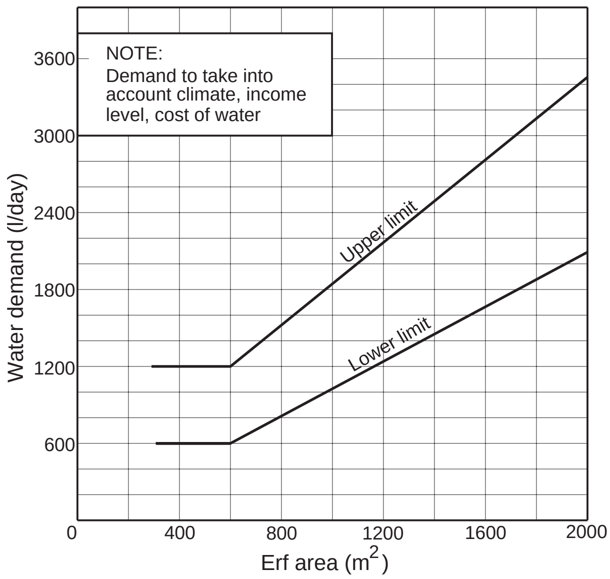


Figure 9.9: Annual average daily water demand for erven in developed areas

Table 9.10: Water demand for developing areas (IRC 1980)		
TYPE OF WATER SUPPLY	TYPICAL CONSUMPTION (ℓ/c/d)	RANGE ℓ/c/d
Communal water point		
• well or standpipe at considerable distance (>1000 m)	7	5-10
• well or standpipe at medium distance (250-1000 m)	12	10-15
• well nearby (<250 m)	20	15-25

Table 9.11: Water consumption in areas equipped with standpipes, yard connections and house connections (adapted from Department of Water Affairs & Forestry, (1992): Guidelines for the selection of design criteria)			
DOMESTIC WATER CONSUMPTION			
TYPE OF WATER SUPPLY		TYPICAL CONSUMPTION (ℓ/c/d)	RANGE ℓ/c/d
Standpipe (200 m walking distance)		25*	10 - 50
Yard connection			50 - 100
With dry sanitation		55	30 - 60
With LOFLOs			45 - 75
With full-flush sanitation			60 - 100
House connection (developed areas) #			60 - 475
Development level:	Moderate	80	48 - 98
	Moderate to high	130	80 - 145
	High	250	130 - 280
	Very high	450	260 - 480

* This consumption of 25 ℓ/c/d is the minimum to be made available per person in terms of government policy.
# The water demand in this category, based on a different approach, is also given in Table 9.14 and Figure 9.9.

Notes:

- A handpump should be considered as being similar to a well, since additional effort is required to obtain the water.
- A spring should be considered as being similar to a standpipe, especially when it has been protected.
- A climb of more than 60 m over a short distance should be considered as being similar to walking a distance of about 1 000 m.

Factors influencing water demand

- The type of sanitation system and the development level affect the water consumption, particularly in the category "House connection".

  The development levels are as follows:

  - *Moderate*: medium-sized formal housing with limited finishing, moderate gardens.
  - *Moderate to high*: limited formal suburban housing, moderate finishing, extensive gardens.
  - *High*: extensive formal suburban housing, small stands, extensive gardens, moderate-flush toilets.
  - *Very high*: formal suburban housing, large stands, extensive gardens, fully reticulated.

- Inhibiting factors like topography, water quality and water tariff.
- Metering and cost-recovery mechanisms.

Non-domestic water demand in developing areas

Water requirements for non-domestic purposes are difficult to estimate and, where possible, field measurements should be taken. Provision must also be made for the water demand at public open spaces. See Table 9.12 and 9.14 category 13.

Water demand for stock

The water demand for stock is given in Table 9.13. It must be pointed out that the provision of potable water for stock is highly undesirable and has serious cost-recovery implications.

Water demand in developed areas

The water demand figures in Table 9.14 should be used for detail design where applicable. Studies on water demand show there is usually a large degree of variance about the mean demand, and several factors can cause short-term variations. Therefore, the differences between Tables 9.11 and 9.14 should not be seen as significant and adjustments can be made to these demand figures to take local conditions into account. Attempts to base water demand on other erf-related data have not yet been validated.

Table 9.12: Non-domestic water demand

NON-DOMESTIC USERS	WATER DEMAND
Schools: day boarding	15-20 90-140 litres/pupil/day
Hospitals	220-300 litres/bed/day
Clinics	5 - outpatients 40-60 - in-patients litres/bed/day
Bus stations	15 - for those persons outside the community litres/user/day
Community halls/ restaurants	65-90 litres/seat/day

Table 9.13: Water demand for stock

STOCK	WATER DEMAND litres/head/day
Intensive: meat: LS	50
SS	12
Dairy: LS	120
Extensive: LS	50
SS	10

LS refers to large stock.
SS refers to small stock.
Intensive: the business of the land owner is farming.
Extensive: keeping a few animals for domestic purposes.

Table 9.14: Water demand for developed areas

CATEGORY	TYPE OF DEVELOPMENT	UNIT	ANNUAL AVERAGE WATER DEMAND (ℓ/day) UNLESS OTHERWISE STATED
1	Dwelling houses *(Residential zone I)*	Erf area for dwelling house	See Figure 9.9 for erven not exceeding 2 000 m^2. For erven >2 000 m^2, base demand on local conditions
2	Low-rise multiple-dwelling unit buildings *(Residential zones II and III)*	Dwelling	Upper limit 1 000[(a)] Lower limit 600[(a)]
3	High-rise multiple-dwelling unit buildings *(Residential zone IV)*	Dwelling	Upper limit 700[(a)] Lower limit 450[(a)]
4	Offices and shops	100 m^2 of gross floor area[(b)]	400
5	Government and municipal	100 m^2 of gross floor area[(b)]	400
6	Clinic	100 m^2 of gross floor area[(b)]	500
7	Church	Erf	2 000
8	Hostels	Occupant	150
9	Developed parks	Hectare of erf area	≤2 ha: 15 kℓ[(c)(d)] >2 ha ≤10 ha: 12,5 kℓ[(c)(d] >10 ha: 10 kℓ[(c)(d)]
10	Day school / créche	Hectare of erf area	As per developed parks[(d)]
11	Boarding school	Hectare of erf area plus boarders	As per developed parks plus 150 ℓ/boarder
12	Sportsground	Hectare of erf area	As per developed parks
13	Public open spaces[(e)]	Hectare of erf area	See note [(e)] below

(a) Water demand includes garden watering of all common areas outside the limits of the buildings.

(b) Gross floor area obtained using applicable floor space ratio from the town planning scheme.

(c) Demand for developed parks to be considered as drawn over six hours on any particular day in order to obtain the peak demand.

(d) Where the designer anticipates the development of parks and sportsgrounds to be of a high standard, e.g. 25 mm of water applied per week, the annual average water demand should be taken as follows: ≤2 ha: 50 kℓ[(c)]; >2 ha ≤10 ha: 40 kℓ[(c)]; >10 ha: 30 kℓ[(c)].

(e) Refer to Chapter 5 and distinguish between "soft open space" and "semi-public open space".

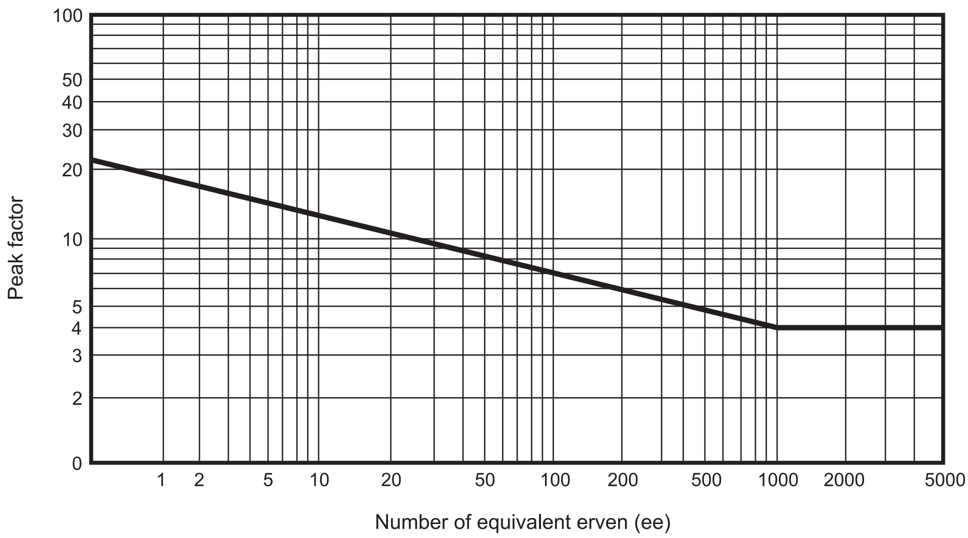


Figure 9.10: Factor for obtaining the peak flow in mains for low-cost housing, incorporating individual on-site storage

Peak factors

Figure 9.10 could be used as a guide where yard tanks are supplied and a single 15 mm tap is fitted on the service pipe between the consumer connection and the storage tank (usually a 200 litre capacity).

The peak factors mentioned in Table 9.15 are intended as a guide only. The actual choice of the peak factor requires considerable thought from the designer, and depends on several factors that must be taken into account. Recent studies have indicated that the peak factors currently in use are conservative; however, a comprehensive review is still outstanding.

The following are some of the factors that may significantly influence the choice of a specific peak factor:

- employment trends and practices in the community;
- gardening activities;
- number of persons per tap;
- agricultural activities;
- number of dwellings (where supply to less than 200 dwellings is being considered, consideration should be given to a higher peak factor; Figure 9.10 could be used as a guideline in this case);
- economic status;
- extent of unauthorised connections;

Table 9.15: Peak factors for developing areas

PEAK FACTORS: DEVELOPING AREAS – UNRESTRICTED FLOW SYSTEMS #				
TYPE OF DOMESTIC SUPPLY	SUMMER PEAK FACTOR	DAILY PEAK FACTOR	INSTANTANEOUS PEAK #	
			Low density**	High density**
House connection	1,5	2,4	3,6 - 4,0	4,0 minimum*
Yard connection	1,35	2,6	3,5 - 4,0	4,0 minimum*
Street tap / standpipe	1,2	3,0	3 - 3,6	4,0 minimum*
Yard tanks	-	-	see note	see note

Unrestricted systems are those systems where no specific arrangements restrict the flow at all. The instantaneous peak factor for restricted flow systems (yard tanks) is 1,5 at all times.

** Low-density areas are typically found in rural localities. High-density areas are those areas typically found in urban localities.

* Increases with diminishing number of consumers. Figure 9.10 could be used as a guide.

- "skeletonising" (see Glossary) of reticulation networks; in the case of low-level serviced communities, due consideration should be given to the design of the network for the ultimate scenario and the reticulation network being skeletonised to the requirements of the immediate level of service; and

- system constraints (e.g. maximum possible flow from a tap, or limited supply by a water bailiff). Reticulations in the developing areas may be significantly affected by the discharge rate from standpipes. Table 9.7 gives guidelines on tap discharges.

It is not advisable to reduce peak factors to effect cost savings. Cognisance must be taken of the fact that the water supply to developing areas could be upgraded at a later stage, and the long-term development of the water supply to the community must be taken into account.

Peak factors for developed areas

In order to determine the instantaneous peak factor for developed areas from the graph, the type of development should first be converted to "equivalent erven" (ee) according to the design annual average daily demand, accepting as a basis for design that one ee has an annual average daily demand of 1 000 litres.

Using the ee thus obtained, the instantaneous peak factor pertaining to any point in the network should be obtained from Figure 9.11.

The annual average daily demand multiplied by the peak factor gives the instantaneous peak flow.

Storage

The peak factor will be reduced in the case of the provision of terminal storage (in which case only the terminal storage volume is designed to cater for peak demands).

The provision of intermediate storage will also result in a reduction in the peak flows in the elements prior to the intermediate storage facility.

Where the installed capacity is unable to cater for the peak demand, the demand curve will flatten out, resulting in the actual peak demand being limited to the supply capacity of the system, extended over a longer period of time. This may be of some inconvenience to residents, but will not lead to a water shortage.

Residual pressures in developing and developed areas

To obtain the residual head at any point in the reticulation, the network should be balanced using instantaneous peak flows and fire flows.

Hydraulic formulae for sizing components

Any of the recognised hydraulic formulae may be used to size pipeline components.

WATER TRANSMISSION

General

Pipelines are the most common means of transmitting water, but canals, aqueducts and tunnels may also be used. Water transmission conduits usually require considerable capital investment and therefore all technical options with their associated costs should be carefully evaluated when selecting the best solution in each particular case.

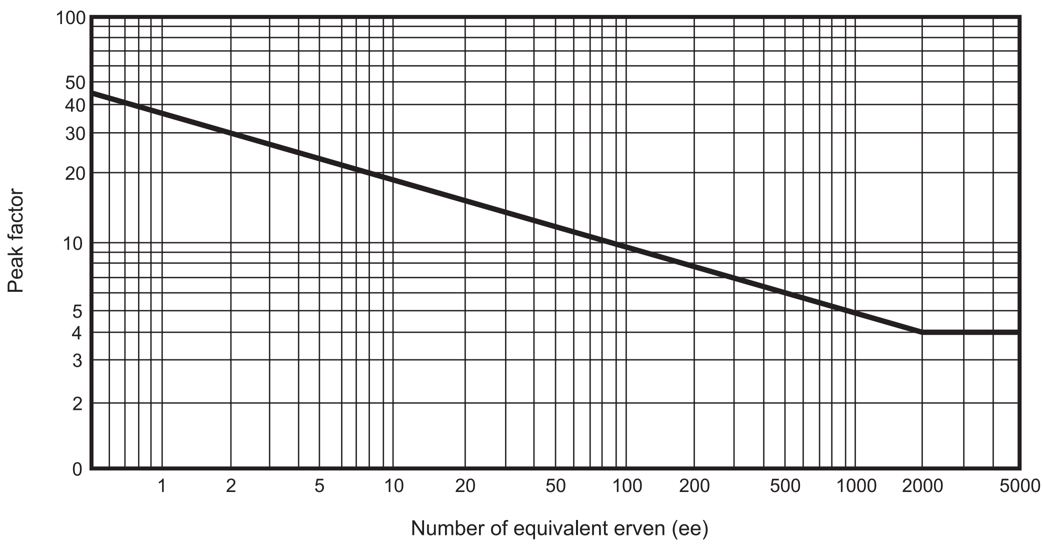


Figure 9.11: Factor for obtaining the peak flow in mains in developed areas

Pipelines will usually mean minimum water losses, and also imply the shortest transmission distance. However, pipeline costs may be considerable and the option of canals for the transportation of non-potable water could be considered. Canals will result in higher losses, longer transmission distances, and the possibility of deterioration in water quality due to algal growth. However, the lower costs and the option of labour-intensive construction may make this option more attractive. Designers should also take into account the habits and lifestyle (keeping of livestock) of those communities where canal systems for water supply are considered.

Water can be transported either by gravity or pumping, or a combination of these. Clearly, the preferred choice will always be a gravity supply. Aqueducts and tunnels should only be used in special circumstances. However, physical or economic constraints may limit the options and necessitate a pumping component.

Canals

Canals may be used to transport large volumes of water over long distances. They should be lined (usually with concrete) and inspected regularly for cracks and leaks in the joints. The growth of algae may need to be addressed by shock chlorination from time to time. Canals should only be used for transporting non-potable water.

Water tankers

The operational costs of supplying water by tanker are usually extremely high, but may serve as a temporary measure in an emergency situation, or for a new settlement. However, alternative tank size and delivery vehicle combinations should be considered when undertaking a feasibility study. The use of multi-purpose vehicles (e.g. tractors with different trailer combinations) could also be considered as a means of reducing the capital costs.

PIPELINE DESIGN

Basic requirements

- The static pressure should be kept as low as possible by reducing the pressure in a balancing or separate break-pressure tank, or by means of a pressure-reducing valve.

- To avoid air pockets, the number of high and low points should be kept to a minimum by trying to follow the contour lines, rather than roads or tracks.

- To minimise the number of air-release valves, the pipeline trench depths may be varied to avoid local high and low points.

- The cost of a water transmission system is more sensitive to the total length of pipe installed than the diameter of the pipes. Therefore, it is generally advantageous to design a transmission system (at least the major components) to meet the ultimate capacity.

- Velocities in pipes should be approximately 0,6 m/s and should not exceed 1,2 m/s.

- Velocities in special fittings (fittings specifically manufactured) should not exceed 6 m/s.

- Air valves should be installed at summits, and scour valves at low points between summits.

- Thin-walled pipes susceptible to buckling must have valves that automatically allow air to enter when the pipeline is emptied, so as to prevent a vacuum that will cause the pipe to collapse.

- To facilitate the location of a buried pipe during maintenance, curved pipe routes should be avoided. All bends should be marked with a post or a suitable beacon, and the pipeline laid in a straight line between bends.

- To avoid air pockets in pipelines, the slope should be greater than 0,3% (0,3 m per 100 m length), or 0,2% for large-diameter pipes (>200 mm).

- To avoid damage to pipelines during backfilling of a trench, a proper pipe-laying specification should be provided by the designer. Recommended minimum trench depths are as follows:

  - *road crossings*: pipe diameter + bedding + 0,80 m;

  - *otherwise*: pipe diameter + bedding + 0,60 m.

- Bedding thickness should normally be a minimum of 0,10 m or one-sixth of the pipe diameter, whichever is greater.

- The likely effect of water hammer/surge pressure should be considered in the design of a pressure pipeline system, as this may be the crucial factor in the selection of pipe class, or may indicate the need to provide surge or accumulator tanks.

The suitability of any pipe for a particular application is influenced by:

- its availability on the market, both in respect of dimensions and pressure classes;

- its purchase price and associated costs of valves and fittings;
- its susceptibility to corrosion, mechanical damage and material ageing, as well as any other cause of material deterioration in the particular application;
- its storage costs; and
- the diameter of pipeline (internal and external).

Pipes laid above ground

It may happen that pipes have to be laid above ground due to adverse conditions, such as rock. When considering laying pipes above ground, the following factors need to be taken into account:

- Provision should be made for expansion joints (the effects of thermal changes must be considered).
- Each pipe section should be properly supported. The supports should be designed to carry the load of the pipe as well as the water it conveys. Sufficient supports should be included in order to prevent sagging of the pipeline. The pipe should be strapped to the support, leaving room for movement.
- Adequate thrust blocks should be designed to cater for hydraulic forces at bends.
- Adequate anchoring should be provided, especially in steep slopes, and directional and elevation changes.
- The consequences of pipe failure should be evaluated.
- Heavy equipment like valves should be supported independently.
- Adequate protection should be provided to cope with external abrasion.
- Vulnerability to damage from veld fires, animals and rodents should be assessed.

VALVES AND OTHER FITTINGS

General

Valves and fittings should be carefully located and designed to facilitate the operation of the system. Careful routing of the pipeline will minimise the number of costly fittings required.

Isolating valves

Isolating valves should be installed at one- or two-kilometre intervals on transmission mains. Where possible, these should be combined with air-release valves. Pressure-relief valves should be installed on pumping mains to avoid damage caused by pumping against closed valves.

In reticulation networks, isolating valves should be provided so that not more than four valves need to be closed to isolate a section of main. Valves should be spaced so that the total length of main included in an isolated section does not exceed a nominal 600 m. This will obviously depend on circumstances.

In order to facilitate identification, valves should be located at street corners opposite erf corner boundary (splay) pegs, and intermediate valves opposite the common boundary peg for two erven.

Where pipes intersect, isolating valves should generally be installed in the smaller-diameter branches.

Isolating valves should be installed to facilitate maintenance of the main, and generally located to suit the topography.

To reduce cost, isolating valves in larger mains may be of lesser size than the pipeline. The design should ensure that the cost of the smaller valve, together with reducers, is less than the cost of a full-size valve. In addition, care should be taken to ensure that velocities through the valve are not excessive.

Depending on the size of the valve and the unbalanced pressure across the valve, devices such as thrust bearings, spur gearing and a separate bypass valve may be required.

When flanged isolating valves are used, a flange adaptor coupling should be installed to facilitate removal of the valve.

Air valves

Air valves are required to release air from the pipeline during the filling process and during normal operation. Whereas automatic small-orifice air-release valves are desirable, these may be replaced with public standpipes or other suitable distribution points. As air-release valves require servicing from time to time, it is recommended that a gate valve be installed with the air-release valve for easy removal and repair.

Where possible, pipelines should be laid such that the need for air valves is avoided. Fire hydrants can also be used to vent the main during charging.

Air valves are a possible source of contamination, and the air-valve installation arrangements should be such that contamination of the system cannot occur, while an adequate air flow for the valve is always maintained.

Air valves should be provided to suit the longitudinal section of the pipeline in relation to the hydraulic gradient.

Air valves should be sized according to the air flow rate generated by the rate of inflow or outflow of the water in the pipeline.

Air valves should be installed with an isolating valve on the air valve branch to facilitate maintenance, and should preferably be fitted with a cock tapped into the bottom of the valve body, to enable the effective operation of the valve to be checked.

Scour valves and outlets

Scour valves should be installed at low points in pipelines with a diameter of 80 mm or more. A scour valve comprises a hand-operated valve on a drainpipe of a diameter 0,4 to 0,6 times the diameter of the pipe being drained. There should be an open drain to lead the washout water to a suitable watercourse.

Scour outlets not connected to a stormwater drain system should be designed to limit the erosion caused by the escaping water.

In reticulation networks, a fire hydrant should, if possible, be positioned so that it can be used as a scour valve. Dead-end mains should terminate in a scour point.

Scour outlets should be sized to permit complete draining of a section of main between isolating valves within two hours.

Anti-vacuum valves

Anti-vacuum (or air-admission) valves should be provided downstream of each section valve in a transmission pipeline, to prevent the build-up of a vacuum when the section valve is being closed. Most air-release valves also act as air-admission valves.

Break-pressure devices

Break-pressure devices may be either break-pressure tanks or pressure-reducing valves.

Where possible, break-pressure tanks should be combined with balancing tanks.

When used, pressure-reducing valves should be provided with a pressure-relief valve on the outlet side, to prevent the possible build-up of pressure resulting from failure of the pressure-reducing valve to operate correctly. The discharge from the relief valve should be conspicuous when it occurs.

The installation should also be provided with a dirt box upstream of, and a bypass pipe around, the pressure-reducing valve, complete with an isolating valve protected against accidental opening. A pressure gauge should be provided on both the upstream and downstream sides of the dirt box.

Marker posts

Marker posts should be placed along the pipelines at intervals sufficient to facilitate location of the route. Marker posts should also be placed at all pipe bends, junctions, and other features.

Anchorage and thrust blocks

Anchorage and thrust blocks should be used whenever the pipeline changes vertical or horizontal direction by more than 10°. Thrust blocks should also be used where the size of the pipeline changes, at blank ends, and on steep slopes (more than 1:6).

Surge control

The likelihood of pressure surges should be investigated and, where necessary, provision made for surge control.

Valve chambers

Sufficient working space to allow a spanner to be used on all bolts should be provided in chambers for isolating, air and other valves.

Venting of air-valve chambers should allow for adequate air flow.

Roof slabs should be designed to allow for removal and replacement of the valve.

Valve chambers should, where possible, be finished proud of the final ground level.

Where necessary, the design should make provision for the possibility of differential settlement between the valve chamber and the pipeline.

WATER STORAGE

General

The purpose of storing water is to meet balancing requirements and cater for emergencies (e.g. fire-fighting) or planned shut-downs.

The balancing volume is required to cater for peak outflows while a constant (or variable) inlet flow is being received.

Reservoir storage

Where water is obtained from a bulk water supply authority, the storage capacity provided should comply with the requirements of the authority. A storage capacity of 48 hours of annual average daily demand is suggested, although there may be situations where 24 hours will suffice.

The nominal capacity for elevated storage, based on the typical period involved in power failures, is given in Table 9.16.

The nominal capacity of the duty pump should be equivalent to the sum of the instantaneous peak demand and the fire demand (obtained from the section on provision of water for fire-fighting), or the instantaneous peak demand plus an allowance of 20%, whichever is the greater.

All pumps should be rated for similar duties so that they are interchangeable.

The standby power source should operate automatically in the event of an electricity supply failure.

Under certain limited circumstances, as an alternative to providing elevated storage and pumps, a scheme comprising booster pumps (variable speed can also be considered) delivering directly into the reticulation can be considered. The total cost, including running and maintenance, should be taken into account. This type of scheme is, however, not a preferred option.

The capacity of the supply main to the reservoir should be designed to provide an inflow rate to the reservoir of not less than 1,5 x annual average daily demand for the area served by the reservoir.

Note should be taken of existing water consumption patterns that can be applied to the area to be served by the planned service reservoir. Demand patterns should lead the design engineer at all times.

It will be to the advantage of the local authority to make use of optimal design techniques for determining reservoir storage, like the time-simulation and the critical-period techniques. Both these methods were developed in the mid-1980s and make full use of the interrelationship between the feeder-main capacity and the reservoir capacity. The time-simulation technique is based on analysing river reservoir behaviour. The critical-period technique is based on the relationship between the total storage required and the feeder-main capacity. If use is made of the techniques mentioned, 48 hours' storage capacity need not be provided.

Caution should be exercised when determining the capacity of reservoirs – too large a reservoir may cause problems associated with stagnant water.

Other storage reservoirs

Storage reservoirs may also be required for the following primary purposes:

- water collection from various sources;
- to provide contact time for a certain water treatment operation, such as chlorination; and
- to provide water to a pump station (booster reservoir).

A reservoir may be either at ground level or elevated.

Location of service reservoirs

Where the main storage reservoir also serves as the service reservoir (i.e. it supplies water at the required pressure to the farthest point in the area), the reservoir should be located near the centre of the area. In flat areas this may be achieved by constructing an elevated tank at the centre. In undulating areas it will usually be more advantageous to select the highest point for its construction. By locating the tank as close to the centre as possible, distribution pipe costs can be minimised, and a more even distribution of pressure achieved.

Alternatively, the reservoir could be situated between

Table 9.16: Elevated storage capacity

PUMPING PLANT SERVING THE ELEVATED STORAGE FACILITY	CAPACITY OF ELEVATED STORAGE (HOURS OF INSTANTANEOUS PEAK DEMAND)*
One electrically driven duty pump, plus one identical electrically driven standby pump, plus standby power generation independent of the electricity supply.	2
One electrically driven duty pump, plus one identical electrically driven standby pump	4

* derived as described in the section above on peak factors.

the distribution area and the source of supply, or at the highest point surrounding the distribution area to obviate the need for elevated storage.

It is also advisable that, if possible, the difference in elevation of the highest water level in the storage reservoir and the lowest laid pipeline should not be more than 60-70 m. If this difference is greater it may be necessary to provide break-pressure devices in the distribution system.

Intermediate storage

The provision of intermediate storage can have a number of objectives, the most important of which are:

- a reduction in the sizes of the main distribution pipes, by reducing the peak-flow demand of these mains;
- a reduction in pipeline pressures;
- a reduction of the impact of supply breakdowns;
- a division of the supply into smaller subsections which can be more easily managed by community organisations; and
- a reduction in the size of the main storage reservoir, in terms of both balancing storage and emergency storage.

The provision of intermediate storage will usually be economically feasible only in areas where the topography is steep enough to obviate the need for elevated storage, or where undulating topography dictates the need for different pressure systems for different sections of the community.

The selection and design of intermediate storage will be based on criteria similar to that for bulk-storage reservoirs.

On-site storage is discussed in the section on "Terminal consumer installations" elsewhere in this chapter.

DISTRIBUTION NETWORKS

General

One of the most important requirements for an economic distribution system is the location of the service reservoir as near to the distribution network as possible. Among other advantages, peaks are evened out and fire protection can be more easily achieved.

General requirements for distribution network design

- The maximum head during the reticulation (under static conditions) should not exceed 90 m.
- The minimum head during the design peak flow should be according to Table 9.17.
- Minimum pipe sizes should not be less than 50 mm (internal diameter).
- Major reticulation pipes should be sized to suit the design period.
- It is advantageous to use the minimum number of different pipe sizes to reduce the holding stock required for maintenance and repair.
- Wherever possible, pipelines should be laid in road reserves and preferably not pass through residential or privately owned property.
- Pipelines on private land should be protected by servitudes in favour of the service owner.
- Where pipelines need to cross roads, care should be taken to ensure that the pipe is well bedded and at a sufficient depth (min 0,8 m cover). It is advisable to maintain a larger-diameter pipe for road crossings than may be required from design considerations.
- Comments in the section on valves and other fittings are also valid for distribution networks.

Table 9.17: Residual pressures

TYPES OF DEVELOPMENT	MINIMUM HEAD UNDER INSTANTANEOUS PEAK DEMAND (m)	MAXIMUM HEAD UNDER ZERO FLOW CONDITIONS (m)
Dwelling houses: house connections	24*	90
Dwelling houses: yard taps + yard tanks	10*	90

* Plus the height difference between the main and the highest ground level at any point on the erf not exceeding 50 m from the boundary adjacent to the main. A minimum head of 5 m for site-specific cases (e.g. developing on top of a hill) may be considered.

- Where air valves and scour valves are required, taps on standpipes or at other terminals should be sited to fulfil this function wherever possible.
- Isolating valves should be located at street corners, or opposite erf corner boundary pegs.
- Where pipes intersect, isolating valves should be installed in the smaller-diameter branches.
- Pipes should not rise above the hydraulic grade line.
- Flushing points (or fire hydrants) should be provided where dead-end mains cannot be avoided.
- A developing practice, "skeletonising" of the network, should be considered where developing areas' services are subject to future upgrading.

Residual pressures

The reticulation system should be designed so that the residual pressure in the reticulation main at any point is within the limits given in Table 9.17 (the desirable residual pressures applicable during fire-flow conditions are given in Table 9.20).

MATERIALS

Considerations in the selection of materials

Most of the materials referred to in these guidelines are listed and described in the relevant sections of the SABS 1200 series and SABS product specifications. Refer to product specifications for details of working pressures and dimensions of pipes made from the alternative materials. Specifications other than SABS should also be consulted where no applicable SABS specifications exist (e.g. ISO).

The materials suitable for use on a particular project and the internal and external corrosion-protection systems for the pipes, joints, fittings and specials may be specified by the controlling authority. If not, the following factors should be considered when selecting suitable materials:

- the life-cycle cost (initial capital plus maintenance costs);
- the chemical composition of the water to be distributed or stored (for example, certain types of pipes may not be advisable for conveying water with a Langelier Saturation Index of less than -0,5, and a detailed assessment of the circumstances will be necessary in such cases); brass fittings, couplings, valves, etc, particularly if soft water is conveyed, should be especially resistant to de-zincification;
- the corrosive nature of the soil and ground water, and the possible existence of stray electric currents; and
- the structural strength of the pipes and reservoirs.

Circumstances requiring particular attention are heaving clay soils, dolomitic areas and high external loading.

In the case of rigid pipes of small diameter, the designer should check for the possibility of beam-type failure. SABS Code of Practice 0102:1987 – Part 2 gives guidelines on the external loadings that can be applied to buried pipelines. The minimum class of pipe, from a structural consideration, should be Class 9.

Materials for pipelines

- Cast iron, steel and galvanised steel are the strongest pipe materials and should be used where high operating pressures are expected. The cost of fittings, especially at high pressures, and the susceptibility of these pipes to corrosion, should, however, be kept in mind. Joint types include threaded, Viking Johnson-type flexible couplings, continuously welded, flanged or spigot and socket types with rubber rings.
- Fibre-cement (asbestos-cement, FC) pipes cost less than iron and steel pipes. FC pipes should preferably be bitumen-dipped. Care must be exercised to ensure good bedding of the pipes when they are installed, as they are susceptible to fracturing as a result of ground movements. Couplings include asbestos-cement sleeves with rubber rings, cast-iron flexible couplings, or Viking Johnson-type flexible couplings. FC bends are not recommended.
- Unplasticised polyvinyl chloride (uPVC) and modified polyvinyl chloride (mPVC) provide easy-jointing pipes and good corrosion resistance. However, PVC pipes suffer a loss in strength when exposed to sunlight, and should therefore not be stored in the open. Pipes may be damaged by careless handling and, as with FC pipes, must be carefully bedded, avoiding stones and hard edges. The preferred type of coupling is spigot and socket rubber ring joint.
- Polyethylene (PE) pipes are supplied in rolls and are relatively flexible. Thus the number of joints and bends is greatly reduced. PE does not deteriorate significantly when exposed to sunlight. There are two types of polyethylene: low-density polyethylene and high-density polyethylene. Low density PE is mainly used for irrigation purposes. High-density PE is suitable for small-diameter mains, secondary pipelines and service pipes. Joints on larger diameter HDPE pipes are typically made

by butt-welding. On smaller pipe sizes, compression-type joints are used.

- Reinforced and pre-stressed concrete are suitable for long, large-diameter transmission lines. Both types have considerable strength and are resistant to corrosion. Spigot and socket joints are used for most reinforced concrete pipes. Pre-stressed pipe-jointing systems can vary, and depend to some extent on the pre-stressing design.

- Glass-reinforced polyester pipes have been made available on the market recently. Various projects have been completed successfully using these pipes. The pipes are also suitable for long and large transmission lines. No corrosion control is required and the pipe compares favourably with the PE pipe.

Materials for communication pipes

Materials generally suitable for communication pipes are:

- galvanised steel with screwed and socketed joints or Viking Johnson-type flexible couplings; and

- polypropylene (PP), high-density polyethylene (HDPE) and low-density polyethylene (LDPE) with external compression-type joints.

Where pipes are laid in aggressive soils, especially where moisture is retained in the soil under a paved surface, metallic pipes must be well protected against corrosion. Plastic pipes are more suitable under these conditions.

Materials for reservoirs

Large reservoirs (>200 m^3) are usually constructed of steel or reinforced concrete. Elevated tanks of steel panels have proved reasonably successful in areas away from the aggressive coastal environment. Lined earth reservoirs with floating covers, or concrete reservoirs with floating covers, are an economical choice for ground reservoirs in South Africa.

For smaller (<50 m^3) reservoirs, ferrocement, masonry, galvanised iron, asbestos-cement and certain plastic and rubber tanks may also be used. Polyethylene and fibreglass tanks, if used for potable water, should be constructed so as to prevent light penetration, which may encourage algal growth.

Traditional structures employed for water storage in the rural areas are not always durable or hygienic. It is often not possible or desirable to erect reinforced-concrete water-retaining structures in these remote areas because the cost may be prohibitive.

Ferrocement

The use of ferrocement tanks in rural areas may be considered, since their construction can be undertaken without sophisticated equipment or highly trained manpower.

Ferrocement simply consists of one part cement mixed with two parts sand and just sufficient water to form a paste-like consistency. This is forced onto layers of closely and evenly distributed wire mesh reinforcement (chicken netting) by hand or by trowel. This technique allows for complex structures with a thin shell thickness.

It has a high strength-to-mass ratio when compared to reinforced concrete. It also requires little or no maintenance when compared to metal tanks, and is more durable than fibre cement. Readers are referred to the following publications, which are noteworthy:

How to build a small ferrocement water tank: CSIR, Division of Water Technology (1988). ISBN 0 7988 34315.

Ferrocement water tanks: International Ferrocement Information Centre. (Available from the Cement and Concrete Institute, Midrand.)

Masonry

Masonry tanks have been constructed successfully and have been in use for many years. Standard plans are available from the Department of Public Works. This type of construction can also be executed with lesser skilled manpower.

Galvanised tanks

Galvanised tanks are also suitable for use in rural areas. Although these tanks can be erected in a short space of time, designers should consider their cost. Specialist contractors are usually employed and opportunities for training and the use of local manpower are therefore limited. Galvanised tanks are also notorious for poor thermal insulation and their service life, even with regular maintenance, is not comparable with, for instance, concrete reservoirs.

Asbestos cement, plastic, fibreglass, polyethylene and rubber tanks

The main advantage of these products is the speed involved in making available storage capacity. Once again, limited opportunities exist for use of local manpower. Transporting these prefabricated tanks is usually difficult. Polyethylene tanks should be considered as only a temporary measure.

CONSTRUCTION

General

Designers ought to be aware of the need for job creation in the provision of services and facilities, and should take this into account. It is also important to consider the requirements of government departments, municipalities and other service authorities in this regard. The decision as to whether specifications are to be modified in order to promote job creation lies with the employer and is not discussed in these guidelines.

National Standardised Specifications for Engineering Construction

The sections of SABS 1200 listed below are recommended for general use:

SABS 1200 A:	General
SABS 1200 AA:	General (Small works)
SABS 1200 D:	Earthworks
SABS 1200 DA:	Earthworks (Small works)
SABS 1200 DB:	Earthworks (Pipe trenches)
SABS 1200 G:	Concrete (Structural)
SABS 1200 GA:	Concrete (Small works)
SABS 1200 L:	Medium pressure pipelines
SABS 1200 LB:	Bedding (pipes)
SABS 1200 LF:	Erf connections
SABS 1200 LK:	Valves
SABS 1200 LN:	Steel pipe and linings

Watertightness test

For the requirements and tests for watertightness of reinforced concrete reservoirs and elevated storage facilities, refer to Clause 3.3.38 of SABS 0120:1980 – Part 2, Section G.

Disinfection of reservoirs and elevated storage facilities

Following completion of construction, the structure should be cleared of debris and the floor swept clean using damp sawdust, to prevent dust from rising. The walls and floors should be hosed down and the water drained away. Water should be admitted into the structure to a depth of approximately 300 mm and uniformly chlorinated so as to attain a minimum chlorine residual of 10 mg/ℓ.

All internal surfaces of the structure, including pipework, should be thoroughly hosed down with the chlorine solution. After all personnel have vacated the structure, a quantity of the chlorinated solution should be poured over the internal access ladder.

The chlorinated solution should be drained prior to filling the structure with potable water.

Should it be necessary for the structure to be emptied after the initial filling so that personnel can gain access to the water retaining portion of the structure, then the disinfection process described above should be repeated.

Markers for valves and hydrants

The positions of isolating valves and hydrants should be clearly indicated by means of permanent marker posts located on the verge opposite the fitting, or painted symbols on road or kerb surfaces.

Symbols on markers should be durable. Where services pass underneath national or provincial roads, markers should be placed on both sides of the road reserve. Similarly, markers should be placed on both sides of servitudes of other service providers.

MANAGEMENT OF WATER DISTRIBUTION SYSTEMS

General

It is not the purpose of this section to discuss all the functions of management as far as water supply systems are concerned. This section is primarily aimed at informing the engineer of the importance of the control of unaccounted-for water in supply systems, and other aspects relating to regulations in this regard. The Water Services Act requires that a Water Services Authority should have full control of water supply in its area of jurisdiction, and therefore unaccounted-for water will be an integral part of management reports.

Unaccounted-for water

The SABS 0306 Code of Practice should be followed in accounting for potable water within distribution systems and in the corrective action to reduce and control unaccounted-for water.

The code also gives guidance on the design of water reticulation systems with water management in mind, and gives guidance on leak detection and pipeline monitoring.

Metering

The information required for accounting and management is generated by proper metering. The importance of metering cannot be overemphasised. The Regulations relating to Compulsory National Standards and Measures to Conserve Water (Government Notice R 22355 dated 8 June 2001), published in terms of the Water Services Act, is a very important document that governs the relationship between the local authority and the consumer.

The regulations stipulate that water to any consumer must be measured by means of a water-volume-measuring device, and that all water be supplied in terms of an agreement between the local authority and the consumer. Metering water districts within water distribution schemes is also a requirement.

Those involved in water supply to communities should take note of these regulations.

Guidelines for metering can be found in the catalogues of meter suppliers.

It is important to note the following requirements:

- all mechanical meters must comply with SABS specifications;
- all meters must be installed according to the manufacturer's instructions;
- meters must be correctly sized;
- meters are to be tested (and replaced if necessary) at regular intervals;
- unmetered connections should not be allowed;
- regular inspection of actual flow is required to confirm meter sizes, where larger meters are installed;
- meter installations should at all times correspond with financial records;
- prepaid water meters should be considered if the community is in favour of this option;
- meters must comply with the Trade Metrology Act (Act 77 of 1973); and
- consumer installations must comply with SABS 0252: Water supply and Drainage for Buildings.

PROVISION OF WATER FOR FIRE-FIGHTING

General

The provision of water for fire-fighting should comply with the requirements as described in SABS Code of Practice 090:1972 – Community Protection against Fire, but with deviations from and additions to the code as described below.

Scope of the SABS Code of Practice 090:1972

The code covers recommendations for the organisation of fire services, water supplies for fire-fighting, and by-laws relative to fire protection. It includes a fire-rating schedule.

It is also intended for use by designers of water supply systems for normal industrial areas, central business districts and residential settlements. Specifically excluded from this document are special types of development, such as bulk oil and fuel storage facilities and airports. For these types of development, reference must be made to specific standards or regulations governing the fire-service requirements.

Fire-risk categories

Areas to be protected by a fire service should be classified according to the following fire-risk categories.

High-risk areas

These areas in which the risk of fire and of the spread of fire is high, such as congested industrial areas, congested commercial areas, warehouse districts, central business districts, and general residential areas with floor space ratio of 1,0 and greater where buildings are four storeys and more in height (residential zone IV).

Moderate-risk areas

These are areas in which the risk of fire and of spread of fire is moderate, such as industrial areas, areas zoned "general residential" with a floor space ratio of less than 1,0 (residential zones II and III) where buildings are not more than three storeys in height, and commercial areas normally occurring in residential districts where buildings are not more than three storeys in height.

Low-risk areas

These are areas in which the risk of fire and the spread of fire is low. This category is subdivided into four groups as follows.

- Low-risk – group 1: Residential areas (residential zone 1) where the gross floor area of the dwelling house, including outbuildings, is generally likely to be more than 200 m^2.
- Low-risk – group 2: Residential areas (residential zone 1) where the gross floor area of the dwelling house, including outbuildings, is likely to vary between 100 m^2 and 200 m^2.
- Low-risk – group 3: Residential areas (residential zone 1) where the gross floor area of the dwelling house, including outbuildings, is generally likely to be less than 100 m^2 but more than 55 m^2. This group includes low-cost housing schemes where the gross floor area of the dwelling house, including

outbuildings and allowing for extensions by the owner, would generally not exceed 100 m^2. Restrictions in force control the height and area of buildings, materials used in their construction and the distances from common erf boundaries. Attached dwelling units are separated by a fire wall with a minimum fire-resistance rating of one hour

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- Low-risk – group 4: Residential areas (residential zone 1) where the gross floor area of the dwelling house, including outbuildings, is generally not more than 55 m^2. This group includes low-cost housing schemes. Restrictions in force control the height and area of buildings, materials used in their construction and the distances from common erf boundaries. Attached dwelling units are separated by a fire wall with a minimum fire-resistance rating of one hour.

Fire protection in general

In the case of areas not yet developed, a subdivision of the planned layout into areas or zones according to the relevant fire-risk category should be made, taking into account possible planning parameters such as floor space ratios, height restrictions and building-material restrictions.

When water reticulation systems are being designed for industrial areas, these areas should generally be classified as moderate-risk.

Where the reticulation in an industrial area has been designed on the basis of a moderate-risk classification, a limited number of high fire-risk types of industry can subsequently be permitted to be established in the area without warranting a re-classification of the area to the high-risk category. In this case, the approval conditions for the establishment of the industry should specify the provision of the extra water for fire-fighting (as deemed necessary by the fire department) which is over and above that allowed for in the design of the reticulation. Such provision could take the form of an additional supply to the site, or storage of water on the premises, and would be provided at the cost of the applicant.

Examples of high-risk types of development are:

- timber-storage yards;
- timber-clad buildings;
- institutional buildings and buildings in which hazardous processes are carried out; and
- areas where combustible materials are stored which, because of the quantity of such materials, the extent of the area covered by the materials and the risk of fire spread, may be deemed high-risk.

In the case of existing developed areas, a survey of the fire hazards of the area should be made at intervals of not more than three years. Such a survey should take account of the height, the type of construction, the occupancy of the buildings, the means of approach to buildings, the water supply available and any other feature affecting the fire risk.

Should such a survey indicate the need for re-classification of an area into a higher risk category, then the area should be re-classified accordingly, and the chief fire officer, in conjunction with the local authority engineer, must prepare a report for submission to the controlling authority, requesting that the fire service be upgraded according to the new classification.

Water supply for fire-fighting

The elements in a water reticulation system for the supply of water for fire-fighting are:

- *trunk main:* the pipeline used for bulk water supply;
- *water storage:* reservoir and elevated storage;
- *reticulation mains:* the pipelines in the reticulation to which hydrants are connected; and
- *hydrants:* these may be of the screw-down or sluice-valve type.

The capacity of the above elements is determined according to the category of fire risk applicable.

The fire flow and hydrant flow for which the water reticulation is designed should be available to the fire-fighting team at all times. Close liaison between the water department of the local authority and the fire service should be maintained at all times, so that the water department can be of assistance in times of emergency – for example, isolating sections of the reticulation in order to increase the quantity of water available from the hydrants at the scene of the fire.

Note: *Low-risk – Group 4 category*

No specific provision for fire-fighting water is made in trunk mains, water storage, or reticulation mains in these areas. Hydrants should, however, be located at convenient points in the area on all mains of 75 mm nominal internal diameter and larger, and in the vicinity of all schools, commercial areas and public buildings.

Fire-fighting in areas zoned Low-risk – Group 4 should generally be carried out using trailer-mounted water tanks or fire appliances that carry water, which can if necessary be replenished from the hydrants provided in the reticulation.

Development within areas falling into the Low-risk – Group 4 category, and which qualify for inclusion in higher risk categories, should be protected according to the relevant category as outlined in the Code of Practice and these Guidelines.

Design of trunk mains

The mains supplying fire-risk areas should be designed so that the supply is assured at all times.

Trunk mains serving fire-risk areas should be sized for a design flow equivalent to the sum of the design instantaneous peak domestic demand for the area served by it, and the fire flow given in Table 9.18.

Where an area served by the trunk main incorporates more than one risk category, then the fire flow adopted should be for the highest risk category pertaining to the area.

Water storage

Ground reservoirs

The storage capacity of reservoirs serving fire areas should, over and above the allowance for domestic demand, include for the design fire flow obtained from Table 9.18 for a duration at least equal to that given in Table 9.19.

Where an area served incorporates more than one risk category, then the design fire flow and duration used should be for the highest risk category pertaining to the area served by the reservoir.

Elevated storage

There need be no provision for storage of water for fire-fighting when the pumping plant serving the elevated storage facility is sized to deliver the sum of the instantaneous peak demand and the fire flow obtained from Table 9.18, or the instantaneous peak demand plus an allowance of 20%, whichever is the greater. A standby pumping plant should also be provided.

Reticulation mains

Reticulation mains in fire areas should be designed according to the design domestic demand required. The mains should, however, have sufficient capacity to satisfy the criteria given in Table 9.20.

The minimum residual head should be obtained with the hydrant discharging at the minimum hydrant flow rate, assuming the reticulation is operating under a condition of instantaneous peak domestic demand at the time.

The water reticulation design for each reservoir supply zone should be checked for compliance with this paragraph on the minimum basis of the following:

High-risk and moderate-risk areas

The group of hydrants (see Table 9.18) included in each critical area in the reticulation are in use simultaneously. Critical areas should be checked individually.

Low-risk areas

- <u>Areas of less than 2 000 dwelling units:</u> assume one hydrant in use at a time; each critical area should be checked individually;
- <u>Areas of 2 000 and more dweling units:</u> assume a hydrant in each critical area in use simultaneously on the basis of one hydrant per 2 000 dwelling units or part thereof.

Table 9.19: Duration of design fire flow

FIRE-RISK CATEGORY	DURATION OF DESIGN FIRE FLOW (h)
High-risk	6
Moderate-risk	4
Low-risk – Group 1	2
Low-risk – Group 2	1
Low-risk – Group 3	1
Low-risk – Group 4	N/A

Table 9.18: Design fire flow

FIRE-RISK CATEGORY	MINIMUM DESIGN FIRE FLOW(ℓ/min)	MAXIMUM NUMBER OF HYDRANTS DISCHARGING SIMULTANEOUSLY
High-risk	12 000	All hydrants within a radius of 270 m of the fire
Moderate-risk	6 000	
Low-risk – Group 1	900	1
Low-risk – Group 2	500	1
Low-risk – Group 3	350	1
Low-risk – Group 4	N/A	N/A

Table 9.20: Fire-flow design criteria for reticulation mains

FIRE-RISK CATEGORY	MINIMUM HYDRANT FLOW RATE FOR EACH HYDRANT (ℓ/min)	MINIMUM RESIDUAL HEAD (m)
High-risk	1 500*	15
Moderate-risk	1 500*	15
Low-risk – Group 1	900	7
Low-risk – Group 2	500	6
Low-risk – Group 3	350	6
Low-risk – Group 4	N/A	N/A

*With a design maximum of 1 600 ℓ/min per hydrant

Hydrants

Hydrants should not be provided off mains smaller than 75 mm diameter.

Hydrants should be located in vehicular thoroughfares and opposite erf boundary pegs, and according to Table 9.21.

The hydrants for the high-risk and moderate-risk categories should be the 75 mm diameter sluice-valve type. For the low-risk category, the hydrant may be the screw-down type.

In the case of new developments, hydrant types should be similar to those used by an adjacent metropolitan area, if relevant.

The location of hydrants should be clearly indicated.

Hydrants should be serviced and the flow rate checked for conformity with Table 9.20 at intervals not exceeding one year.

Isolating valves

In reticulation networks, isolating valves should be provided so that not more than four valves need to be closed to isolate a section of main, and so that the total length of main included in an isolated section does not exceed a nominal 600 m.

Valves should be located at street corners opposite erf corner boundary (splay) pegs, and intermediate valves opposite the common boundary peg between two erven.

Fire protection in developing and rural areas

Fire protection in developing and rural areas needs special attention. Designers of water-reticulation systems should accept that the local unavailability of fire-fighting resources at the time of design will most certainly change during the lifetime of the scheme. It is not suggested that the design of systems be according to the guidelines given for developed areas, but designers should consider the following:

- Whatever fire-fighting equipment is provided should be compatible with that of the surrounding area; close liaison with the responsible emergency services agency is considered essential.
- The provision of permanent equipment – like fire hydrants at business sites and institutional erven – should be considered and the type and location should be chosen to minimise vandalism or illegal use.
- The accessibility of the area and the space required for vehicles used by fire-fighting services should be taken into account.

Table 9.21: Location of hydrants

FIRE-RISK CATEGORY	LOCATION OF HYDRANTS
High-risk	distance apart: 120 m maximum
Moderate-risk	distance apart: 180 m maximum
Low-risk – Group 1	distance apart: 240 m maximum
Low-risk – Group 2	distance apart: 240 m maximum
Low-risk – Group 3	distance apart: 240 m maximum
Low-risk – Group 4	Convenient points on mains 75 mm diameter and larger

- Dams and rivers could be utilised by placing hydrants close by for the purpose of pumping water from them.
- Close liaison with the community is required to determine what fire-protection arrangements exist and whether these should be revised.
- Where water-reticulation networks are designed, consideration should be given to their possible future upgrading, and allowance should be made for fire flow in pipelines, taking into consideration the other factors mentioned above. Reference should also be made to "skeletonising" (see Glossary).

GLOSSARY

Balancing storage refers to the volume required in a storage reservoir to cater for peak flows while receiving a constant inlet flow.

Developing areas are considered to be those areas where the services to be installed are subject to future upgrading.

Developed areas are considered to be those areas where the services installed are not subject to future upgrading (i.e. the services are already at the highest intended level).

Fire hose: flexible pipe used for fire-fighting purposes, suitable for connection to a hydrant.

Fire flow: the rate of flow of water required by the fire-fighting service for the extinguishing of fires.

Hydrant: a valve-controlled outlet on the water reticulation system to which a fire hose can be attached, either directly or with an adaptor or standpipe.

Hydrant flow: the discharge rate of water from a hydrant.

Package water treatment plant: a prefabricated purification plant that is assembled on site. It may or may not require small civil construction works and piping for complete functioning.

Peak factor: a dimensionless value, indicating the relationship between peak consumption and average consumption.

Residual head: the pressure in the water main at the hydrant take-off point while the hydrant is discharging.

Skeletonising: is the practice of designing and installing major reticulation pipes for a future higher level of service (which implies that the system will have spare capacity under present conditions.)

Turbidity: a measure of the resistance of water to the passage of light through it; it is caused by suspended or colloidal matter in the water.

Water transmission: means the transport of water from the source to the treatment plant (if there is one) and onward to the distribution area.

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