Section J
Water supply

The Neighbourhood Planning and Design Guide

Part II

Planning and design guidelines

Symbols at text boxes

More detailed information is provided about the issue under discussion

Important considerations to be aware of are highlighted

Relevant content from a complementing resource is presented

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Section J
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The Neighbourhood Planning and Design Guide

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J.1 Outline of this section

J.1.1 Purpose

Settlements (and neighbourhoods as the 'building blocks' of settlements) are integrated systems in which various components are interconnected, and this section highlights the role of water supply in this system. The aspects addressed in this section play an essential role in achieving the vision for human settlements outlined in **Section B** and relate in particular to **Section K** which deals with sanitation and **Section L** which deals with stormwater management.

J.1.2 Content and structure

This section (Section J) is structured to support effective decision-making related to the provision of water. The decision-making framework is outlined in Figure J.1, and the structure of this section is briefly described below.

Universal considerations

General aspects that should be taken into consideration when making higher level decisions regarding the provision of water are highlighted, including the following:

- The regulatory environment, including key legislation, policies, frameworks and strategies
- The key objectives that should be achieved as a result of the application of the guidelines provided
- Local or international approaches, mechanisms, concepts and current trends that could possibly be utilised to achieve the key objectives
- Contextual factors specific to the development project to be implemented such as the development type and setting

Planning considerations

Factors to consider when making more detailed decisions regarding the provision of water are outlined, including the following:

- The characteristics of the development, including the nature of the proposed neighbourhood, the anticipated number of residents and specific features that would have to be incorporated or requirements that would have to be met
- The existing features of the site and immediate surroundings (built and natural environment) as determined by the physical location of the proposed development
- Options related to the provision of water that are available for consideration

Design considerations

Guidelines to assist with the design of water supply infrastructure.

Glossary, acronyms, abbreviations and endnotes

A glossary, a list of acronyms and abbreviations, and endnotes (containing sources of information, explanatory comments, etc.) are provided at the end of Section J.

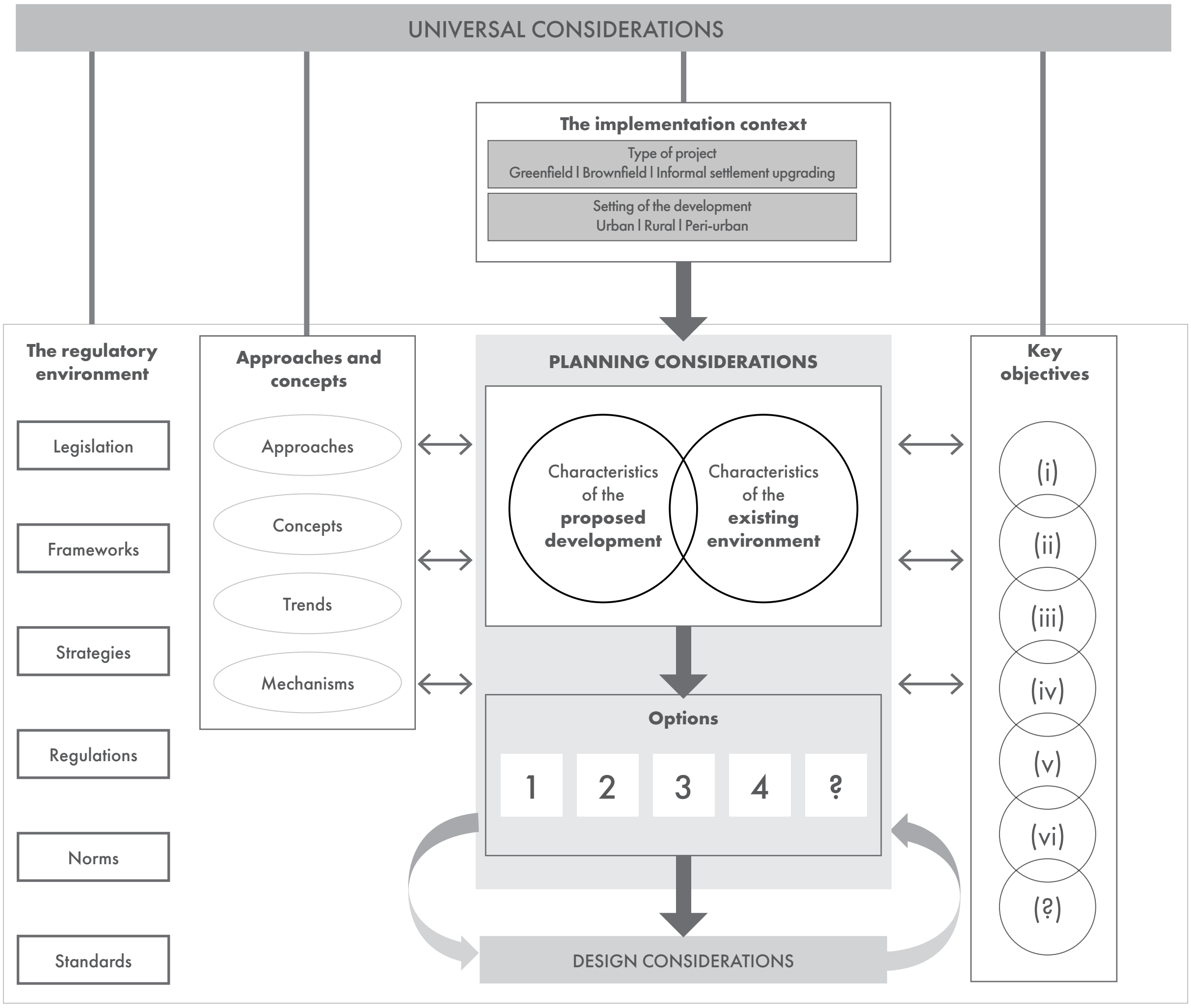


Figure J.1: A framework to assist with planning and design decisions

J.2 Universal considerations

J.2.1 The regulatory environment

A range of legislation, policies and strategies guides the provision of water to South African settlements. Some of these are listed below. Since they are not discussed in detail, it is vital to consult the relevant documents before commencing with any development. (Also see **Section D.1**.)

All building and construction work in South Africa is governed by the National Building Regulations and Building Standards Act, 1977. Always refer to *SANS 10400 - The application of the National Building Regulations available* from the South African Bureau of Standards (SABS).[1] Municipalities may have additional guidelines, regulations and by-laws that may be applicable.

The Department of Water and Sanitation (DWS) is the custodian of the country's water resources. Its legislative mandate seeks to ensure that the country's water resources are protected, managed, used, developed, conserved and controlled through regulating and supporting the delivery of effective water supply. Below is a summary of the main acts and policies for potable water and water services.

The National Water Act

The National Water Act (NWA), 1998 regulates the use, flow and control of all water in the country to ensure that water is allocated equitably, and used beneficially in the interest of the public while promoting environmental values. It aims to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways that take into account, among other factors the following:

- Meeting the basic human needs of present and future generations
- Promoting equitable access to water
- Promoting the efficient, sustainable and beneficial use of water in the public interest
- Facilitating social and economic development
- Providing for the growing demand for water
- Protecting aquatic and associated ecosystems and their biological diversity
- Reducing and preventing pollution and degradation of water resources
- Meeting international obligations
- Promoting dam safety
- Managing floods and droughts
- Establishing suitable institutions and ensuring that these institutions have an appropriate community, racial and gender representation

Basic water supply

A basic water supply is defined as the provision of a basic water supply facility, the sustainable operation of the facility (available for at least 350 days per year and not interrupted for more than 48 consecutive hours per incident) and the communication of good water use, hygiene and related practices.

The National Water Services Act

The National Water Services Act (NWSA), 1997 governs the provision of water services to users. Section 3 of the act states that "everyone has a right of access to basic water supply and sanitation".

The Second National Water Resources Strategy

The Second National Water Resource Strategy (NWRS2) of 2013 provides a framework for the protection, use, development, conservation, management and control of water resources in South Africa. Core Strategy 6 in the NWRS2 spells out that "implementing water use efficiency, conservation and water demand management is a non-negotiable principle". The NWRS2 has adopted a position of developmental water management, a framework that addresses the linkages between water management and the developmental and transformational goals of government. This approach requires the consideration of the entire water cycle and sanitation value chain in terms of how water can contribute to achieving equitable, beneficial and sustainable development across the country.

The Strategic Framework for Water Services

The Strategic Framework for Water Services (SFWS) supports the Water Services Act in providing direction and guidance on water services to ensure that "adequate and appropriate investments are made to ensure the progressive realisation of the right of all people in its area of jurisdiction to receive at least a basic level of water and sanitation services".

The framework also states that "emphasis will be placed on gender-sensitive health and hygiene education so that the provision of water and sanitation services will be accompanied by improvements in health and significant reductions in water-related diseases such as cholera and diarrhoea".

The National Water and Sanitation Master Plan

The National Water and Sanitation Master Plan (NW&SMP) introduces a new paradigm that will guide the South African water sector, led by the DWS and supported by local government and other sector partners, towards the urgent execution of tangible actions that will make a real impact on the supply and use of water and sanitation. The NW&SMP forms part of a suite of initiatives led by the DWS in conjunction with other government departments and agencies, the private sector and civil society to aim for a water-secure future with reliable water and sanitation services for all, and that these contribute towards meeting national development objectives.

National Norms and Standards for Domestic Water and Sanitation Services

The National Norms and Standards for Domestic Water and Sanitation Services of 2017 draw on the principles of universal access, human dignity, user participation, service standards, redress, and value for money. The principles of sustainability, affordability, effectiveness, efficiency and appropriateness should be considered when supplying water to a community. Cognisance is taken of the water scarcity context of the country, and as such, reduction, reuse and recycling are common themes that underpin the norms and standards. The effectiveness of the services towards the protection of public health and the greater economic development agenda of the country also receives attention.

Water quality legislation

All water made available for drinking must be potable. Potable water is water that is clear, tastes and smells good, and is free of contaminants and pollutants that could affect human health - thus water of a quality compliant with *South African National Standard-Drinking Water, Part 1: Microbiological, physical, aesthetic and chemical determinants* (SANS 241-1)[2] as may be amended from time to time. Key references relating to the provision of safe drinking water quality in South Africa include the following:

- Water Services Act, 1997
- National Water Act, 1998
- Municipal Structures Act, 1998
- Compulsory National Standards for the Quality of Potable Water (2001)
- Strategic Framework for Water Services (2003)
- National Health Act, 2003
- Second National Water Resources Strategy (2013)
- South African Water Quality Guidelines (1996)
- Framework for Drinking Water Quality in South Africa (2005)

The National Framework for Sustainable Development

In tandem with the DWS legislation, the National Framework for Sustainable Development (NFSD) by the Department of Environmental Affairs (DEA) emphasises a cyclical and systems approach towards achieving sustainable development through efficient and sustainable use of natural resources; socio-economic systems embedded within and dependent upon ecosystems; and meeting basic human needs to ensure that the resources necessary for long-term survival are not destroyed for short-term gain.

The National Environmental Management Act

The National Environmental Management Act (NEMA), 1998 is the framework legislation for environmental management in South Africa. Any new development should adhere to the national environmental management principles included in this act and comply with the environmental management regulations. Regulations published in terms of NEMA list activities for which Environmental Impact Assessments (EIAs) are required to evaluate the impact of human actions on the receiving environment.

The Housing Act

The Housing Act, 1997 specifies water as a fundamental part of the right to adequate housing. The act defines housing development to include "all citizens, and permanent residents of the Republic having access to potable water, adequate sanitary facilities and domestic energy supply". Services must be balanced with community preferences, affordability indicators, and sound engineering practice.

Water Services Development Plans

Central to the supply of water to a neighbourhood is the Water Services Development Plan (WSDP) of the relevant Water Services Authority (WSA), which is required in terms of the National Water Services Act. The WSDP forms the basis for each WSA to gradually realise the objectives of the National Water Services Act.

The provision of water infrastructure in residential development also provides an opportunity to consider planning of water provision infrastructure for purposes other than potable use, such as toilet flushing, irrigation and laundry.

J.2.2 Key objectives

The water sector strives to establish water-sensitive and waterwise settlements in providing universal access to safe drinking water and adequate sanitation. Objectives related to water supply have been formulated in a range of South African policy and planning publications, and the planning and design assistance included in this Guide aims to support these. The establishment of so-called 'waterwise' settlements[3] requires neighbourhood water supply infrastructure and service provision that provide regenerative water services, create water-sensitive neighbourhoods, promote integrated water management and enable waterwise communities.

(i) Provide regenerative water services

Finite water resources must be protected from overexploitation and pollution, and infrastructure and services dealing with water supply should ensure a clean and healthy living environment. In order for water services to be regenerative, water supply systems should meet the following requirements:

- Replenish water bodies and their ecosystems by discharging to them only what can be absorbed by the natural environment. This will protect the quality of water resources.
- Reduce the amount of water and energy used. Reducing the overall demand for fresh water could be done by promoting waterwise behaviour and by implementing by-laws that require water-efficient appliances and fixtures. It can also be done by installing water systems that do not only minimise real losses, but also curb water usage.
- Reuse and use diverse sources of water, e.g. rainwater, stormwater, greywater and recycled wastewater. The reuse of water is becoming more acceptable and feasible because of growing water shortages, improved purification technology and decreasing treatment costs.

(ii) Create water-sensitive neighbourhoods

A water-sensitive neighbourhood is an area within a settlement where the negative impact of urban development on the environment is minimised and the sustainability of water is maximised. The approach of Water Sensitive Urban Design or Water Sensitive Design (WSUD/WSD) is discussed in Section J.2.3. The intention of WSUD/WSD is to mimic, as far as possible, the natural process of maintaining the water balance when planning and designing a neighbourhood or settlement. This could be done by providing multiple and adaptive options for the sourcing, conveyance, storage, treatment and end use/disposal of water throughout the system. Water-sensitive neighbourhoods also have enhanced liveability, which can among others be achieved by the reduction of flood risk in the settlement and the provision of sustainably irrigated public open space.

(iii) Promote integrated management of water

A settlement (and a neighbourhood) is connected to and dependent on the catchment that it is situated in. The catchment also interacts with neighbouring catchments. The integrated management of water implies that the role that the settlement or neighbourhood plays in this network is acknowledged and considered in the planning and design of water supply infrastructure and services. Among others, such an approach will support planning for drought mitigation, managing extreme events and planning for food security. The integrated management of water also implies that water supply infrastructure should be linked to the provision of transportation, electrical energy, housing and solid waste management within a neighbourhood.

(iv) Enable waterwise communities

Stakeholders' needs, priorities and interests should be considered in the water supply planning and design process. The process should also be used to empower residents and users by improving their understanding of the risks (e.g. flooding and scarcity) and opportunities (e.g. resource recovery and reducing dependency on uncertain future resources) associated with water supply. All built environment practitioners should become more waterwise in their area of expertise, so that they can integrate across sectors and participate in transdisciplinary planning teams.

Climate change is causing an increase in the frequency, intensity and duration of extreme events such as droughts, floods, high winds and tropical storms. Project design, construction and operation should take into account the current and future frequency, intensity and duration of extreme events that may result in infrastructure damages and failure, contaminated drinking water, spread of disease, and water scarcity.

J.2.3 Approaches and concepts

This section briefly summarises possible approaches, strategies and mechanisms, as well as local or international concepts, ideas and trends that could be considered to achieve the objectives discussed in Section J.2.2.

J.2.3.1 Integrated Water Resources Management

Integrated Water Resources Management (IWRM) is a cross-sectoral policy approach, designed to replace the traditional, fragmented sectoral approach to water resources and management. IWRM is based on the understanding that water resources are an integral component of the ecosystem, a natural resource, and a social and economic good. According to the Global Water Partnership, IWRM "promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" [4].

J.2.3.2 Water Conservation/ Water Demand Management

Closely related to IWRM, the concepts of water conservation and water demand management are used in combination (WC/WDM) to refer to a two-pronged water management approach that focuses on preventing wastage of water and influencing how available water is used. Water conservation is defined as the minimisation of loss or waste of water, the preservation, care and protection of water resources and the efficient and effective use of water. By using a WC/WDM approach, the conservation aspect of water management is complemented by efforts to change the demand for water. Water Demand Management therefore refers to the adaptation and implementation of a strategy by a water institution or user to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability.

J.2.3.3 Water quality

Water is fit for purpose when it meets the quality standards relevant to the specific use - whether for domestic use (potable and non-potable), industrial purposes, or the maintenance of ecosystems. Water supply should be planned and delivered to ensure that the design, positioning and conditions of use, as well as its management, are sensitive to people's cultures and priorities. The health and well-being of settlements should be promoted through actively addressing the prevention and control of disease, injury or any form of harm, and facilitating the practice of hygienic behaviours.

J.2.3.4 Water Sensitive Urban Design / Water Sensitive Design

Water Sensitive Urban Design (WSUD), an approach to urban water management that originated in Australia, is an approach aimed at managing the urban water cycle in a more sustainable manner so as to improve water security.[5]

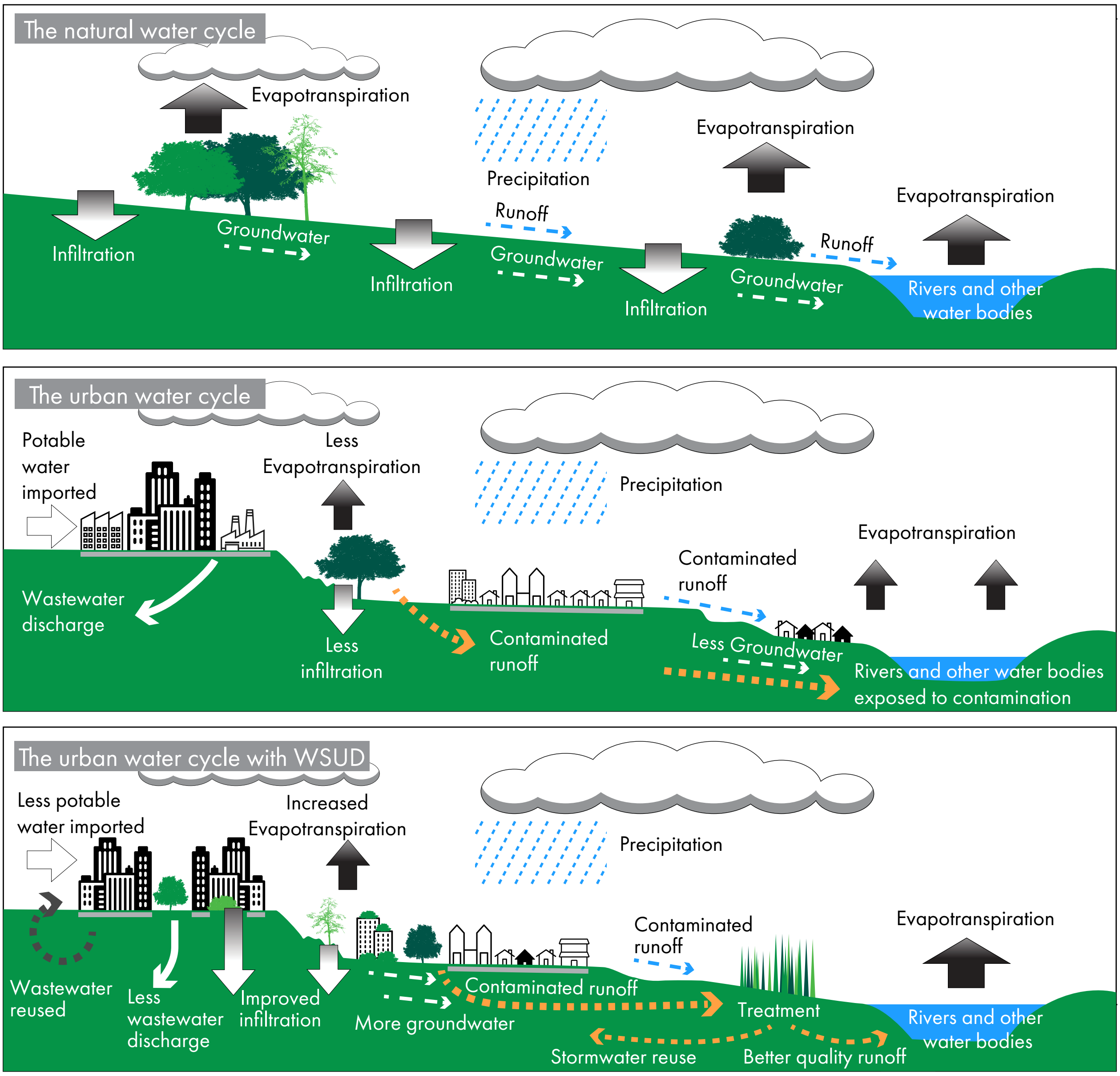


Figure J.2: The water cycle under different conditions

Within the South African context, WSUD is also referred to as Water Sensitive Design (WSD) to acknowledge the fact that the approach could be applied to settlements in general, not only to those in an urban setting.[6] The basic premise of WSUD/WSD is that water is a scarce and valuable resource, and therefore it needs to be managed wisely and with due care (sensitively). This approach encompasses all aspects of the water cycle and integrates urban design with the provision of infrastructure for water supply, sanitation, wastewater, stormwater and groundwater. The purpose of WSUD/WSD is to reduce the negative impact of urban development on the environment and to enhance the sustainability of water. The intention is to, as far as possible, mimic the natural process of maintaining the water balance when planning and designing a neighbourhood or settlement (see Figure J.2).

The natural process (water cycle) involves, among others, precipitation, evapotranspiration, runoff and infiltration. However, in a built-up area other components are added to the process. In addition to precipitation, potable water is imported into the area, wastewater is generated that needs to be discharged somewhere, and evapotranspiration is inhibited. Furthermore, because a substantial part of the area is covered with hard surfaces (buildings, streets, paving etc.), infiltration of water into the earth is reduced while the volume of (poor quality) runoff increases. WSUD/WSD aims to reduce the adverse effects of the built environment on the water sources and to create settlements that preserve the natural water cycle. Strategies or interventions that could be implemented include the following:[7]

- Sustainable Drainage Systems (SuDS). This is an approach to managing stormwater runoff that aims to reduce downstream flooding, allow infiltration into the ground, minimise pollution, improve the quality of stormwater, reduce pollution in water bodies, and enhance biodiversity. Rather than merely collecting and discarding stormwater through a system of pipes and culverts, this approach recognises that stormwater could be a resource. SuDS involve a network of techniques aimed at controlling velocity and removing pollutants as runoff flows through the system. This involves mechanisms and methods such as rainwater harvesting, green roofs, permeable pavements, soakaways, swales, infiltration trenches, bio-retention areas, detention ponds, retention ponds, wetlands etc. These interventions can form a natural part of open spaces in a settlement and contribute to the quality of the environment and the character of a neighbourhood.[8]
- Appropriate sanitation and wastewater systems. Technologies that reduce water use, allow for the use of treated wastewater or recycled water, and minimise wastewater, could contribute significantly to the effective and efficient utilisation of water resources in a settlement.
- Groundwater management. Groundwater should be regarded as a resource, and therefore aquifers should be conserved and protected from contamination and artificial recharge options should be considered where appropriate.
- Sustainable water supply. Various aspects should be considered to improve efficient water use and reduce the demand for potable water, including water conservation, water demand management, addressing water losses, and developing alternative water sources (e.g. rainwater, stormwater, wastewater and groundwater).

WSUD/WSD requires a multi-disciplined, holistic approach to neighbourhood and settlement planning and design. Various sections of this guide relate directly to this approach, in particular **Section F** (Neighbourhood layout and structure), **Section G** (Public open space), **Section I** (Transportation and road pavements), **Section K** (Sanitation), and **Section L** (Stormwater).

A water service is sustainable when:

- the water sources are not overexploited, but naturally replenished;
- it demonstrates a cost-effective use of resources;
- the selection of the water service involves the users by taking into consideration gender issues, establishes partnerships with local authorities, and involves the private sector as required;
- the establishment cost (capital cost), maintenance, rehabilitation, replacement and administrative costs (operational costs) are recovered at local level through affordable user tariffs, or through sustainable financial mechanisms (grants, etc.); and
- effects on the environment are minimised to within acceptable norms and standards.

J.2.3.5 Reliability of water services

A water service is regarded as being reliable if adequate quantity and appropriate quality of water is available and accessible at least 363 days per year, with supply interruptions of no longer than 48 hours. Reliability is measured through the availability of adequate and continuous quantity, required quality, and durable, well-constructed, well-maintained, and correctly used infrastructure. Reliable water services may increase consumers' willingness to pay for services and subsequently may improve the revenue base of the water supply service provider.

J.2.3.6 Infrastructure asset management

Asset management is a collection of management practices using assets as the starting point for making operation and strategic decisions. Life-cycle asset management includes the management of assets, their associated performance, risks and expenditures over their life cycles to extract an optimum functional life from these assets. The infrastructure life cycle comprises three distinct phases namely the planning of the full asset life cycle, the establishment of the infrastructure (design, procure and construct) and the operation and maintenance of the infrastructure. Well-planned, resourced and implemented asset management reduces costs by postponing expensive replacement and avoiding breakdowns. In the water sector, assets are the physical components of water systems e.g. water sources, treatment works, pipes, pumps, meters, storage tanks and valves.[9]

All projects need to be planned for the full life cycle i.e. every infrastructure project plan must include a life-cycle cost analysis that provides for all resources required to ensure the municipality has the finances, materials, equipment, artisans and labour to manage the assets and implement effective operation and maintenance for the whole design life of the infrastructure element. The WATCOST model[10], developed by and available from the WRC, provides guidance on the determination of the life-cycle cost of a water supply system. Refer to the *Asset Management Guideline*[11] available from the DWS for more information.

Energy and water

Energy is needed in the operation of water infrastructure systems through processes related to the abstraction, treatment, transfer, distribution, and discharge of water and wastewater. Water is in most cases also required in the generation of electrical energy. This relationship between energy and water offers opportunities to deliver both water and energy generation and saving through appropriate planning, design and operational initiatives. Infrastructure constructed in the delivery of water services should consider renewable energy as a viable source of electricity that is needed to operate water supply infrastructure. Refer to Section N for guidance on electrical energy.

J.2.4 The implementation context

This section highlights the contextual factors – specifically related to the type of project and the setting of the development – that should be considered when making decisions about planning and designing for water supply. Also refer to Section D.2.1 (Type of development) and Section D.2.2 (The setting of the planned development). Cognisance must be taken of the interdependencies that exist between water supply and the various other water-related services, such as sanitation (see Section K) and stormwater (see Section L).

J.2.4.1 The type of development

(i) Greenfield development

Greenfield projects can theoretically accommodate most water supply types. The deciding factor would normally be the availability of water resources and the most practical, affordable and achievable chance to build neighbourhoods that are waterwise, land efficient, fiscally secure, environmentally responsive, and deliver a better way of life.

When planning and designing the neighbourhood water supply as part of a greenfield development project, the following matters have to be considered:

- Undisturbed portions of the natural environment are often found on greenfield sites. When planning and designing water supply, the preservation or improvement of natural freshwater ecosystems and the creation of additional freshwater habitats that contribute to the availability, protection and enhancement of appropriate, high-quality river and wetland habitat (which mimics the natural condition of open space, trees and on-site natural features) should be considered.
- The provision of water supply needs to be based on a thorough assessment of the surrounding area to evaluate the availability and capacity of nearby bulk supply systems that could supply the planned neighbourhood. If the development is not physically integrated into the existing settlement, it may be necessary to plan for the provision of a new or a separate bulk water supply system.
- Greenfield sites often do not have adequate access to municipal services, such as water supply, sanitation, stormwater management systems, electricity supply, and solid waste removal. These service connections may be a substantial distance away, especially if the site is in a rural area. The capacity of the existing services may also not be sufficient to accommodate the proposed development and may require an upgrade to service the

proposed development adequately. The costs associated with new municipal services, or extensions to existing systems, and the measures to curb these costs, will have a significant impact on planning and designing water supply to the site.

(ii) Brownfield development

When planning and designing the water supply for a brownfield development project, the following has to be considered:

- Since brownfield sites are normally part of the fabric of an existing city or town, existing water supply infrastructure may be readily accessible. Care should be taken to ensure that the existing systems can accommodate the upgrading or redevelopment of an existing area.
- Sites for redevelopment often have built structures that may have heritage value. Identify heritage elements that need to be protected when constructing the water supply infrastructure.

(iii) Informal settlement upgrading

Informal settlement upgrading often involves in-situ development, which implies that existing houses are left in place when the neighbourhood is upgraded – streets are aligned and widened, drainage is improved and homes are connected to the water and sanitation grids. Acceptability and perceptions may be important factors to address when making decisions regarding water supply options. When planning and designing the water supply for an informal settlement upgrading project, the following needs to be considered:

- A Water Services Authority is not allowed to provide water services on land that is not owned by them, unless permission is obtained from the landowner by means of a registered servitude.
- Informal settlements are often isolated from the water supply grid. Linking up with existing water supply networks may have a major impact on the system.
- Informal settlements grow organically and there may be layouts that seem unconventional. Water supply systems for the upgraded informal settlement have to accommodate these anomalies.

J.2.4.2 The setting of the development

(i) Rural

The rural areas of South Africa comprise a variety of settlements types, including rural villages and towns, dense rural settlements and dispersed settlements. When making decisions regarding the water supply infrastructure for a development in a rural setting, the following would typically need to be considered:

- Most traditional villages are located on farm portions or in some instances on land that has not been surveyed. The land is communally owned and is usually managed by a hierarchy of traditional leaders. Water supply planning and design are guided by these decision-makers rather than by the local municipality’s planning and development policies.
- Traditional homesteads may require an approach that is different from urban areas. For example, in a rural residential area, allow for accessing water from boreholes, springs, rainwater harvesting, communal wash houses and communal street taps.

(ii) Peri-urban

The development setting of peri-urban areas is diverse and includes a mix of settlement patterns, socio-economic statuses and access to services. Settlement on the periphery of metropolitan areas and towns may include informal settlements, low-income housing and high-income low-density developments. When planning and designing water supply infrastructure for a development in the urban fringe area, the following should be considered:

- Peri-urban areas are under pressure as most new urban-based developments and changes are concentrated in these zones of rural-urban transition.[12] The often high rate of urbanisation should be considered when planning and designing the water supply infrastructure of new developments as there is a likelihood that peri-urban areas have to accommodate more people and higher densities in future.
- The costs of providing conventional urban infrastructure in peri-urban areas are often prohibitive. In many cases, alternative ways of service provision need to be considered, e.g. package plants for water treatment, rainwater harvesting, etc.

(iii) Urban

Urban settings can take on different forms, and therefore developments will vary in nature. Urban areas include central business districts (CBDs), residential suburbs, informal settlements, and so-called townships, and this will influence the type of water supply infrastructure to be provided. Residential densities are often high and yard connections usually offer the most appropriate intervention and should be regarded as a basic level of service in terms of the free basic services policy.

J.3 Planning considerations

This section deals with the planning of a water supply service. In this context, the term 'planning' means making informed decisions regarding the type or level of service to be provided, and then choosing the most appropriate water supply option(s) based on a thorough understanding of the context within which the planned development will be implemented.

This section outlines a range of questions that should be asked and factors that have to be considered to inform decisions regarding water supply to be provided as part of a development project.

Decisions regarding water supply must be informed by a clear understanding of the features and requirements of the proposed project. This would require an assessment of the characteristics of the proposed development. Furthermore, the characteristics of the environment in which the new development will be located, need to be examined and possible services and infrastructure that could be utilised must be identified.

J.3.1 Characteristics of the proposed development

Decisions regarding water supply need to be guided by an assessment of the characteristics of the proposed development and an understanding of the requirements or needs that will have to be met. Aspects that should be considered are discussed below.

J.3.1.1 The nature of the proposed development

Various factors relating to the nature of a development could influence decisions regarding the provision of water supply. For instance, smaller projects may not be able to accommodate a wide range of water supply options, while large (or mega) projects may have to include a wide range of water supply options. Mixed-use, mixed-income projects and projects that are primarily residential in nature would also need different approaches to the provision of water supply. Similarly, inner city infill projects would be different from (for instance) an informal settlement upgrading project. The nature of a project therefore needs to be understood to make informed decisions regarding appropriate water supply options. In addition, the nature of the planned development will influence the type of water supply services to be delivered. The following questions can be asked to gain clarity:

- What is the dominant land use of the proposed development? Reliable information will ensure an accurate estimate of water demand, which in turn forms the basis of designing water infrastructure of adequate capacity.
- What is the average stand size per land use category? This information provides a useful means of estimating unit demand for residential land use.
- Where will large water users or non-residential water users be located? Such users could have a significant impact on the design of the water supply network. Large prospective users should be consulted to obtain both short- and long-term demand projections and peak factors. The water demand for non-residential users should also be calculated using the calculations provided in **Section J.4.1**, based on a demand-per-hectare calculation. Where the floor area ratio is known, it can be used to improve water demand estimates.
- If a mixed development is proposed, what type of mix is proposed, e.g. a variety of housing types, sizes, densities and/or tenures? (see **Section F.4.5**)

J.3.1.2 The residents of the area to be developed

Decisions relating to the types of water supply to be provided in a development should be guided by information about the potential residents and users of the planned facilities. It may be possible to make assumptions regarding the nature of the future residents and users of water by assessing the surrounding neighbourhoods or similar developments in comparable locations or contexts. It is important to establish the following:

- The total number of users to be accommodated. Actual numbers may be higher than anticipated because the provision of services may attract more people than originally planned for.
- The number of households, the range of household sizes and their composition, for instance, whether there is likely to be child-headed or single-parent households. This will indicate the level of water services that would have to be provided.
- The number of persons and existing structures on the land. For traditional rural areas, the term 'homestead' represents a household, but typically consists of various structures – some of which may be occupied and others used for other (non-residential) purposes – that collectively constitute a family unit. For example, counting structures from aerial photos for traditional rural areas and applying a typical water demand/structure may lead to an overestimate of the water demand requirements. In this case, reliable population statistics such as the Stats SA Census small area layer (SAL) data should rather be used, in combination with a per capita water demand.
- The application of Water Sensitive Design measures (refer to Section J.2.3.2) and the potential impact on the potable water demand requirement, especially in respect of domestic (indoor) and non-domestic (outdoor) demand.
- The likelihood of homeowners subletting a dwelling in their backyard (either formally or informally). Overlooking this form of densification will result in an underestimation of water demand. Using per capita water demand estimates should be considered to determine water demand when this type of densification is anticipated.
- Any change (improvement) of service levels that can be anticipated in future for both water and sanitation services, as this could have a significant impact on the future water demand requirements. For example, upgrading a residential area with standpipes and ventilated improved pit latrines to full waterborne sanitation with house connections will increase the water demand requirement substantially.
- Whether the development experiences a significant influx of people during certain periods with a resulting increase in seasonal water demand, as is the case in coastal holiday destinations or rural areas with seasonal migration. The average daily water demand as calculated for the peak period, and not the average annual daily demand, should be used to avoid underestimating the design water demand.
- Income and employment levels, and spending patterns. This would indicate what types of water supply service would be most appropriate. For instance, indigent households should at a minimum be provided with a basic water supply.

J.3.2 Characteristics of the existing environment

Decisions regarding water supply need to be guided by an assessment of the context within which the development will be located. Issues that should be considered are discussed below.

J.3.2.1 The physical location of the proposed development

Constraints and opportunities posed by the site could influence the water supply infrastructure to be provided.

(i) Topography

The topography of the project site is a key factor when making decisions regarding the street layout of the development, and as such it will also guide decisions regarding the provision of water supply infrastructure. A steep slope could mean that additional costs will have to be incurred when constructing a water supply system. Topography should be considered not only to reduce the risk of flooding (by placing pipes on the high end of a road elevation) but also to provide better access for maintenance on valve chambers, etc. Distribution pipelines should be provided to preferably supply developments in a downward sloping direction.

(ii) Geotechnical characteristics

The ground condition of a site can sometimes necessitate the use of specialised construction methods or materials, or it can mean that certain areas of the site may not be suitable for construction of water supply infrastructure. The following questions might be helpful:

- What is the soil condition and quality?
- Was the site used for mining and exploration in the past? Are there any aggressive chemicals or minerals present?
- Is the site part of or close to a dolomitic area?
- Are there large rock outcrops on the site? Are there gullies or other ditches on the site?
- Is there groundwater (springs, wells, boreholes) present on the site? What is the height of the water table? The presence, amount and depth of deep underground water can normally not be predicted 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 hydrogeologists or geophysicists can estimate the most likely sites and even the approximate depth of the water table by using aerial photography to identify surface features and to make ground-penetrating measurements such as gravity and electrical resistivity. National and regional groundwater maps that provide synoptic and visual information on South Africa's groundwater resources are available from the WRC and the DWS. These maps are not site specific and cannot be used for borehole siting or any site-specific groundwater conditions, but they are an aid in determining borehole prospects and other groundwater-related information. This source of untreated water can be used for water supply purposes, but the protection of groundwater sources from pollution should be critical in the planning stage of civil projects by careful consideration of infrastructure in the vicinity of the groundwater source. Consult the *Guidelines on Protecting Groundwater from Contamination*[13], as well as *Towards a Guideline for the Delineation of Groundwater Protection Zones in Complex Aquifer Settings*[14].
- Are there other sources of untreated water present on the site? These may include surface water sources (streams, rivers, lakes, pans and dams), rainwater (to be harvested from rooftops, etc.), greywater (wastewater from baths, basins and laundry), seawater (to be desalinated), wastewater (pre-used water) that can be reclaimed and stormwater (see **Section L**). The use of on-site supplementary water sources could potentially reduce the municipal water demand requirement.
- What are the yields of untreated water sources present on the site? Any available untreated water sources should be evaluated for use based on costs, environmental impact, social acceptability and any other relevant considerations. As part of this evaluation, the yield of the water source should be considered. A yield analysis and tests should be conducted, or the safe yield should be obtained from available reports to confirm the capacities of existing water sources, such as river abstraction points, surface dams, aquifers (springs, wells and boreholes). The implications and recommendations from available water resources reconciliation studies, as well as the knowledge of local residents, should be considered. Design aspects related to the use of these water sources as well as methods to calculate the yields of these sources are discussed in **Section J.4.2**.

(iii) Landscape and ecology

The physical features of the landscape could have a substantial impact on the types of water supply that can be provided. If the development is located in or near an ecologically sensitive area, restrictions may exist that will influence the positioning (and ease of construction) of a water supply system. Gain an understanding of how the landscape is continuously evolving and changing, either through natural or human-induced processes, to assist in developing the site in the most ecologically sensitive manner. Gather information about the following:

- The position of any telephone poles, overhead power cables, rock outcrops, water features, dongas, etc., that could restrict building work or may require involvement (especially permission) from various government departments.
- Wetlands, surface water bodies, or other ecologically sensitive areas on or near the site. Information on Critical Biodiversity Areas (CBAs) or Ecological Support Areas (ESAs) is available on the website of the South African National Biodiversity Institute (SANBI).[15]
- Endangered or protected animal or plant species on or near the site.
- Existing vegetation, especially trees, and whether they are deciduous or evergreen, indigenous or alien.
- Natural features that may have cultural significance.
- The prevalence of veld fires in the area. Any additional demand for firefighting should be determined as this often has a major impact on the sizing of reticulation and distributions systems.

Firefighting

The following should be considered when planning a water supply system for firefighting:

- Undertake assessments in accordance with *South African National Standard, Community Protection against Fire* (SANS 10090)[16] or relevant regulations to determine the fire-flow requirements of high-risk users such as airports, bulk oil and storage facilities as well as large sports stadiums.
- 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 area ratios, height restrictions and building material restrictions.
- When designing water reticulation systems for industrial areas, these areas should generally be classified as moderate-risk 1. Where the reticulation in an industrial area has been designed on the basis of a moderate-risk 1 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 firefighting (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 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 the following:
  - Timber storage yards
  - Timber-clad buildings
  - Institutional buildings and buildings in which hazardous processes are carried out
  - Areas where combustible materials are stored which, because of the quantity of such materials, extent of the area covered by the materials and the risk of fire spread, may be deemed high-risk

(iv) Adjacent land uses and edge conditions

Adjoining properties have an impact on each other. It is therefore important to be aware of the land uses adjacent to the development site, as well as the edge conditions that affect the site. Determine what the adjacent land uses are and how these uses can potentially influence decisions regarding water supply to the site. In particular, the types of water supply that are available or that have been planned for in the neighbouring areas should be considered.

J.3.2.2 Available engineering infrastructure

Developments create additional demand for water and therefore have a potential impact on existing infrastructure. The provision of water supply infrastructure may also mean the extension of existing systems and connections to bulk supply infrastructure. The following need to be determined:

- What bulk water supply infrastructure is available close to the new development? Can the new development be supplied from the existing bulk infrastructure system? Can a suitable connection point be identified? The available capacity of such a supply system to accommodate the proposed development should be determined through hydraulic modelling.
- Is there a storage reservoir in the vicinity of the site? What is the capacity of the reservoir? Storage reservoirs should be appropriately sized to meet both peak demand and emergency requirements.
- What water conveyance infrastructure is available close to the new development? Will the existing system's distribution mains and reticulation have sufficient capacity to accommodate the demand of the new development? Undersized pipes could result in high flow velocities, which may in turn result in a loss of pressure and potential issues with water hammer. The risk of water hammer or pressure surges (transient pressures) should be addressed and mitigated through appropriate design measures (e.g. thrust blocks, surge valves, slow-closing valves) and appropriate operational design considerations. Conveyance infrastructure should have sufficient capacity for peak demand conditions and fire-flow requirements, in accordance with the design guidelines in this document.
- Is the existing water supply system in working order? For instance, confirm that pump stations are operational, reservoirs are not leaking, and water treatment plants are operational.
- Are there existing pipelines on the site? Water and sewerage pipes should not be positioned directly adjacent to each other. This is done to reduce the risk of cross-contamination when pipe bursts occur.
- What source of energy is available for the operation of water supply infrastructure? The efficient use and management of energy is important when planning water infrastructure. Refer to the WRC's *Energy Efficiency in the South African Water Industry: A Compendium of Best Practices and Case Studies*[17] for information on energy-efficient best practice, tools and technologies to be considered by the South African water industry.
- What does the street layout of the neighbourhood look like? Ideally, the position of bulk pipelines and main distribution pipelines should be planned along main routes. Restrictions on road reserves should be determined during initial route planning.
- What are the long-term water demand and bulk system requirements of the neighbourhood and the settlement? This information should be available in planning documents of the relevant authorities. Infrastructure needs of the proposed development should be aligned with the requirements of these plans so that infrastructure is sized and positioned appropriately to meet the long-term development requirements in the area. The typical planning horizon should be 25 to 40 years.

J.3.2.3 Quality of existing water sources

The quality of the water (both treated and untreated) that is available to the new development should be determined as it might imply that additional infrastructure is required. Consider the following:

- Test the quality of existing water sources, new sources or the water quality at the proposed bulk connection point. Potable water must comply with *SANS 241-1*[18], which prescribes health-based water quality requirements irrespective of the source and treatment process. Extending the existing water supply system to the proposed development site may require additional disinfectant potential to be provided. While potable water must comply with *SANS 241-1* in all cases, industrial water, water used for irrigation and water used in sanitation systems do not have to. It is important that the end-use water quality be paired with quality requirements and treatment cost to ensure that available water services are utilised optimally.
- Determine the alkalinity and hardness of the water. These aspects may have an effect on the treatability of the water, as well as on infrastructure. Typical concerns relate to pH stability and whether the water will lead to excessive scaling in pipework and plumbing, or possibly aggressive attack of pipework. These requirements are not included in *SANS 241-1* as they have no direct health implication. For more guidance refer to *South African Water Quality Guidelines – Volume 1: Domestic Use.*[19]

J.3.2.4 Existing socio-economic features

The planning and design of a development have to be guided by the potential needs of the residents of the new and existing neighbourhoods. The following questions should be answered with respect to the existing community (if known) and the adjacent neighbourhoods, especially those that are functionally linked to the development:

- How many people live there?
- What is the average size of households in the area?
- What is the income profile of the residents?
- What is the employment profile of the residents?
- What types of housing are people living in?

J.3.2.5 Legal / administrative considerations

Legal issues relating to the site can influence the development and may cause considerable delays if not dealt with pro-actively. A new development may, for instance, result in additional demand which may imply that an application to increase the water use licence should be made.

J.3.3 Water supply options

Water supply systems typically consist of bulk supply, treatment, storage, reticulation and end-user supply connections. This section presents a short description of each of these components and, where relevant, offers different options that are available to decision-makers. Options for water meter selection are also included.

J.3.3.1 Bulk supply

Bulk potable water supply systems are installed by using pipelines that provide the backbone of the water supply infrastructure. The bulk supply generally terminates at a distribution reservoir from where it supplies the reticulation systems. Typically, house connections are not permitted on bulk supply systems and generally not to pipelines ≥ 200 mm diameter, except for some consumers (such as farmers or other direct users), in which case a pressure-reducing valve is recommended at the connection point. Raw water bulk supply systems may comprise a network of dams, canals, aqueducts, and pipelines.

J.3.3.2 Water treatment

Treatment of water for potable and other purposes, whether from conventional surface or groundwater sources or supplementary sources, is a specialist competency, owing to the significant health implications associated with the delivery of water to users. Water treatment infrastructure is expensive, and it is crucial that informed decisions are made during the planning stages of the project. Refer to **Section J.4.4** for guidance on the design of water treatment facilities.

J.3.3.3 Storage

The purpose of storage reservoirs is to balance out peaks in demand (by providing a balancing volume) and to provide emergency storage, for instance when bulk supply is interrupted or in the event of a fire. Consider the following factors when selecting storage reservoirs:

- Reservoirs with pumped bulk supply are sized bigger than gravity-supplied storage reservoirs due to the increased risk of power failure causing interruptions in water supply.
- The function of the storage reservoir has an impact on its sizing and positioning. Locate command reservoirs preferably at an elevation from where the entire town can be supplied through smaller distribution reservoirs. A reservoir may also serve the sole purpose of providing pressure, such as an elevated (water tower) or a break pressure tank. Smaller storage reservoirs are referred to as tanks and are commonly manufactured from polyethylene plastic. These tanks can serve as water collection points when fitted with taps as applied in rural communities. They are also often used for rainwater harvesting purposes.
- Larger reservoirs are generally built using reinforced concrete, but various other material types are available. Some are pre-fabricated, which can be an advantage when rapid deployment is needed.
- Storage reservoirs can be erected below ground, above ground or be elevated – the choice is primarily affected by environmental, cost, geological, and pressure constraints.
- Cylindrical reservoirs are the most common shape, some with conical bottoms and typically a flat or dome-shaped roof. However, there may be instances where a rectangular or square reservoir is preferred (such as when there are space constraints), but be aware of the increased risk of circulation problems (stagnant water).
- Consider the water demand of the fully developed area that the reservoir should serve. It may be appropriate to phase reservoir storage by building several smaller reservoirs rather than erecting one big reservoir to suit the ultimate demand.
- Especially in rural areas, the use of smaller tanks could provide the dual benefit of reducing pressures and also providing storage. Such tanks can be placed at ground level or slightly elevated by targeting maximum pressures below 30 m where feasible.

Figure J.3: Examples of concrete and metal reservoirs (L) and a concrete reservoir (R)

J.3.3.4 Reticulation

Reticulation systems consist of smaller diameter pipelines (typically < 200 mm diameter) that supply consumers through a house or yard connection or through a communal water point. Water reticulation systems can be either gravity flow, or pressurised, or a combination of both. In a gravity pipeline system, the water storage is higher than all points in the delivery pipeline and no pump is required downstream of the storage. In a pressurised system, water needs to be lifted and pressurised by means of pumps and pump control. As illustrated in Figure J.4, distribution networks can be:

- **Branched:** Main line, sub-main lines, branches in which water flows from the source to the consumer.
- **Grid pattern with loops:** Water flows in more than one direction from the source to the consumer.

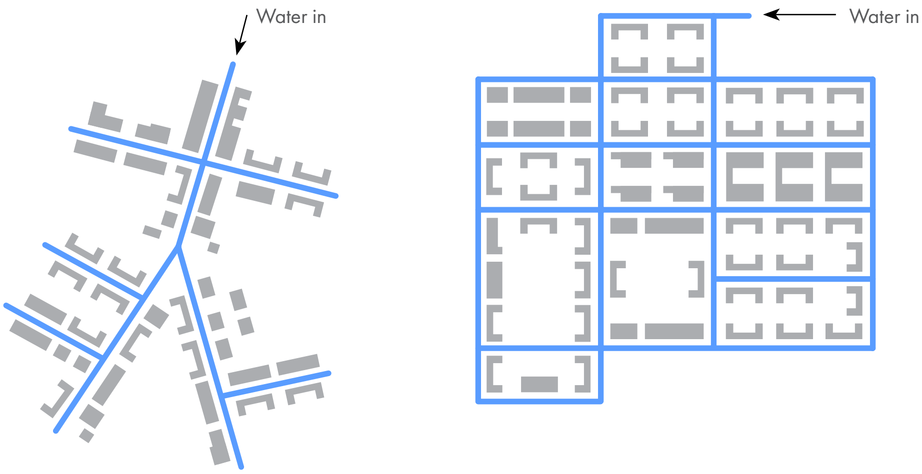


Figure J.4: Branched network (L) and a grid pattern with loops (R)

Adapted from Smet and Van Wijk[20]

Most water supply systems are complex combinations of loops and branches, with a trade-off between loops for reliability and branches for infrastructure cost savings. Most systems are divided into zones for metering and maintenance purposes (see Section J.4.6.1). For example, if any one section of a water distribution main fails or needs repair, that section can be isolated without disrupting all users on the network. Refer to Section J.4.5 for guidance on designing water distribution infrastructure.

J.3.3.5 Water metering

Water meters are not only used to measure water consumption of end users (in order to charge consumers equitably). The consumption per individual stand or per communal facility should be metered, even if the readings are not used for billing purposes. Metering is also done to measure water losses (through leakage), improve maintenance of infrastructure, manage water levels of storage facilities, etc.

A wide range of metering technologies and meter sizes exist. A summary is provided in Table J.1. The specifications provided by meter manufacturers should be consulted in the selection of appropriate meters. Guidance in meter selection and management can be obtained from *Introduction to Integrated Water Meter Management*[21], available from the WRC. As indicated in Table J.1, the factors that affect meter selection include the following:

- **The flow rate and range:** Meters are only sufficiently accurate for a specified range of flows. If a large proportion of actual flow falls outside of this range, it will result in either undermeasurement of flow or potential damage to the meter.
- **Level of accuracy required/budgetary constraints:** Mechanical meters are typically less accurate than ultrasonic or electromagnetic meters. However, they are likely to be the most cost-effective option for metering flow into (for instance) a District Metered Area (DMA). Conversely, in the case where water is supplied to a large paying user, an electromagnetic meter may be more appropriate.
- **Water quality:** Some metering technologies are sensitive to water quality, which may lead to a blockage or inaccurate measurement.
- **Hydraulic requirements:** Consider the orientation requirements (horizontal or vertical) and straight length of pipe required both upstream and downstream of the meter to ensure accurate meter readings. Additionally, be aware that some metering technology incurs a head loss.

Table J.1: Summary of conventional metering technology[22]

Property	Rotary Piston	Single Jet	Multi Jet	Horizontal Woltzmann (WP)	Combination	Electro-Magnetic	Ultrasonic
Classification	Mechanical volumetric	Mechanical Inferential	Mechanical Inferential	Mechanical Inferential	Mechanical Varies*	Electro-Magnetic Inferential	Ultrasonic Inferential
Typical classes	B, C and D	B, C and D	B, C and D	B	B	Not categorised	Not categorised
Common sizes (mm)	15 - 40	15 - 40	15 - 40	40 - 500	50/20 - 150/40	300 - 2 000	400 - 4 000
Sensitivity to velocity profile	None	Medium	Low	High	Medium*	Medium	High

Table J.1: Summary of conventional metering technology[22]

Property	Rotary Piston	Single Jet	Multi Jet	Horizontal Woltzmann (WP)	Combination	Electro-Magnetic	Ultrasonic
Minimum straight length upstream required	None	0-5 d	None	5 d	5 d	5-10 d	10 d
Minimum straight length downstream required	None	0-3 d	None	3 d	3 d	3 d	3 d
Orientation	Any	Horizontal	Horizontal	Almost any	Horizontal	Almost any	Almost any
Sensitivity to Water Quality	High	Medium	Medium	Low	Medium*	Very Low	Low
Pressure loss	High	Low	Low	Medium	High*	Very low	Very low
Electricity required?	No	No	No	No	No	Yes	Yes

Notes:
* Varies – the values depend on the individual meter types used
# d is the diameter of the pipe, thus 10 d means a length of pipe equal to 10 times the pipe's diameter

Automatic Meter Reading (AMR) uses a phone connection (cellular or fixed) or radio technology to transmit a meter reading to a remote database. In the case of radio-based systems, transmission of the reading is typically activated by a local mobile hand-held or vehicle-mounted transmitter. The primary benefits of using AMR are the saved expense of physically reading a meter and reduced likelihood of reading error. However, there is a cost associated with installing and maintaining this communication technology.

More advanced systems, known as Advanced Metering Infrastructure (AMI) or smart metering, allow for two-way communication between the meter and a remote command centre. Other than receiving real-time readings, typically at 15-minute intervals, smart meters can be programmed to identify leakage, as well as receive instructions to limit supply in the event of non-payment, a leak or to provide a fixed daily water quota. Consider the following when selecting a smart meter:

- Does the meter require a battery, and if so, is the battery life acceptable?
- What communication technology is used? Evaluate the local conditions, network availability and data costs before deciding on an appropriate technology.
- Is the meter housing secure, and robust, and does it have or need tamper detection?
- Does the meter have a trickle flow function, and is the trickle flow adjustable? The adjustability of the trickle flow function (as used during non-payment) is needed when there is the possibility that the municipality may change the monthly water volume allowance to certain users.
- Can the meter provide a fixed daily water quota before automatically closing, and is this volume adjustable?

- Does the meter have both pre-paid and a post-paid ability? What vending options does it have (kiosk, credit card, etc.)? Does it make provision for all types of consumers, for instance, some that do not have credit cards?
- Does it offer a front-end service (smartphone application) that informs users about usage and a potential burst or leak?
- Can the meter be closed remotely, when for example a burst is reported?

J.3.3.6 End-use delivery

The types of delivery to end users 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, such as communal standpipes. Private installations are those that render water to individual households either through a yard tap or a house connection. If possible, individual connections should be provided to schools, clinics, and possibly some businesses, no matter which option is selected.

Closely linked to the enduser delivery method is the level of service required or requested by a community, which will have a significant impact on the total demand. The minimum level of service is 25 litre/capita/day, based on a community standpipe that is within 200 m of all households it supports. The National Norms and Standards for Domestic Water and Sanitation Services[23] that were published in 2017 provide minimum requirements for the provision of potable water to end users.

Figure J.5 and Figure J.6 provide examples of options available for end-user point of supply. Design guidance for a typical standpipe is provided in Section J.4.5.10.

Communal standpipe

Communal standpipe

Figure J.5: Examples of public (communal) end-user points of supply

Figure J.5: Examples of public (communal) end-user points of supply

Figure J.6: Examples of private end-user points of supply

J.4 Design considerations

Once an appropriate water supply system has been identified, the infrastructure can be designed. As a first step it is critical to calculate the water demand. Then decisions have to be made regarding the use of supplementary water sources, water quality, water treatment, water distribution infrastructure, water demand management and materials to be used for construction of infrastructure.

J.4.1 Water demand

The design of water distribution and storage infrastructure requires a robust estimate of water demand. Use the following guidelines to calculate the design water demand.

J.4.1.1 The Average Annual Daily Demand

The Average Annual Daily Demand (AADD) refers to the average annual daily water requirement of the user at the point of connection and thus excludes real losses as separately accounted for in **Section J.4.1.3**.

For instances where the detailed stand layout of the proposed development is not available (typically in the initial planning stage), estimate the AADD using the area-based demand method (Equation J.1) and the unit water demands (kilolitre (kL)/hectre (ha)/day(d)) provided in Table J.2 and Table J.4 for the respective land uses. All area-based AADD calculations in this guideline use the net area, i.e. the gross area minus an assumption of 20% allowance for roads, servitudes and public open spaces.

Equation J.1: Area-based method for calculating AADD

From gross area:

$$\text{AADD (kL/d)} = \text{Area Water Demand (kL/ha/d)} \times \text{Gross area (in hectares)}$$

From net area:

$$\text{AADD (kL/d)} = \text{Area Water Demand (kL/ha/d)} \times \text{Net area (in hectares)} \div \text{Net area factor}$$

Where more detailed information is available, such as land use, the number and sizes of stands or the developed floor area (for non-residential), use the unit water demands (kL/unit/d) provided in Table J.2 and Table J.4 to calculate the AADD for the respective land use types using Equation J.2. If land use density is available, then the area-based calculations in this guideline to determine the number of land use units use the net area, i.e. the gross area minus an assumption of 20% allowance for roads, servitudes and public open spaces.

Equation J.2: Unit demand method for calculating AADD

$$\text{AADD (kL/d)} = \text{Unit Water Demand (kL/unit/d)} \times \text{number of units}$$

Use the per capita method (Equation J.3) to calculate the AADD based on the type of supply infrastructure to be provided, as per Table J.2, where reliable estimates of the population to be served are available. Also use this method in instances where the area-based and unit demand methods would not be appropriate, such as the supply to rural villages and for low-cost housing with backyard dwellings.

Equation J.3: Per capita method for calculating AADD

AADD (kL/d) = Unit Water Demand per capita (L/c/d) × population ÷ 1 000

Table J.2: Recommended unit Average Annual Daily Demands

Land use		Density [#1] units/ha	Stand size [#1] m^2	Unit of measure	Water demand (AADD)	
					kL/ha/d [#1]	kL/unit/d [#3]
Residential stands	High density, small sized	20 to 12	400 to 670	kL/unit	11	0.60 to 0.80
	Medium density, medium sized	12 to 8	670 to 1 000	kL/unit	9	0.80 to 1.00
	Low density, large sized	8 to 5	1 000 to 1 600	kL/unit	8	1.00 to 1.30
	Very low density, extra large sized	5 to 3	1 600 to 2 670	kL/unit	7	1.30 to 2.00
Stands for low-income housing (waterborne sanitation)	High density, small sized	30 to 20	270 to 400	kL/unit	9	0.30 to 0.40
	Medium density, medium sized	20 to 12	400 to 670	kL/unit	7	0.40 to 0.50
	Low density, extra large sized	12 to 8	670 to 1 000	kL/unit	6	0.50 to 0.60
Stands for low-income housing (dry sanitation)	High density, small sized	30 to 20	270 to 400	kL/unit	7	0.25 to 0.30
	Medium density, medium sized	20 to 12	400 to 670	kL/unit	6	0.30 to 0.35
	Low density, extra large sized	12 to 8	670 to 1 000	kL/unit	4	0.35 to 0.40
Group/cluster housing	High density	60 to 40	130 to 200	kL/unit	21	0.40 to 0.45
	Medium density	40 to 30	200 to 270	kL/unit	17	0.45 to 0.50
	Low density	30 to 20	270 to 400	kL/unit	14	0.50 to 0.60
Flats	Very high density	100 to 80	80 to 100	kL/unit	25	0.25 to 0.30
	High density	80 to 60	100 to 130	kL/unit	23	0.30 to 0.35
	Medium density	60 to 50	130 to 160	kL/unit	21	0.35 to 0.40
	Low density	50 to 40	160 to 200	kL/unit	19	0.40 to 0.45
Agricultural holdings	Including irrigation	< 3	< 2 670	kL/unit	12	4.00
	Domestic water only	< 3	< 2 670	kL/unit	6	2.00
Golf estate - excluding golf course water requirements		< 3	< 2 670	kL/unit	9	3.00

Land use	Density [#1] units/ha	Stand size [#1] m²	Unit of measure	Water demand (AADD)	
				kL/ha/d [#1]	kL/unit/d [#3]
Retirement village	20 to 12	400 to 670	kL/unit	11	0.60 to 0.80
Business/commercial	FAR = 0.4	n.a.	kL/100 m² [#2]	21	0.65
Industrial	FAR = 0.4	n.a.	kL/100 m² [#2]	13	0.40
Government institutions	FAR = 0.4	n.a.	kL/100 m² [#2]	13	0.40
Warehousing	FAR = 0.4	n.a.	kL/100 m² [#2]	10	0.30
Institutional	FAR = 0.4	n.a.	kL/100 m² [#2]	20	0.60
Municipal services	FAR = 0.4	n.a.	kL/100 m² [#2]	20	0.60
Educational	FAR = 0.4	n.a.	kL/100 m² [#2]	20	0.60

[#1] - Assumed net area factor = 0.8 x gross area (20% allowance for roads, servitudes and public open spaces)

[#2] - FAR (Floor Area Ratio) is the ratio of the floor area of a building to its site area. Also referred to as FSR (Floor Space Ratio).

[#3] - Unit type as defined in the column "unit of measure"

d = day

Table J.3: Residential AADD (per capita)

Land use		Persons per unit	Typical AADD [#1] L/c/d	AADD range [#1] L/c/d
Standpipe		5	25	10 to 40
Yard connection	With dry sanitation	5	50	40 to 60
	With low-flow (LOFLOs) sanitation	5	60	50 to 70
	With full-flush sanitation	5	70	60 to 80
House connection	Low-income housing	5	90	60 to 120
	Residential	5	230	120 to 400
	Group/cluster housing	3 to 5	120	130 to 120
	Flats	1 to 4	150	250 to 110

[#1] - per capita calculated on persons per unit

Table J.4: Typical AADD unit demands for special land use categories

Land use		Unit demand	Unit of measure
Residential type of development			
Frail care centres and hospitals	According to bed	0.60	kL/bed
	Building according to FAR	1.20	kL/100m²
	Grounds only	12	kL/ha
Gate house for security villages		0.30	kL/unit
Guest houses, boarding houses, lodges	Single room	0.30	kL/single room
	Double room	0.60	kL/double room
Hotels, guest houses, lodges, boarding houses, retirement centres & villages	Buildings according to FAR	0.90	kL/100m²
	Grounds only	12	kL/ha

<table>
<tr><th colspan="4">Table J.4: Typical AADD unit demands for special land use categories</th></tr>
<tr><th colspan="2">Land use</th><th>Unit demand</th><th>Unit of measure</th></tr>
<tr><td colspan="2">Residential type of development</td><td></td><td></td></tr>
<tr><td rowspan="3">Living units, student housing, tenement buildings, orphanages and hostels (units between 20 m² and 40 m²)</td><td>According to bed</td><td>0.30</td><td>kL/bed</td></tr>
<tr><td>Building according to FAR</td><td>1.20</td><td>kL/100m²</td></tr>
<tr><td>Grounds only</td><td>12</td><td>kL/ha</td></tr>
<tr><td colspan="4">Business type of development</td></tr>
<tr><td rowspan="4">Abattoir</td><td>Cattle</td><td>0.80</td><td>kL/cattle head</td></tr>
<tr><td>Pig</td><td>0.40</td><td>kL/pig head</td></tr>
<tr><td>Sheep</td><td>0.14</td><td>kL/sheep head</td></tr>
<tr><td>Fowl</td><td>0.80</td><td>kL/100 fowl</td></tr>
<tr><td colspan="2">Brewery (usage for the production of 1 L of beer)</td><td>10</td><td>L/1 L of beer</td></tr>
<tr><td rowspan="2">Car wash facility</td><td>Wash bay</td><td>10</td><td>kL/wash bay</td></tr>
<tr><td>Cars</td><td>0.20</td><td>kL/car</td></tr>
<tr><td colspan="2">Fuel depot</td><td>0.40</td><td>kL/100 m²</td></tr>
<tr><td colspan="2">Garage or filling station</td><td>0.80</td><td>kL/100 m²</td></tr>
<tr><td>Industrial (wet)</td><td>Development specific</td><td>-</td><td>kL/100 m²</td></tr>
<tr><td colspan="2">Motor city/retail park as a single zoning (car sales + limited offices 100 m²)</td><td>0.60</td><td>kL/100 m²</td></tr>
<tr><td colspan="2">Taxi rank (with ablution facilities)</td><td>0.30</td><td>kL/100 m²</td></tr>
<tr><td colspan="2">Wellness centre, gymnasium</td><td>2.40</td><td>kL/100 m²</td></tr>
<tr><td colspan="4">General type of development</td></tr>
<tr><td colspan="2">Cemetery</td><td>12</td><td>kL/ha</td></tr>
<tr><td rowspan="2">Club</td><td>Buildings only</td><td>2.40</td><td>kL/100 m²</td></tr>
<tr><td>Grounds only</td><td>12</td><td>kL/ha</td></tr>
<tr><td rowspan="2">Church</td><td>Buildings only</td><td>0.30</td><td>kL/100 m²</td></tr>
<tr><td>Grounds only</td><td>12</td><td>kL/ha</td></tr>
<tr><td rowspan="2">Nursery</td><td>Buildings only (sales area)</td><td>0.80</td><td>kL/100 m²</td></tr>
<tr><td>Planting and production area</td><td>12</td><td>kL/ha</td></tr>
<tr><td rowspan="2">Park</td><td>Buildings only</td><td>0.40</td><td>kL/100 m²</td></tr>
<tr><td>Grounds only</td><td>12</td><td>kL/ha</td></tr>
<tr><td colspan="2">Parking grounds (car park)</td><td>3</td><td>kL/ha</td></tr>
<tr><td colspan="2">Private open space</td><td>12</td><td>kL/ha</td></tr>
<tr><td colspan="2">Roads</td><td>0</td><td>kL/ha</td></tr>
<tr><td rowspan="2">School, crèche, educational</td><td>Buildings only</td><td>60</td><td>L/student</td></tr>
<tr><td>Grounds only</td><td>12</td><td>kL/ha</td></tr>
<tr><td rowspan="4">Sport grounds</td><td>High intensity < 2 ha</td><td>50</td><td>kL/ha</td></tr>
<tr><td>High intensity 2 to 10 ha</td><td>40</td><td>kL/ha</td></tr>
<tr><td>High intensity >10 ha</td><td>30</td><td>kL/ha</td></tr>
<tr><td>Low intensity</td><td>12</td><td>kL/ha</td></tr>
<tr><td rowspan="2">Stadiums</td><td>Buildings only</td><td>1.50</td><td>kL/1000 seats</td></tr>
<tr><td>Grounds only</td><td>12</td><td>kL/ha</td></tr>
<tr><td rowspan="2">Zoological activities</td><td>Buildings only</td><td>0.60</td><td>kL/100 m²</td></tr>
<tr><td>Grounds only</td><td>12</td><td>kL/ha</td></tr>
</table>

Various uses			
Airports		20	L/passenger
Camps	Campers	60	L/camper
	Resorts	200	L/person
Factories		100	L/worker
Garages		400	L/vehicle
Hotels		200	L/person
Picnic spots		60	L/picnicker
Restaurants		10	L/person
Schools	Live-in student	300	L/student
	Day student	60	L/student
Theatres		20	L/seat

J.4.1.2 The AADD with the use of on-site supplementary water sources

The large-scale use of on-site supplementary water sources such as rainwater, greywater and groundwater could reduce the AADD requirement from the municipal water supply system and thus have an impact on the design of the network. Estimate the potential reduction in AADD to be supplied via the municipal system depending on the extent of such measures to be implemented for both indoor and outdoor demand in accordance with the generalised demand profiles provided in Table J.5 and Table J.6 respectively.

Table J.5: Typical breakdown of internal residential water use

Point of use	Proportion of indoor demand
Toilet	25%
Shower/bath	30%
Washing machine	25%
Tap	18%
Dishwasher	2%

Table J.6: Typical outdoor use as % of Average Annual Daily Demand

Land use category		Outdoor use
Low-income housing		0 - 15%
Single residential stands	<500m^2	0 - 20%
	≥500 - ≤1 000m^2	0 - 30%
	>1000 - ≤1 600m^2	0 - 40%
	>1 500 - ≤2 000m^2	0 - 50%
	>2 000m^2	0 - 60%
Cluster housing		0 - 10%
Flats and low-income walk-ups		0 - 5%

Example: Calculate the adjusted AADD for a 1 000 m² residential stand that is using on-site supplementary sources for all outdoor use and all toilet flushing:

Step 1: Obtain the AADD from Table J.2

AADD for 1 000 m² stand = 1 kL/d

Step 2: Reduce the AADD to account for all outdoor use being from on-site sources (see Table J.6)

For 1 000 m² stand outdoor use = 30%

$$\text{Reduced AADD} = 1 \text{ kL/d} \times (1 - \frac{30}{100}) = 0.7 \text{ kL/d}$$

Step 3: Reduce AADD further to account for all toilet flushing being from on-site sources (see Table J.5)

For 1 000 m² stand toilet use = 25% of indoor use

$$\text{Reduced AADD} = 0.7 \text{ kL/d} \times (1 - \frac{25}{100}) = 0.53 \text{ kL/d}$$

J.4.1.3 Real losses

Real losses (leakage, etc.) should be accounted for when calculating the design water demand. The loss of water from storage and distribution infrastructure before reaching the user connection point is unavoidable, even in well-designed and well-maintained systems. The water demands calculated in Section J.4.1.1 and Section J.4.1.2 provide the AADD downstream of the user connection point and do not account for the real losses. Method 1 below should be used to estimate the potential real loss. Method 2 should be used if detailed information is available to calculate the Current Annual Real Losses (CARL).

(i) Method 1: Real loss percentage estimate

Real loss should be estimated by using a percentage value when a lack of data or knowledge of the proposed development makes it difficult to estimate real losses using Method 2. Use a percentage of between 15-25% to account for the anticipated real losses. Obtain real loss percentages from the municipality, if available.

(ii) Method 2: Determine losses using a target Infrastructure Leakage Index (ILI)

First, calculate the Unavoidable Annual Real Losses (UARL) for the development using Equation J.4:

Equation J.4: Calculate Unavoidable Annual Real Losses

$$UARL = ((18 \times L_m) + (0.8 \times N_c) + (25 \times L_p)) \times AZP$$

Where:

$UARL$ = Unavoidable Annual Real Losses (L/d)

L_m = Length of mains (km)

= Total length of reticulation mains as estimated from Table J.6 plus length of bulk and distribution mains

N_c	=	Number of service connections
	=	Typically equal to number of stands to be supplied
L_p	=	Total length of underground pipe between street edge to the user meter (km)
	=	Typically equal to 10 m for residential stands
AZP	=	Average Zone Pressure (m)
	=	Typically use 40 m to 50 m, depending on flat or steep topography respectively

Table J.7: Typical length of mains per stand

Land use		Stand size #1	Pipe length #2
		m^2	m
Residential stands	High density, small sized	400 to 670	10 to 13
	Medium density, medium sized	670 to 1000	13 to 16
	Low density, large sized	1 000 to 1 600	16 to 20
	Very low density, extra large sized	1 600 to 2 670	20 to 26
Stands for low-income housing (waterborne sanitation)	High density, small sized	270 to 400	8 to 10
	Medium density, medium sized	400 to 670	10 to 13
	Low density, extra large sized	670 to 1 000	13 to 16
Stands for low-income housing (dry sanitation)	High density, small sized	270 to 400	8 to 10
	Medium density, medium sized	400 to 670	10 to 13
	Low density, extra large sized	670 to 1 000	13 to 16
Group/cluster housing	High density	130 to 200	6 to 7
	Medium density	200 to 270	7 to 8
	Low density	270 to 400	8 to 10
Flats	Very high density	80 to 100	4 to 5
	High density	100 to 130	5 to 6
	Medium density	130 to 160	6 to 6
	Low density	160 to 200	6 to 7
Agricultural holdings	Including irrigation	< 2 670	> 26
	Domestic water only	< 2 670	> 26
Golf estate – excluding golf course water requirements		< 2 670	> 26
Retirement village		400 to 670	10 to 13

Notes:

#1 - Assume net area factor = 0.8 x gross area (20% allowance for roads, servitudes and open spaces)

#2 - Calculation based on a square-shaped stand

This equation assumes an average length of pipe of 10 m from the water main to the consumer meter and the term L_p is therefore only used in cases where the meter is located more than 10 m from the water reticulation main. Where water meters are located on the street edge, as is frequently the case, it is acceptable to simplify the equation as follows:

$$\text{UARL} = ((18 \times L_m) + (0.8 \times N_c)) \times AZP$$

Then, use Equation J.5 to calculate the anticipated real losses.

Equation J.5: Calculate Real Losses

$$CARL = UARL \times ILI$$

Where:
$CARL$ = Current Annual Real Losses (L/d)
$UARL$ = Unavoidable Annual Real Losses (L/d)
ILI = Infrastructure Leakage Index

Calculate UARL using Equation J.4. Subsequently, select a target ILI and use Equation J.5 to calculate the anticipated CARL. Table J.8 presents the typical ILI values for developing countries. A design ILI of between 6 and 8 is recommended, but consider the ILI of existing areas to decide if a lower or higher ILI is appropriate for estimating real losses.

Table J.8: ILI benchmark values[25]

Anticipated level of infrastructure leakage	Typical ILI range for developing countries
Excellent	1-4
Good	4-8
Average	8-16
Poor	>16

The resulting CARL will provide an estimate of the real losses from the supply zone in L/d.

J.4.1.4 Total Average Annual Daily Demand

The Total Average Annual Daily Demand (TAADD) is calculated as the sum of the AADD and Real Losses, ensuring unit consistency, by applying Equation J.6 below:

Equation J.6: Calculation of Total Average Annual Daily Demand (Design Demand)

When using % for estimating real losses (Method 1):

$$TAADD = AADD/(1 - \text{Real Losses})$$

Or, when using the ILI (Method 2) for calculating real losses:

$$TAADD = AADD + \text{Real Losses}$$

J.4.1.5 Peak demand

Where a peak demand is required for design purposes as per design requirements set out in Section J.4.5, calculate this as the product of the Total Average Annual Daily Demand (TAADD) and a Peak Factor (PF). Peak factors for the peak hour, day and week are provided in Table J.9. Use the TAADD for a supply zone to select the appropriate peak factors for different land use categories.

Table J.9: Recommended peak hour, day and week factors, based on land use

Predominant land use	TAADD (kL/d) in supply zone	PF_{week}	PF_{day}	PF_{hour}
Low-income housing (LIH)	<1 000	1.50	1.90	3.60
	1 000 - 5 000	1.40	1.80	3.40
	5 000 - 10 000	1.35	1.70	3.30
	10 000 - 15 000	1.30	1.50	3.20
	15 000 - 20 000	1.25	1.40	3.10
	>20 000	1.25	1.40	3.00
Residential (RES)	<1 000	1.80	2.20	4.60
	1 000 - 5 000	1.65	2.00	4.00
	5 000 - 10 000	1.50	1.80	3.60
	10 000 - 15 000	1.40	1.60	3.50
	15 000 - 20 000	1.35	1.50	3.30
	>20 000	1.30	1.50	3.00
Business/commercial/ industrial (BCI)	<5 000	1.45	1.70	3.30
	5 000 - 10 000	1.30	1.60	3.15
	>10 000	1.25	1.50	3.00
Large single users (LRG)	>500	1.45	1.70	2.50
Inner city (CBD)	<5 000	1.30	1.60	2.00

Example: Determine the relevant peak factors for each land use based on the total zonal demand. For instance, in a zone comprising of 4 000 kL/d of BCI and 4 000 kL/d of residential use, the total demand is 8 000 kL/d, and the appropriate PF_{hour} for the two land use classes are 3.15 and 3.6 respectively. The Peak Hour Demand is then calculated as follows, converted from kL/d to L/s:

BCI: 4 000 kL/d × 3.15 = 12 600 kL/d ÷ (60 min × 60 sec × 24 h ÷ 1 000) = 145.83 L/s

RES: 4 000 kL/d × 3.6 = 14 400 kL/d ÷ (60 min × 60 sec × 24 h ÷ 1 000) = 166.67 L/s

Total Peak Hour Demand = 312.50 L/s

J.4.1.6 Special considerations

Consider the following special factors when determining the design water demand as set out in Section J.4.1:

- In some cases, such as holiday towns and residential areas that experience significant seasonal occupation patterns, calculate the AADD as the average daily demand for the peak seasonal period.

- The demand for developed parks is to be considered as drawn over six hours on any particular day in order to obtain the peak demand.
- Identify and consult with prospective large users to obtain the AADD and peak demand. The AADD that defines a large user increases in relation to the total demand for the zone.
- Where post-development densification is likely to occur in the form of backyard dwellings, use the per capita method to calculate the AADD as per Equation J.3.

J.4.2 Water sources

The use of on-site supplementary water sources could potentially reduce the municipal water demand requirement. When existing traditional water sources such as surface water and groundwater are not adequate, both in terms of quality and quantity, the benefits of supplementary water sources could be considered as part of Water Sensitive Design (WSD) (refer to **Section J.2.3.3**).

The uptake and use of supplementary water can form part of a coordinated community effort. It can take place at a consumer level (people's own initiative). The augmentation of available water sources through predominantly user-driven rainwater harvesting, greywater reuse and private boreholes can defer or even eliminate the need for large-scale water resource augmentation as supplied through municipal systems. Aspects to consider when designing water supply systems using different water sources are discussed below.

J.4.2.1 Surface water

Surface water sources, such as streams, rivers, lakes, pans, and dams will always contain suspended solids (turbidity) and microbiological pollutants. The following measures should be taken when designing a system to use surface water to supply for a new development:

- Conduct a yield analysis or source information from relevant reports for direct abstraction from a surface water system to determine if the system has the capacity to accommodate the additional demand imposed by the proposed development. The yield analysis can be done by doing the following:
  - Obtain the historic streamflow sequence using gauge data that would typically show a declining flow due to human impact.
  - Convert this to a naturalised streamflow sequence by "adding back" the impact of any human activity (such as irrigation, afforestation, inter-basin transfers, construction of reservoirs).
  - Subtract the current level of abstractions/human impact from the naturalised streamflow sequence to obtain a streamflow sequence that is representative of the current level of demand. This effectively becomes the streamflow pattern to be used for planning purposes, as it allows for all historical levels of streamflow to be assessed equally relative to the present day demands on the water source.
  - Conduct a yield analysis to determine, among other things, the firm yield point for a given period of historical data. The firm yield is the maximum base yield that can be abstracted from a reservoir for a given historical streamflow record, demand pattern, and reservoir operating policy. There is a probability associated with the firm yield point that depends on the length of record analysed, and the yield point value should always be accompanied by an associated risk of failure.
- Treat the water for the removal or destruction of pathogenic organisms (e.g. bacteria, viruses, protozoa), as well as for turbidity.
- Where deemed necessary, provide a backup source (e.g. a borehole) for times of shortage and drought, to ensure a minimum supply for domestic use.

- Protect pump stations or other water extraction facilities from possible damage by floods, the elements, vandalism or animals. Water intake pumps should be sized to avoid adverse conditions while providing the required water volume and pressure.
- Design surface water intakes to minimise impacts on fish and other organisms, to prevent pollution and contamination and to cater for the effects of sedimentation in the river and on the raw water abstracted. For more information refer to the World Health Organization's publications on water supply.[26]
- Place the water supply intake 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.
- The type of intake structure will be unique to every project, be it a protected side intake, a river-bottom intake, a floating intake or a sump intake. In the case of a small stream or river, construct a weir with concrete, cement blocks, gabions or rocks covered with impermeable plastic sheeting across the river bed (if necessary) to provide enough depth for the intake and to maintain the water level within a fairly narrow range.
- Select the river or dam intake point to abstract the best quality water from the source. For example, a floating intake 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 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 to accommodate the river bed becoming unstable during floods. 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, extracting water from too deep may affect the quality as this water may differ markedly from the surface water. This is due to the possible thermal stratification of the lake in the warm summer months when the oxygen levels in the deeper waters could be depleted, causing a deterioration in quality.

The location and design of water intake systems require expertise in, among others, hydraulics and hydrology, geo-technical, and environmental engineering.

Figure J.7: Water abstracted from a river (L) and from a stream (R) could contain pollutants

J.4.2.2 Groundwater

Groundwater refers to water found in the subsurface in the saturated zone below the water table occupying all the voids or pores within geological formations. With the aid of appropriate drilling and abstraction technology, groundwater is more widely available directly to users than surface water.[27] Groundwater can be accessed via springs, wells and boreholes.

(i) Springs

A spring is a visible outlet from a natural underground water system. Identify a spring's location by visual inspection of the topography and identifying plant species associated with saturated ground conditions, or consult with local residents. Collecting water from a spring depends on the type of spring, which can fall into three broad categories:

- Open springs: occurring as pools in the open country. Include a sump or central collection point from which an outlet pipe can be connected. 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. Construct a 'spring chamber' around the eye of the spring and completely enclose it. Provide some form of a manhole to allow desilting, routine maintenance, and inspection of the pipe intake. 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. Design the spring chamber 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. Use infiltration trenches and sub-soil drains to feed the spring water to a central collector pipe. Make sub-soil drains from stone, gravel, brushwood, tiles, river sand, slotted pipes, filter material or a combination of the above.

Estimate the reliable yield from a spring by measuring the outlet flow rate during the driest months of the year. Calculate the reliable yield by multiplying this flow rate by a factor. This factor depends on variables such as geology, soil types, land use, and hydrological characteristics. As a first approximation, use the factors provided in Table J.10. When calculating the yield of a spring, obtain additional information where possible. Usually, the residents can provide information on whether the spring ever dries up, or how many containers are filled in an hour during drought years. Also, assume some level of risk, especially since during at least 90% of the year better flow conditions than the reliable yield can be expected.

Table J.10: 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

Protection of the whole spring system, including the unseen underground part, is essential if the spring is used for water supply. Consult *Groundwater Protection - Guidelines for Protecting Springs*[28] for more information on spring protection. Also, consult the World Health Organization's publication on spring protection[29], and other international publications[30,31]. Examples of how springs can be protected, include:

- Fence off the area immediately above and around the spring outlet or protection works to prevent faecal contamination by humans and animals. Include a furrow and berm on the upstream side of the outlet, to prevent the direct ingress of surface water into the spring after rains.
- Provide safe distances between the spring and potential contaminating activities such as cattle kraals, stock watering points and pit latrines.
- Plant gardens and trees some safe distance downstream of the spring and not within the seepage area above the eye of the spring.

Figure J.8: An open spring (L) and a protected spring (R)

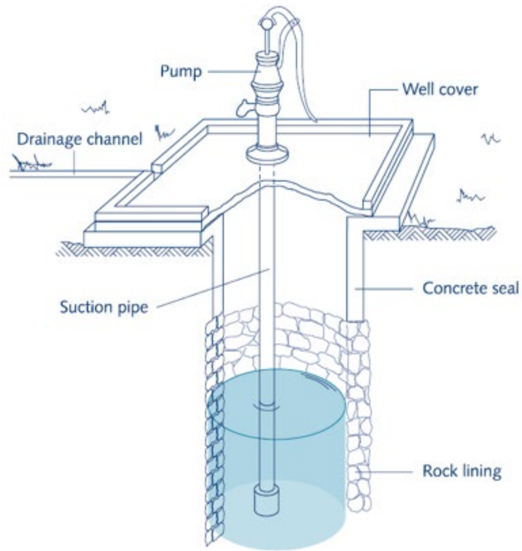
(ii) Wells

Where groundwater does not emerge above the natural surface of the ground and the water table is shallow, water can be accessed by digging a well.

When digging a well, use some form of a lining to prevent the walls of the shaft collapsing, both during and after construction. Types of linings that can be used include:

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

The well lining should be extended above the ground surface to prevent contaminated surface water from running down into the well. For the same reason, and to prevent subsidence, the space between the lining and the side of the shaft should be backfilled and compacted. A concrete apron, cast around the well entrance and sloping away from the well should be included. The joints between the linings should be sealed with mortar or bitumen above the water table, but should be left open below it. The well should be covered with a slab and a suitable pump or bucket and lifting mechanism should be provided.



Acknowledgement: Smet and Van Wijk[32]

Figure J.9: Hand-dug well

Be aware that the well shaft will need to be sunk sufficiently deep below the groundwater level to achieve the following three main functions:

- Provision of storage
- Increasing of the infiltration capacity into the well
- Accommodating seasonal fluctuations in the depth of the water table

It is advisable to cover the bottom of the well with gravel or a 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.

Tube wells are preferable in sandy soil and should be sunk using jetting, hand-drilling and auguring of small-diameter holes (50 mm to 500 mm). Line the hole using unplasticised polyvinyl chloride (PVC-U) or mild steel casings to prevent collapse. Ensure that 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 a suitable pump and concrete apron should be provided.

(iii) Boreholes

A borehole can be sunk when the water table is at a deeper level (10 to 100 m), or when the subsurface formations are of hard rock, or of a softer material unsuitable for hand-dug or tube wells. Tests should be conducted to estimate the yield likely from the borehole before drilling to ensure viability. A reputable driller registered with the Borehole Water Association of South Africa (BWASA) should be used to drill a borehole. The drilling should be executed in accordance with the *South African National Standard, development, maintenance and management of groundwater resources – Part 4: Test Pumping of water boreholes.*[33]

Groundwater is vulnerable to pollution. All boreholes that are not in use should be closed properly. Boreholes for domestic use should be positioned at least 30 to 50 m away from potential pollution sources such as on-site toilets, cattle kraals or cemeteries and site-specific conditions should be considered to determine the appropriate distance. The direction of the aquifer flow is also an important consideration.

The diameter of the borehole should be sized based on the casing required, as well as 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. As with hand-dug wells and tube wells, consider the inclusion of a concrete apron around the borehole to prevent ingress of surface water. To prevent aquifer pollution, the installation of a sanitary seal is required. Wherever possible, a 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 to provide early warning of source depletion.

J.4.2.3 Rainwater

Rainwater harvesting is the direct capture of stormwater runoff, typically from rooftops, for supplementary water, which is used on site.

Photo credit: Christian Ruz – Wikimedia Commons (R)[34]

Figure J.10: Rainwater harvesting (L) and fog harvesting (R)

The quality of harvested rainwater is dependent on the quality of the rain itself and possible contamination of the catchment. Rainwater is naturally slightly acidic, but can be made very acidic by industrial pollution.[35,36] Filtered rainwater is suitable for all non-potable use, including toilet flushing, laundry, garden irrigation and topping up of swimming pools.

To calculate the yield of a rainwater harvesting system, multiply the roof area with the mean annual rainfall and adjust by an efficiency factor (runoff coefficient) to calculate the average quantity of water available from a roof area. Average rainwater (litres) = catchment area (m^2) x mean rainfall (mm) x efficiency, where efficiency has a value between 0 and 1).

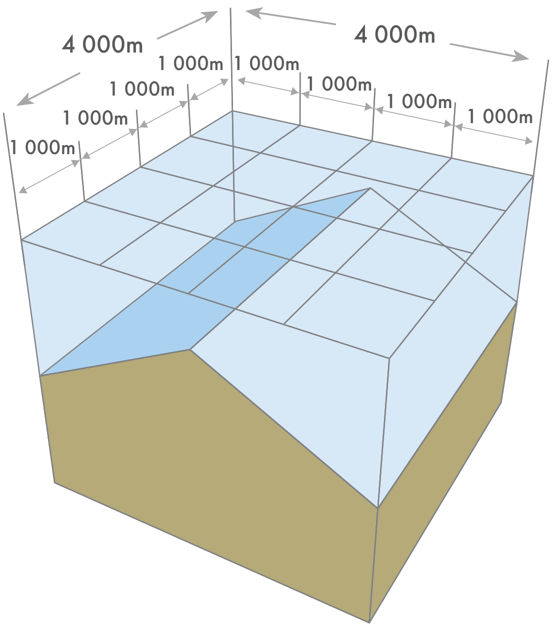
The typical runoff coefficient for different roof surfaces are shown in Table J.11. Runoff coefficients are variable and dependent on the antecedent moisture conditions and the depth of rainfall.

Table J.11: Typical runoff coefficients for rainwater harvesting off roofs[37]

Roof	Runoff coefficient
Pitched roof, tiled	0.85
Flat roof, tiled	0.6
Flat roof, gravel	0.4
Extensive green roof	0.3
Intensive green roof	0.2

A common practice is to use average coefficients for various types of areas and to assume that the coefficients would be constant throughout the rainfall event. For roofs, an efficiency of 0.8 is usual. Thatch roofs are generally not suitable for rainwater harvesting.

Note that it is not the total roof surface that is calculated, but the horizontal exposure of the roof's footprint to the sky. Figure J.11 shows the calculation for the roof area.



Adapted from Duncker and Lindeque[38]

Figure J.11: The total square meters that will be exposed to the rain

The first water to run off a roof can contain a significant amount of debris and dirt that accumulated on the roof or in the gutter. Some mechanism (such as the one illustrated in Figure J.13) has to be installed to discard the first flush. The inlet to the storage tank should be protected by a gauze screen to keep out debris, as well as insects and rodents.

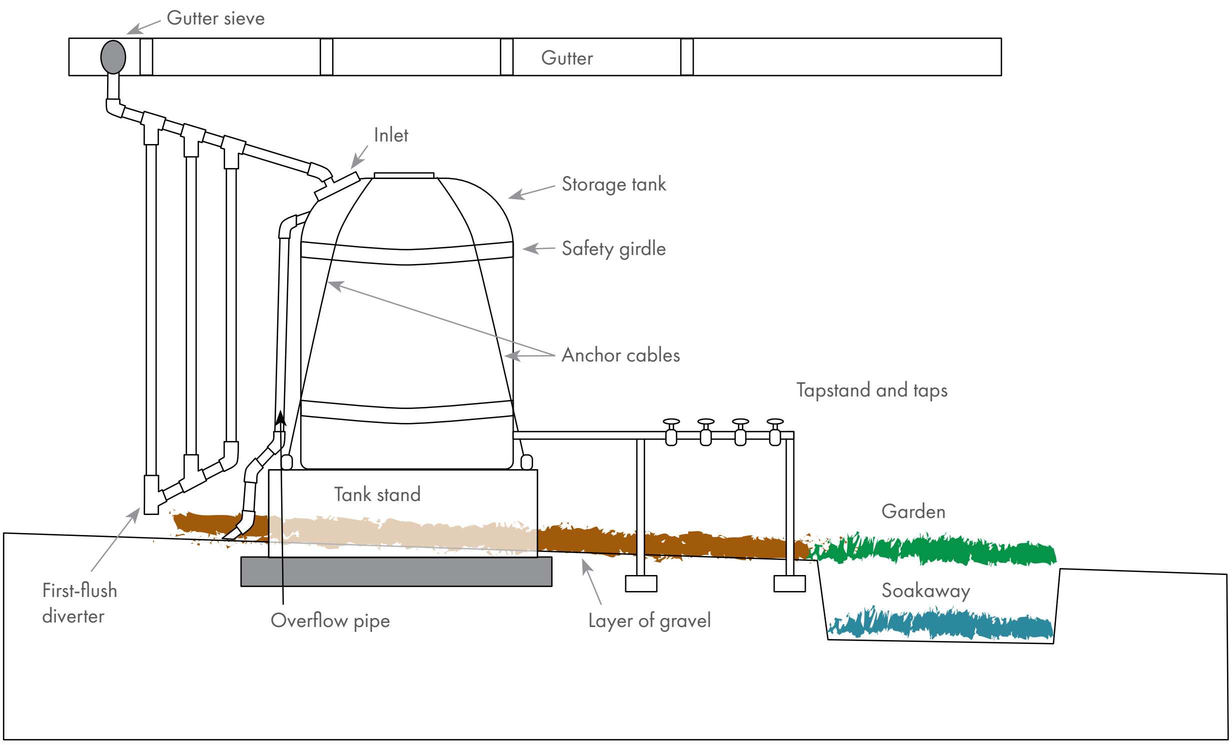


Figure J.12: Components of a rainwater harvesting system

Place water tanks on solid foundations, platforms or stands to ensure that they are level, will not fall over and are above the ground in order to build up the necessary water pressure for the outlet. These platforms could be made of cement, steel, wood or any other material that is strong enough to handle the weight of the full tank. Take note that a 50 L tank filled with water can weigh more than 50 kg and a 5 000 L tank can weigh more than 5 000 kg. The platform or stand must be level and must have hooks onto which the tank can be anchored or fastened. The pipes leading to and from the tank to the wall or the platform should also be anchored to prevent them from breaking, cracking and leaking.

Each tank should have an overflow pipe to prevent water being forced out of the inlet when the tank is full. The overflow must be the same size as the inlet to prevent a bottleneck situation. The overflow water can be diverted to a flower or vegetable garden, or led into a stormwater drainage system.

A layer of gravel should be placed around and/or under the platform or stand to ensure good drainage and to prevent the forming of mud and water puddles.

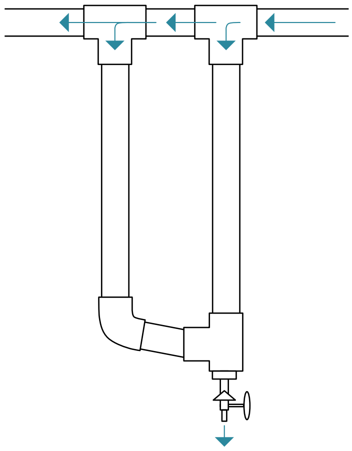


Figure J.13: Example of a tank stand (L) and a first flush diverter (R)

J.4.2.4 Greywater

Greywater is defined as all untreated domestic wastewater other than toilet water and wastewater from the kitchen (kitchen sinks and dishwashing machines). Other water that may be contaminated with harmful pathogens, such as water used for baby and nappy washing, is also excluded from greywater to be potentially used as a water resource. Greywater therefore includes wastewater from baths, basins, and laundry. Greywater is not only produced on private residential stands, but also at communal washing places, businesses, and taxi ranks.

Greywater is a handy alternative water source to potable water in instances where the reduced water quality can be tolerated e.g. for the flushing of toilets or for garden irrigation. The utmost care and consideration must be taken in the decision-making process to account for the risks involved in utilising greywater as a resource. Under no conditions must greywater be utilised in homes in untreated form, or must greywater be utilised if a household is not fully serviced.[39] Figure J.14 relates to the permissibility of greywater use for individual households.

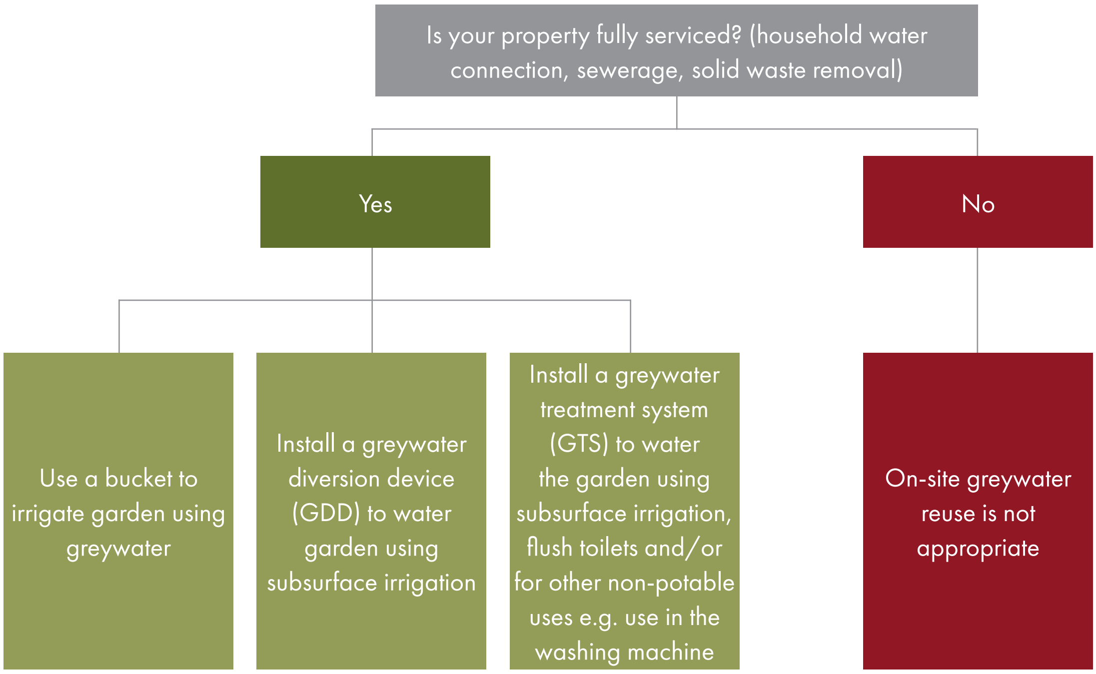


Figure J.14: Permissibility of greywater use[40]

The large-scale community supply of supplementary water sources such as greywater and rainwater for non-potable uses (toilet flushing and irrigation) is not without risk and operational challenges. Supplying non-potable water in separate reticulation systems presents a risk of cross-contamination between the potable and non-potable systems when such systems are accidentally connected.

An indicative estimation of the breakdown of internal water use is provided in Table J.5 to guide the designer in terms of the quantity of greywater that may be available as a source. Guidance on greywater use is included in **Section K** (Sanitation).

J.4.2.5 Seawater

Desalinated seawater can be used as an alternative water source in coastal region settlements. The operation of desalination plants, however, requires higher levels of operational care than conventional treatment plants. The design of a desalination plant should consider the financial, ecological and operational implications of the brine produced, the relatively high electricity requirements, and the need for a seawater intake/discharge. Also, consider the possibility of the desalination plant being taken temporarily out of commission when other water sources are adequate. For more detailed information, refer to the *Desalination guide for South African municipal engineers*[41] and *Investigation into the cost and operation of Southern African desalination and water reuse plants.*[42] These publications are available from the WRC.

J.4.2.6 Reclaimed water

Water reclamation is important for balancing water availability with water requirements in the future. Reclaimed water is wastewater that has been treated to a level that is suitable for sustainable and safe reuse. The reclamation of 'pre-used' water is becoming more viable because of advancement in technology.

While re-introducing reclaimed water from wastewater treatment sites into the potable water system is a possibility, treating the water to lower standards for industrial or other non-potable purposes (such as irrigation of sports fields, golf courses or for certain agricultural uses) can possibly offer a reduction in potable water requirements. Mine water reclamation can be considered in areas where the treatment of mine water discharge is essential in any event. Treating wastewater originating from industrial areas to potable standards can be problematic due to the presence of heavy metals and other contaminants, hence the quality of the effluent needs to be considered. It is therefore recommended that residential effluent should be primarily considered for reclamation. For more detailed information, consult *Direct Reclamation of Municipal Wastewater for Drinking Purposes, Volume 1*[43] and *Direct Reclamation of Municipal Wastewater for Drinking Purposes, Volume 2.*[44] Both publications are available from the WRC.

J.4.2.7 Stormwater

Stormwater is an indirect water source as recharging of the aquifer takes place through the Sustainable Urban Drainage System (SuDS) and the stormwater can subsequently be abstracted as groundwater. Stormwater can also serve as a potential non-potable water source when stored in retention/stormwater ponds. See Section L (Stormwater) for design guidance on SuDS.

J.4.3 Water quality

The source of water may be pristine and may require low levels of treatment intervention, or it may be more complex, such as in a reuse situation. To minimise water-related diseases, the disinfection of domestic water supplies must be observed as a basic requirement. The filtration of all water sources before use is recommended.

The compliance requirements of SANS 241-1[45] differentiate between the population size served and the risk levels associated with specific water quality parameters. On this basis, the legal compliance levels vary between 90% and 99%, depending on the water quality parameter under consideration and the planned use of the water.

The raw water quality data should be compared against the potable water quality standards to determine the overall treatment requirements. The treatment technologies selected should focus on those specific parameters in the raw water that do not meet the potable water quality standards. Additionally, there may be parameters of concern that are not listed in the SANS 241-1[46], such as stability, alkalinity and any contaminants of emerging concern that may be present in the source water, which need to be considered during design.

J.4.4 Water treatment infrastructure

This section provides a broad background only. For more information on water treatment plant design considerations, refer to *Water Purification Works Design*[47] and *Package Water Treatment Plant Selection.*[48] Both publications are available from the WRC.

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 only disinfection. Disinfection is a precautionary, but mandatory (SANS 241-1[49]) measure to minimise biological activity in the storage reservoirs and pipelines. A disinfectant that leaves a residual in the treated water should be used. Ozone treatment or ultra-violet radiation should be augmented with a disinfectant to provide for the longer-term protection of the water in the distribution system.

Most surface water will require treatment, both to remove turbidity and for disinfection. Certain surface waters and groundwater will require additional treatment for the removal of organic and inorganic contaminants. Many groundwater sources in Southern Africa are saline and, unless a suitable alternative economic source of water can 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. Groundwater is the preferred choice[50] for rural community supplies, as it often does not require treatment (other than disinfection). The need for treatment will be determined by the extent of contamination and by the characteristics of the raw water. For treatment to not be needed, raw water must comply with the below minimum quality requirements:

- Turbidity < 5 NTU
- Nitrate as N < 10 mg/L
- Chlorophyll –a < 5 µg/L
- Iron < 0.3 mg/L
- Manganese < 0.05 mg/L
- True colour < 25 mg/L Pt

However, a decision not to treat raw water should be evaluated against SANS 241-1[51] and the requirements of the Department of Water and Sanitation.

Water in distribution pipelines should be neither corrosive nor scale-forming. Corrosive water may lead to corrosion of the pipelines, fittings and storage tanks, resulting in costly maintenance, and even the presence of anti-corrosion products in the final water being delivered to the user. The stability and alkalinity requirements must be addressed at the plant. Various indices are used to define the stability level of water to estimate the likelihood of pipe corrosion or excessive carbonate deposits. These indices include, amongst others, the Langelier Index, the Ryzner Index, and the Calcium Carbonate Precipitation Potential (CCPP). Although all the listed indices are widely used, the Langelier and Ryzner indices have been superseded by the CCPP, which incorporates consideration of a wider range of chemical constituents that react with metal and concrete surfaces. The CCPP index is, therefore, the preferred stability index and a target of 4 mg/L as $CaCO_3$ is recommended.[52]

A summary approach to process selection for treatment, which supports slow sand filtration as an initial process consideration, is provided in *Water Purification Works Design*[53], available from the WRC. Slow sand filtration is valid for areas where skilled persons 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. Slow sand filtration can be an economical and successful option for water treatment plants in developing areas.

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

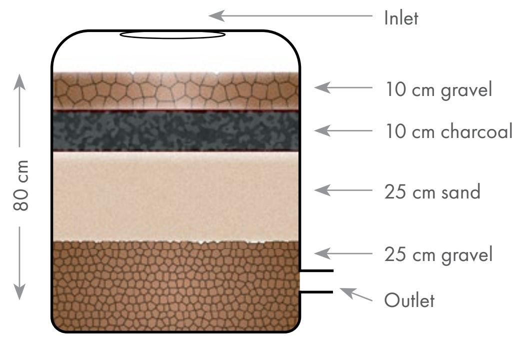


Figure J.15: A sand filter (L) and an example of packaged water treatment (R)

Package water treatment plants could be used to treat water to potable standards for smaller communities. Attention should be paid to the operation and maintenance requirements of these plants, as well as to the backup support from suppliers. Approval for the construction and operation of package plants must be obtained from the responsible Water Services Authority. More information can be obtained from the *Package Water Treatment Plant Selection*[54] and *Package plants for drinking water treatment: Technology survey, operation and maintenance aspects.*[55] Both these publications are available from the WRC.

The economics and operation of any size plant will be affected by the sustainability of the residuals management system provided. All treatment plants generate 'waste streams' that may be characterised by its content of treatment chemicals, organic and inorganic contaminants and salts. Based on this classification and the process from which the waste stream emanates, it is called wastewater, sludge or brine. These treatment residuals must be handled with due consideration of regulatory and sustainability requirements. In most cases, the ability of the plant to appropriately deal with this matter is determined during the initial planning, design and construction of the plant. Plant designers are required to ensure that the plant is adequately equipped to deal with this matter. Plant designers are also strongly encouraged to investigate options that will lead to reuse of the treatment residuals. Refer to reports published by the WRC on residuals handling (*Water Purification Works Design*[56]), on disposal (*Guideline for the Utilisation and Disposal of Water Treatment Residues*[57]), and on brine handling (*A Desalination Guide for South African Municipal Engineers*[58]).

J.4.5 Water distribution infrastructure

This section describes the methodology and design constraints to be considered in designing and sizing water distribution infrastructure.

J.4.5.1 Design methodology

Hydraulic modelling software should be used for the sizing of water distribution infrastructure. The demand estimates of the proposed development should be assigned to a modelled pipe network and simulated for the following scenarios:

- Peak hour demand conditions
- Static conditions (during minimum flow conditions – typically during the night)
- Extended time simulation (peak week) for the bulk system and storage analysis
- Fire-flow Analysis

J.4.5.2 Pressure criteria for reticulation systems

Water supply systems should be designed not only for the peak-water-demand scenario, but also the low-water-demand (static) scenario, and hence a minimum and maximum pressure range should be catered for by selecting the appropriate pipe class to withstand the design pressures. The higher the pipe class, the greater the cost and the smaller the internal pipe diameters (for certain pipe materials).

Water reticulation systems should be designed according to the pressure criteria as defined in Table J.12, but with the general objective of keeping pressures as low as possible (refer to Section J.4.6.3 for guidance on the installation of pressure sensors).

Table J.12: Pressure criteria for reticulation systems

Pressure criteria		Comment
Minimum peak pressure	20 m	To be determined under peak hour demand conditions, without fire flow.
Recommended maximum static pressure	60 m	During static conditions to minimise losses.
Absolute maximum static pressure	90 m	During static conditions to prevent pipe breaks

The following exceptions apply:

- In very steep rural or semi-rural areas where a maximum pressure of 90 m is acceptable.
- In high-lying areas surrounding reservoir or tower sites where an absolute minimum pressure of 15 m is acceptable.
- In bulk systems where higher pressures are acceptable to be commensurate with the selected pipe class.

Refer to Section J.4.5.8 for additional pressure criteria applicable to fire-flow analysis.

J.4.5.3 Design of pressure management zones

Appropriate supply zone boundaries should be designed to achieve the pressure criteria as per Table J.12. Storage reservoirs or tanks have the dual role of providing storage and controlling pressure, but consider implementing additional Pressure Management Zones (PMZs) through the use of Pressure Reducing Valves (PRVs), or in some cases by using break-pressure tanks. Consider the following criteria in the design of PMZs:

- A PMZ should have no more than two different supply points, each of which can be controlled using a PRV, or where feasible, through a tank. If more than two PRVs are required, split the zone into additional PMZs.
- The pressure at the PRVs should be set to achieve the minimum pressure criteria at the critical points (lowest pressure point) of the zone, which may not necessarily be at the highest elevation in the zone.
- Cascading PMZs should be avoided when designing new reticulation systems. The same outcome should rather be achieved through the use of a high-pressure main with PMZ sub-zones branching off at the appropriate elevation.
- Allow for a meter to monitor the flow into each PMZ (and thus at each PRV or tank).

A wide variety of pressure management technologies are available, ranging from simple fixed outlet control valves to a variety of hydraulic and electronic smart controllers.

J.4.5.4 Pipes

The sizing of reticulation pipes should be based on the following general parameters:

- Peak Demand Flow Velocity < 1.5 m/s - this is primarily to minimise head loss, but also to provide a degree of protection against water hammer. As pipe diameter increases, the impact of velocity on head loss decreases and velocities higher than 1.5 m/s are acceptable. The impact of water hammer should however still be considered.
- Peak Demand Head > 20 m - pipe diameters should be sized to ensure peak demand head is greater than 20 m at all user connection points. At other locations in the network, such as directly downstream of a storage structure or on a distribution main without any connections, it is often neither possible nor necessary to achieve this pressure and the only requirement is a positive pressure.
- Fire flow - pipe sizes should have adequate capacity to meet the fire-flow requirements. Communication pipes (otherwise known as stand connections) should be sized according to the guidelines in Table J.12.

The following hydraulic, physical/structural, financial and environmental factors should be considered in the design of pipelines:

(i) Hydraulic considerations

- The pressure should be kept as low as possible to minimise real losses.
- The number of low and high points on pipes should be kept to a minimum to reduce the number of scour and air valves respectively.
- The velocities in the pipeline should be kept between 0.6 m/s and 1.2 m/s.
- Velocities through special fittings should not exceed 6 m/s or as per manufacturer's specifications.
- Pipelines should be designed to be protected against water hammer/surge pressures.
- Using 110 mm as the minimum pipe size for ring mains in urban areas should be considered where the provision of fire flow is required.

(ii) Physical/structural considerations

- Size and position air-valves at high points to avoid vacuum pressures in the pipe leading to collapse and water quality contamination.
- Wherever possible, avoid curves on pipe routes. Provide marker posts at directional changes and intermediate locations.

- It is advantageous to use the minimum number of different pipe sizes to reduce the holding stock required for maintenance and repair.
- Minimum recommended trench depths:
  - Road crossings: Pipe diameter + bedding+ 0.8 m.
  - Otherwise: Pipe diameter + bedding + 0.6 m.
- Pipe-laying specification:
  - Bedding thickness should be one-sixth of the pipe diameter with a minimum of 100 mm.
  - Use anchorage and thrust blocks whenever the pipeline changes vertical or horizontal direction by more than 10 degrees. Use thrust blocks where the size of the pipeline changes, at blank ends, and on steep slopes (more than 1:6).
  - Ensure that jointing and sub-soil design receive careful attention where poor trench conditions might exist (rivers, swamps, etc.).
- Consider the inclusion of corrosion protection for pipelines to protect against external and internal conditions. External conditions include soil conditions, cathodic (electric currents – required for metal pipes only); and external abrasion (above-ground pipes). Internal conditions include chemicals and sediment that could cause abrasion of the pipe or pipe lining.
- Where services pass underneath national or provincial roads, put markers on both sides of the road reserve. Similarly, put markers on both sides of servitudes of other service providers.
- Wherever possible, pipelines should be laid in road reserves and preferably not pass through privately owned property, in which case a servitude must be registered.

(iii) Financial considerations

- Consider sizing bulk or main distribution systems to meet the future capacity requirement (as per master plan) or make provision for phased implementation of components such as pumps and reservoirs to reduce the total future cost of the infrastructure.
- Consider the associated energy implications when selecting the pipe material and lining system. Less friction in the pipeline relates to lower electricity input in rising mains. For long bulk pipelines, a general rule of thumb is to keep the head loss < 4 m/km.

(iv) Environmental considerations

- The installation of large diameter pipelines longer than 1 000 m and with an internal diameter ≥ 355 mm, or peak flow throughput of ≥ 120 L/s, requires an Environmental Impact Assessment (EIA) in terms of the National Environmental Management Act (NEMA).

J.4.5.5 Communication pipes

Communication pipes should be sized according to Table J.13.

Table J.13: Stand connection pipe sizing

Length of pipe	Income level	Minimum actual internal diameter (mm)	
		Serving two stands	Serving one stand
Pipe crossing road to house	Higher	40, branching to 2 x 20	25, reducing to 20 at stand
	Middle	40, branching to 2 x 20	25, reducing to 20 at stand
	Lower	20, branching to 2 x 15	15
Pipe not crossing road to house	Higher	40, branching to 2 x 20	20
	Middle	40, branching to 2 x 20	20
	Lower	20, branching to 2 x 15	15

J.4.5.6 Reservoir storage

Water distribution systems should be planned to have redundancy so as to minimise supply interruptions when pipe bursts occur. Different options to consider when planning for storage reservoirs are discussed in Section J.3.3.3. The volume of water required for the balancing function, which is dependent on the supply rate (inflow) to and the demand requirement (outflow) pattern from the reservoir, is typically represented as hours x Total Average Annual Daily Demand (TAADD). A trade-off exists between the two parameters (inflow and storage volume): a small reservoir with a high inflow rate and a large reservoir with a low inflow rate can achieve the same objective.

(i) Determine the reservoir supply rate

An appropriate bulk supply rate to storage reservoir is essential to be in the following range (refer to Table J.9 for peak factors):

> Peak Week Factor (PF_{week}) x TAADD

< Peak Day Factor (PF_{day}) x TAADD

When a new development is to be supplied by an existing reservoir and bulk supply pipe, the most practical and economic outcome may be to supply the reservoir at a rate slightly higher than the PF_{day} x TAADD to avoid the construction of a new reservoir.

For gravity supply into a reservoir, assume the supply rate to be a constant 24-hour supply into the reservoir during its critical peak draw-down period.

The same design assumptions can be applied to pumped supply, i.e. only during the critical peak draw-down period will 24-hour pumping be required. During periods of lower demand, pumps will run for shorter periods during the day. In cases where there is uncertainty regarding the peak demand, consider designing the pumped supply to a reservoir in such a way that the pumps run for only 20 hours during the critical peak day. This has the effect of building in some spare capacity that can be utilised should the actual demand exceed the design demand.

The required reservoir storage volume should be calculated using the following methodology:

Total Reservoir Volume = Balancing Storage + Emergency Storage

(ii) Calculate the balancing storage

The balancing storage requirement should be designed so that there is adequate capacity for extended periods of high demand. The latter should ideally be determined using critical period analysis or time-simulation modelling. Use the following guidelines as parameters for the critical period analysis/time-simulation modelling:

- Select an appropriate inflow rate according to the guidance provided above.
- Simulate the outflow from the reservoir using 24-hour demand patterns for the relevant land use over a peak week demand period (refer to Table J.14 and Figure J.16 for an illustration of typical patterns).
- Assume that the peak week includes the seven peak days of the year.
- Determine the maximum balancing volume required to ensure that the reservoir does not empty during this week.

Economic balancing storage is typically between 6 hours and 12 hours x TAADD. Next, add the necessary emergency storage volume to determine the total reservoir storage required.

Table J.14: Typical 24-hour demand patterns

Hour	Res. Large Stands	Res. Medium Stands	Res. Small Stands	Low income Housing	B/C/I* large	B/C/I* medium
	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5	Pattern 6
0	0.50	0.30	0.10	0.50	0.40	0.40
1	0.50	0.30	0.10	0.60	0.40	0.40
2	0.50	0.30	0.10	0.60	0.40	0.40
3	0.50	0.30	0.20	0.60	0.45	0.40
4	0.50	0.40	0.30	0.70	0.50	0.50
5	0.60	0.50	0.50	0.75	0.60	0.60
6	0.90	0.80	1.00	0.80	0.85	0.70
7	1.20	1.20	1.40	0.95	1.10	1.00
8	1.40	1.60	1.90	1.20	1.30	1.30
9	1.60	1.75	2.00	1.30	1.40	1.40
10	1.60	1.80	2.10	1.50	1.50	1.60
11	1.40	1.60	1.90	1.60	1.40	1.70
12	1.30	1.40	1.60	1.60	1.35	1.80
13	1.20	1.25	1.20	1.60	1.35	1.80
14	1.20	1.20	1.00	1.55	1.30	1.70
15	1.20	1.30	1.20	1.50	1.40	1.50
16	1.30	1.40	1.60	1.50	1.45	1.40
17	1.40	1.50	1.80	1.40	1.50	1.30
18	1.40	1.40	1.60	0.85	1.40	1.10
19	1.10	1.20	1.00	0.70	1.20	0.80

Hour	Res. Large Stands	Res. Medium Stands	Res. Small Stands	Low income Housing	B/C/I* large	B/C/I* medium
	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5	Pattern 6
20	0.90	0.90	0.70	0.60	1.00	0.70
21	0.70	0.70	0.40	0.60	0.75	0.60
22	0.60	0.50	0.20	0.50	0.55	0.50
23	0.50	0.40	0.10	0.50	0.45	0.40
24	0.50	0.30	0.10	0.50	0.40	0.40
Total	24.00	24.00	24.00	24.00	24.00	24.00

* = Business/Commercial/Industrial

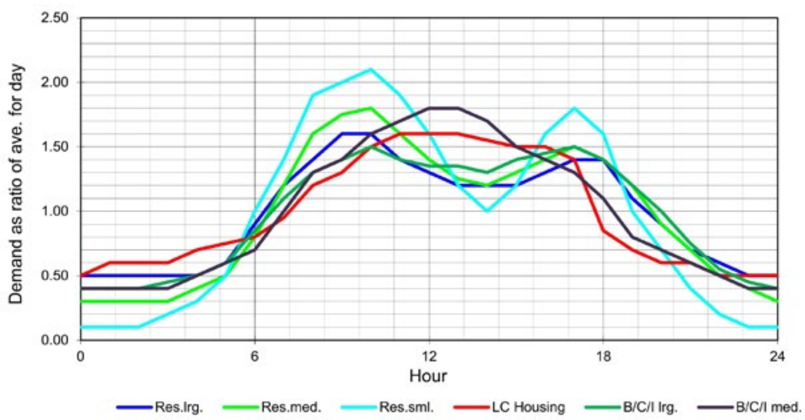


Figure J.16: Typical 24-hour demand pattern

(iii) Determine the emergency storage requirements

The following factors should be considered in selecting the required emergency storage:

- **Supply conditions** – A reservoir that is gravity fed by a large upstream bulk reservoir may have a far more reliable supply than an isolated reservoir supplied by a borehole and pump station.
- **Bulk system redundancy** – A well-integrated bulk system may have multiple/backup supply options to a reservoir, which significantly reduce the probability of reservoir failure.
- **Operational capacity** – A well-maintained network with a maintenance team on 24-hour standby would require considerably less emergency time than an isolated rural network.
- **External bulk operator requirements** – In many instances, an external party supplies the bulk water from its nearby reservoirs. The latter may already include emergency storage capacity, which may potentially result in extra redundancy.
- **Fire-fighting** – In areas with limited firefighting resources it may be necessary to include additional emergency storage.

In a metropolitan area with a well-integrated bulk system and multiple supply options, 18 hours of emergency storage would be adequate. In an isolated area with a high dependency on one source, more than 24h x TAADD may be necessary.

(iv) Generalised storage values

In the absence of a time simulation, or over a peak week demand period described above, use the generalised values shown in Table J.15.

Table J.15: Suggested minimum reservoir storage volumes

Suggested minimum reservoir storage provision (Expressed in hours x TAADD)		
Available bulk supply rate	h x TAADD	
	Well maintained, integrated bulk system, high levels of redundancy, 24h operational staff	An isolated bulk system with a high level of dependency on one supply, limited operational capacity
High (PF_{day} x TAADD)	24	36
Low (PF_{week} x TAADD)	30	48

Note: For strategic bulk reservoirs that on-supply to numerous smaller reservoirs (often referred to as 'Command Reservoirs'), a minimum storage volume of 48 hours x TAADD is recommended. However, with high levels of redundancy and sufficient emergency storage in the downstream reservoirs, a storage volume of 36 hours x TAADD may be acceptable.

Be aware that the water may be stored for ancillary purposes such as to provide contact time for chlorination. Also be aware that reservoirs that are very large in relation to TAADD may result in very long retention times that may lead to stagnation of water.

J.4.5.7 Elevated storage/towers

The following design guidelines should be used for calculating elevated storage/towers volumes:

(i) Selection of supply rate

Ensure that the capacity of the supply to the elevated storage is greater than the instantaneous peak demand of the tower zone plus an allowance of 10% calculated as follows:

Tower supply ≥ 1.1 x PF_{hour} x TAADD,

Where PF_{hour} is as per Table J.9; and

TAADD = the total average annual daily demand of the zone supplied by the tower.

(ii) Storage volume

Table J.16 provides the required minimum capacity for elevated storage depending on the reliability of the bulk supply.

Table J.16: Minimum elevated storage capacity	
Supply to elevated storage facility	Capacity of elevated storage (hours x TAADD)
One electrically driven duty pump, plus one identical electrically driven standby pump, plus automatically activated standby power generation independent of the electricity supply.	2
One electrically driven duty pump, plus one identical electrically driven standby pump with no backup power supply.	6

(iii) Additional supply considerations

Include a by-pass pipe equipped with a pressure reducing valve (PRV) to provide the same head as provided by the tower, which can be used in emergency situations or during maintenance of the tower. Size the by-pass pipe for the PF_{hour} x TAADD flow requirement.

Consider a variable speed booster pump as a viable alternative to providing elevated storage; it has a lower capital cost and does not have an aesthetical impact on the skyline. Conversely, the pump is required to run constantly, and storage provided by a tower provides a limited degree of security in the event of supply failure.

J.4.5.8 Provision of water for firefighting

(i) Fire flow

The water requirements for firefighting are dependent on the relevant fire-risk classification as indicated in Table J.17.

Table J.17: Design criteria for the provision of fire flow				
Risk classification	Total fire flow (L/s)	Minimum flow at one hydrant (L/s)	Minimum pressure at fire node (m)	Minimum pressure at rest of system (m)
High risk: CBD and high-risk industrial	100	25	15	5
Moderate risk 1: Industrial, business, high-rise flats ≥ four storeys	50	25	15	5
Moderate risk 2: Cluster & low-income housing, high rise flats ≤ three storeys	25	25	10	5
Low risk: Single residential housing	15	15	10	5

(ii) Fire duration

The volume of water to be available for firefighting should be calculated by multiplying the Total Fire Flow from Table J.17 with the recommended fire duration from Table J.18. Although, generally speaking, no additional reservoir storage would typically be required to accommodate the typical firefighting volumes, there are instances, such as when an area is supplied via an elevated tank, where the required volume must be available.

Table J.18: Duration of design fire flow	
Fire-risk category	Duration of design fire flow (h)
High risk	6
Moderate risk 1	4
Moderate risk 2	2
Low risk	1

(iii) Sizing of reticulation

Hydraulic modelling software should be used to simulate fire incidents (using various hydrant combinations) to ensure the water supply system can supply the fire flow as specified in Table J.17 for the respective risk areas at the minimum pressures indicated. A water demand scenario of the greater of 2 x TAADD or PF_{day} x TAADD in conjunction with the required fire flow should be assumed.

(iv) Sizing and positioning of fire hydrants

When providing fire hydrants, the following should be considered:

- Hydrants should not be provided off mains smaller than 75 mm diameter.
- Hydrants should be located in vehicular thoroughfares and opposite stand boundary pegs, and at a maximum spacing of 200 m (or as otherwise required by the local fire department).
- 75 mm diameter sluice-valve hydrants should be used for the high-risk and moderate-risk categories. For the low-risk category, the hydrant may be the screw-down type.
- The location of hydrants should be indicated by using permanent marker posts on the verge opposite the fitting or painted symbols on road or kerb surfaces. Symbols on markers should be durable.
- The hydrants' flow rate should be serviced and checked for conformity with Table J.17 at intervals not exceeding one year.
- Where possible, fire hydrants should be positioned to also serve as a scour valve.

(v) Sizing of distribution mains

Distribution mains should be sized to have sufficient capacity for fire flow by using a demand equal to the flow requirement specified in Table J.17, added to the greater of 2 x TAADD or PF_{day} x TAADD. In cases of mixed land use, design for the land use with the highest risk classification. For example, in Figure J.17, Distribution Main A and B would be sized based on their respective fire-risk classifications and demand, whereas Distribution Main AB would be sized based on the risk category of Sub Zone B and the total demand of the entire supply zone.

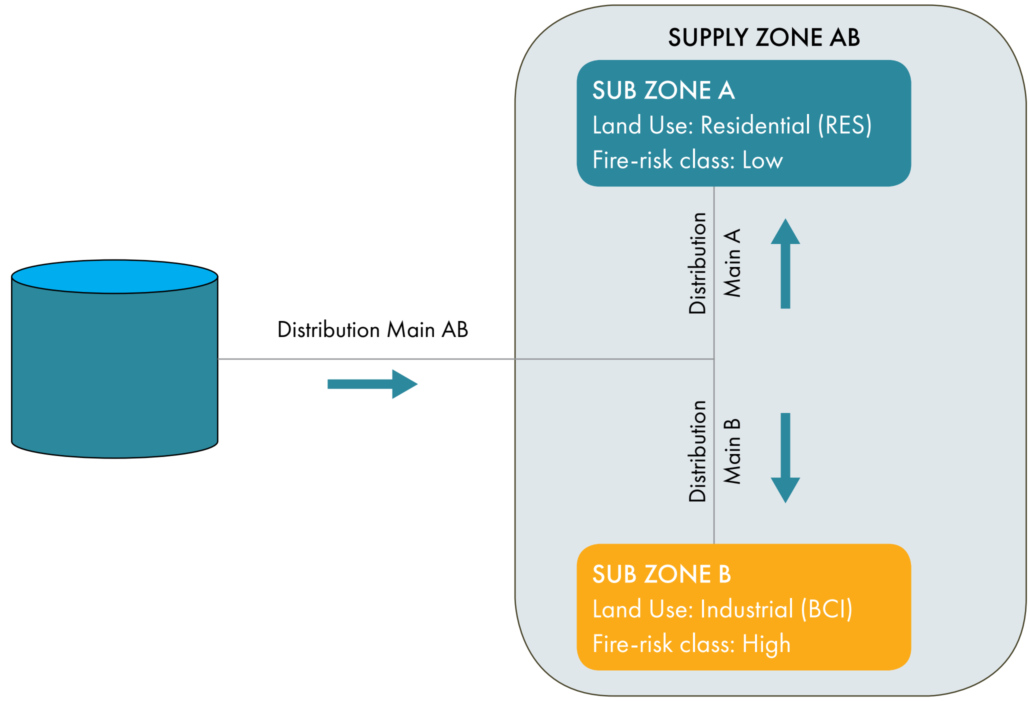


Figure J.17 Design of distribution mains with differing fire-risk categories

The sizing of reticulation and distribution mains should consider the fire-flow requirements presented in this section in conjunction with general pipe sizing requirements as per **Section J.4.5.4**.

(vi) Provision of storage for firefighting

The provision of emergency storage is discussed in **Section J.4.5.6**. Provided these requirements are met, no further emergency storage is required for firefighting.

J.4.5.9 Valves and other fittings

Valves are usually required to either isolate sections, or to aid in the operation of the water supply system. Careful positioning of valves will ensure effective operation.

(i) Isolating valves

- Valves should be installed at intervals as required for maintenance of the pipeline sections depending on the local operational requirements. The cost associated with the loss of water by scouring versus containment during maintenance should guide the designer.
- Consider the installation of air and pressure relief valves at the location of the isolation valves.
- Consider topography and access in locating/placement of isolation valves.
- Consider a reduction in valve size to reduce the cost – isolating valves in larger mains may be of lesser size than the pipeline. Use maximum velocities and life-cycle cost implications to guide the decision to install smaller valves.

- Consider the removal of valves as part of the fittings associated with the installation.
- Indicate the location of isolating valves by using permanent marker posts on the verge opposite the fitting, or painted symbols on road or kerb surfaces. Symbols on markers should be durable.
- In reticulation networks, provide sufficient isolating valves so that no more than four valves need to be closed to isolate a section of the main pipe, and so that the total length of the main included in an isolated section does not exceed a nominal 600 m.
- Locate valves at street corners opposite stand corner boundary (splay) pegs, and intermediate valves opposite the common boundary peg between two stands.

(ii) Air valves

- Air valves should be sized according to the air-flow rate generated by the inflow or outflow of the water in the pipeline.
- The sizing of the branch from the main pipe should not jeopardise the structural integrity of the pipe and be large enough to provide sufficient access for air. Generally, the branch pipe shall be between 50% and 60% of the main pipe's diameter.
- Install air valves with an isolating valve on the air-valve branch to facilitate maintenance.
- Install air valves to prevent ingress of contaminants into the main pipe.
- Provide air valves to suit the longitudinal section of the pipeline in relation to the hydraulic gradient.

(iii) 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 drained. There should be an open drain to lead the washout water to a suitable watercourse.
- Scour outlets should be sized to permit complete draining of a section of main between isolating valves within two hours.
- Dead-end pipes ≥ 80 mm diameter should terminate in a scour valve or fire hydrant.
- The scour installation should have erosion control infrastructure to protect the environment.
- Where possible, fire hydrants should be positioned to also serve as a scour valve.

(iv) Break-pressure devices

- Break-pressure devices may be break-pressure tanks, pressure-reducing valves and, in some cases, strategically located reservoirs/tanks.
- Where possible, combine break-pressure tanks with storage tanks.
- When used, provide pressure-reducing valves with a pressure-relief valve on the outlet side, to prevent the possible build-up of pressure resulting from the failure of the pressure-reducing valve. The discharge from the relief valve should be conspicuous when it occurs.
- Provide a dirt box upstream of the pressure-reducing valve, and a bypass pipe around it, complete with an isolating valve that is protected against accidental opening. Provide a pressure gauge on both the upstream and downstream sides of the dirt box.

(v) Valve chambers

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

- Vent air-valve chambers to allow for adequate air flow.
- Design roof slabs to allow for removal and replacement of the valve.
- Where possible, finish valve chambers proud of the final ground level to prevent ingress of water.
- Where necessary, make provision for the possibility of a differential settlement between the valve chamber and the pipeline. The installation of flexible couplings is recommended.
- Check the valve chamber for susceptibility to floatation due to high groundwater levels and design accordingly.
- Provide access via ladders or step-irons.

J.4.5.10 Design of end-user delivery

Different types of delivery to end-users are presented in **Section J.3.3.6**. Figure J.18 illustrates the design of a typical standpipe as the end-user delivery method.

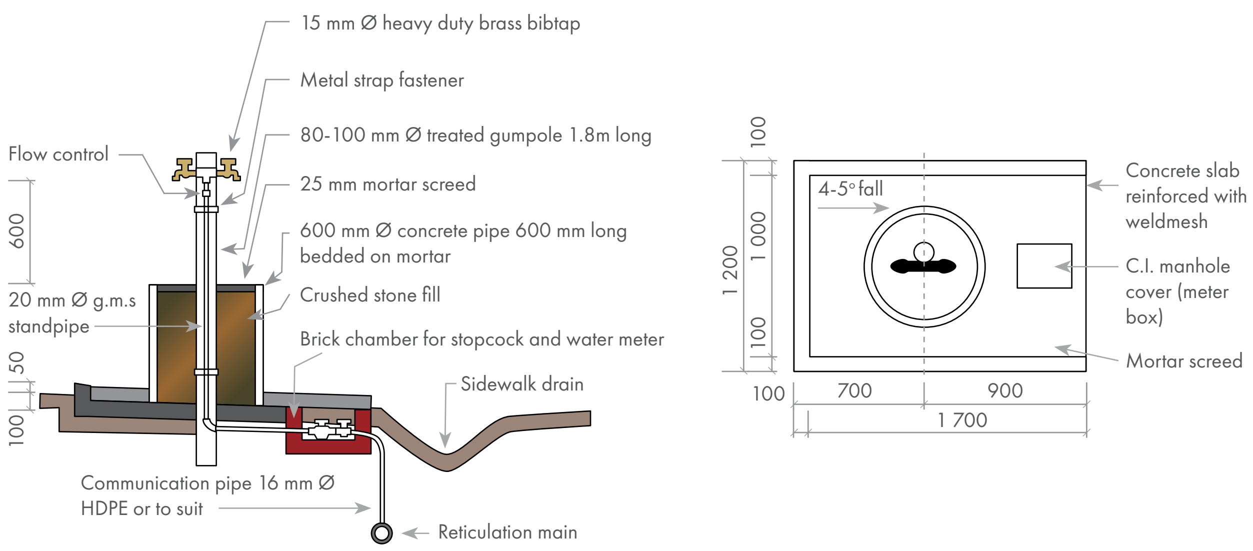


Figure J.18: Typical standpipe detail

J.4.6 Water demand management

The provision of water infrastructure needs to consider appropriate Water Conservation/ Water Demand Management (WC/WDM) measures. Monitoring water demand through bulk metering of discrete pressure zones or district metered areas is important. Boundary valves should be avoided or minimised to reduce the risk of zones being bridged intentionally or accidentally by operational personnel. The guideline pressure envelope should be achieved by carefully selecting distribution zone boundaries or using pressure-regulating devices. The impact of high pressures should be mitigated through the appropriate selection of pipe pressure class.

J.4.6.1 Sectorising into district metered areas

Water distribution zones should be divided into smaller discrete District Metered Areas (DMAs) to improve water auditing and calculating water balances in accordance with the relevant standards (refer to Figure J.19).

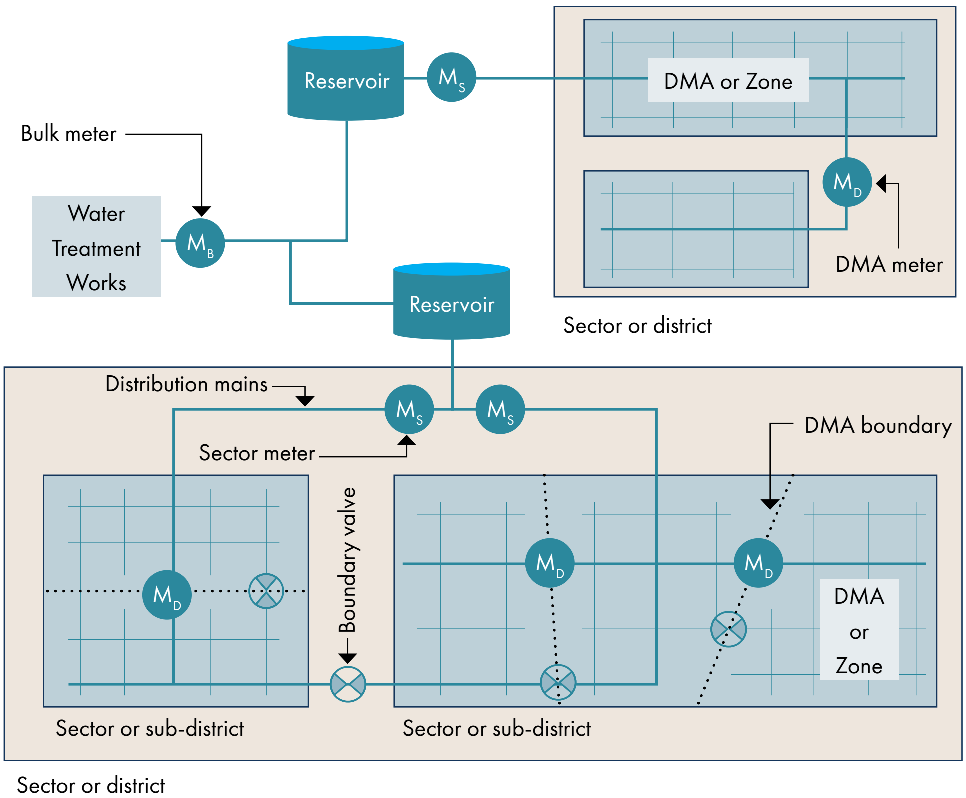


Figure J.19: Sectorising of a water supply zone

Use the following guiding criteria in the design of DMAs:

- Existing boundaries such as main roads, highways, railway lines, rivers, new developments, topographical features (e.g. mountains or valleys) should be used to determine DMA boundaries. Preferably select zone boundaries that can easily be distinguished and maintained by operational personnel, to reduce the risk of zones being breached accidentally.
- The ease of establishing, operating and maintaining, land use and staff capacity of the utility should be taken into consideration when sizing a DMA. Large zones are often easier to establish, operate and maintain, but areas of high leakage could be difficult to determine. Small zones could be costly to establish, operate and maintain, but finding areas of high leakage could be simpler.
- Consider the option of keeping boundary valves above ground so that they are easily identified and accessible.
- Multiple supply points to a DMA result in multiple meters to be read and maintained. A single supply point results in simpler metering, but a loss in supply redundancy.
- As a minimum, a supply zone should be designed in such a manner that it can be split into smaller areas, even if on a temporary basis, as this will enable high water loss areas to be identified in future through step-testing. Step-testing is the process of isolating sections of the DMA while monitoring the minimum night flow. A significant drop in the minimum night flow could suggest a possible leak or cross-boundary supply in the isolated section.

J.4.6.2 Bulk metering

Bulk meters (as opposed to user meters discussed in Section J.3.3.5) should be installed to allow monitoring of the flow in a distribution network (at least monthly) and to obtain diagnostic information for calculation of the system input volume needed for water balance calculations.

(i) Location of bulk water meters

Bulk water meters are recommended at the following locations:[59]

- Supply points to DMAs and Pressure Management Zones (PMZ)
- Points in the system where it is important to know how much water is distributed, such as reservoir inlets and outlets, pump stations and off-takes to different areas
- Connection points to bulk water suppliers or other municipalities and water service providers
- Clean water production at the outflow of water treatment plants
- Raw water withdrawals from dams, boreholes or other sources

Meters should be sized for the current demand as per manufacturer's specifications.

J.4.6.3 Pressure sensing

Consider installing sensors to measure the pressure at the following places:

- The critical point in a supply zone (point of lowest pressure). Be aware that this does not always correspond to the highest point in the zone, and that there may be different critical points at different times of day depending on the demand.
- The lowest point in the supply zone (point of maximum pressure), especially for zones where very high static pressure occurs and where there is a risk of accidental opening of boundary valves or Pressure-Reducing Valve (PRV) failure, leading to even higher pressures that could cause pipe bursts.

- The pressure downstream of a PRV, to allow monitoring of the operational status of the PRV installation.
- The upstream and downstream sides of pump stations.

J.4.6.4 Intermittent supply

Intermittent supply or rationing is a common phenomenon in developing countries, and although it should be avoided at all costs, the potential impact of operating the system on intermittent supply should be considered during the design to avoid damage to infrastructure. Factors to consider for the selection of pipeline materials and meters include the following:

- During system drainage, negative pressures inside the pipeline will damage the pipe seals that were designed for positive pressures. Continuous negative and positive pressure fluctuations will damage pipe seals to such an extent that they can only be repaired by total replacement of the network.
- During system pressurisation, the air in the pipelines dissipates through the users' water meters. Air passing through a water meter could damage the mechanism, as the air causes the meter to spin excessively which exceeds the maximum flow rate of the meter. The air passing through the meter also distorts the meter readings and corrupts the billing database. This could have a profound effect on the water balance calculation in times of drought.
- The negative pressures inside the pipeline, during system drainage, will suck any contaminants (sewer, soil, stormwater, chemicals, etc.) into the pipeline, which can cause waterborne diseases such as cholera and typhoid. Pipe material should be carefully selected.
- Water distribution systems are designed for stable pressures and continuous drainage, and pressurisation will increase burst pipes, operational problems, overtime claims, user dissatisfaction and general disruption in supply.
- Isolating valves in water distributions systems are not designed for daily operation and will inevitably get damaged over time when frequently operated. This will increase maintenance costs.
- If the water supply becomes uncertain, users will start leaving taps open and wait for the water to fill buckets, baths and tanks. Once users start leaving taps open, it becomes increasingly difficult for the water services teams to fill reservoirs and pressurise the system. Service delivery will deteriorate, resulting in an increased reluctance to pay for services.
- Users quickly adapt to their new supply conditions and revert to on-site storage to mitigate the inconvenience caused by the disruption in supply. Once on-site storage is established, users revert to their usual lifestyle, oblivious of the disruption in supply. This practice results in hardly any reduction in actual demand.

J.4.7 Materials

J.4.7.1 Selection of materials

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

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

- The life-cycle cost (initial capital plus maintenance costs).
- The chemical composition of the water distributed or stored (for example, it is advisable to convey water with a Calcium Carbonate Precipitation Potential (CCPP) of 4 mg/L as $CaCO_3$ – at lower values the CCPP will indicate the likely corrosion of metal and concrete surfaces while higher values will indicate the possibility of excessive calcium carbonate precipitation.[60] Brass fittings, couplings, valves, etc., particularly for soft water, should be especially resistant to dezincification.
- The corrosive nature of the soil and groundwater, and the possible existence of stray electric currents.
- The structural strength of the pipes and reservoirs.
- The possiblity of the infrastructure subjected to vandalism. To reduce vandalism, consider materials with lower re-sale value and products that are more resistant to damage.

Circumstances that require special attention are heaving clay soils, dolomitic areas, and high external loading.

The anticipated construction methods and skills levels influence the choice of pipe material broadly categorised as rigid, semi-rigid and flexible pipes. In the case of rigid pipes of small diameter, the designer should check for the possibility of beam-type failure. Guidelines on the external loadings applicable to buried pipelines can be obtained in SANS 10102-2.[61]

J.4.7.2 Materials for pipelines

Due to superior strength, ductile iron and steel should be used where high operating pressures are expected. Joint types include threaded, flexible couplings, continuously welded, flanged or spigot and socket with rubber rings. Keep in mind the cost of fittings, especially at high pressures, and the susceptibility of these pipes to corrosion. When steel pipes are used, consider the corrosion protection systems described in Table J.19.

Table J.19: Corrosion protection for steel pipes

Lining location	Lining type	Application/suitability
Internal linings	Cement mortar (generally used from DN200 to DN1200)	Use Standard OPC CEM5 for water with pH6.5 and greater.
		Use Calcium Alumina Cement (CAC) for pH6.5 and lower.
	Liquid Epoxy Linings	Use 75% solids cross-linked epoxies for pipes of DN600 and smaller.
		Use 100% solids cross-linked epoxies for pipes of DN600 and greater.
External coatings	Galvanised	Note: susceptible to damage when buried.
	Stand-alone Fusion-Bonded Epoxy (FBE)	Can be buried, but best suited for above-ground applications. Best suited for pipes in range DN200-DN700.
	Three-Layer Polyethylene (3PLE)	Use for buried pipelines. Best suited for pipes in range DN200-DN700.
	Fusion-bonded Medium-density Polyethylene (FBMDPE)	Use for above or below ground pipes. Best suited for pipes in range DN200 and greater.
	Rigid Polyurethane (R-PU)	Use above ground provided UV stabilised top coat is used, but best suited for below-ground use. Use for DN200 and above.
	Polymer-modified Bitumen (PMB)	Use above ground if whitewash is applied and well maintained, but best suited for the underground application. Best suited to pipes DN700 and above. Easy to repair in the field.

- Unplasticised polyvinyl chloride (PVC-U) (16 to 630 mm diameter) provides easy-jointing pipes and good corrosion resistance. However, PVC-U suffers a loss in strength when exposed to sunlight for prolonged periods of time, therefore do not store exposed to the sun. Pipes may be damaged by careless handling and must be carefully bedded, avoiding stones and hard edges. The preferred type of coupling is spigot and socket rubber ring joint.
- Modified polyvinyl chloride PVC-M (50 to 630 mm diameter) should be used as an alternative to PVC-U. PVC-M provides the pipe material with a higher impact resistance than PVC-U, which in turn results in a greater balance between strength and ductility.
- Bi-orientated polyvinyl chloride PVC-O (90 to 800 mm diameter) should be used as an alternative to PVC-M and PVC-U. PVC-O provides improved mechanical and physical properties during the manufacturing process, resulting in a higher resistance to shock, punch and crack propagation.
- Polyethylene (PE) pipes (solid wall polyethylene pipes) (16 to 1 200 mm diameter – solid high-density polyethylene (HDPE)) (280 to 1 800 mm diameter Structured Wall HDPE) are relatively flexible. Thus the number of joints and bends is greatly reduced for diameters that are supplied in rolls. PE does not deteriorate significantly when exposed to sunlight. There are two types of polyethylene: low-density polyethylene and high-density polyethylene. Use low-density polyethylene (LDPE) mainly for irrigation purposes. HDPE is suitable for small-diameter mains, secondary pipelines and service pipes. Joints on larger diameter HDPE pipes are typically made by butt-welding. Use compression-type joints on smaller pipe sizes. Alternatively, use electrofusion welds on smaller diameter pipes. Electrofusion welds provide a reduction in installation time and could be considered as an alternative to other joining methods, especially where the conditions on site are difficult or where fast and accurate pipe repairs are necessary.
- Structured wall polyethylene pipes (also known as corrugated PE-HD) are lightweight and cost effective. Structured wall PE-HD pipes are an excellent choice for gravity flow or low head systems. The reduction in weight allows for easier and reduced transportation and installation costs.
- Reinforced precast concrete is suitable for low pressure (2 to 8 bar) bulk lines (2 bar up to 1 500 mm diameter; 4 bar up to 1200 mm diameter; 6 bar up to 900 mm diameter and 8 bar up to 600 mm diameter). They are durable, have considerable strength and are resistant to corrosion. Use spigot and socket joints with a rubber ring.
- Glass-reinforced polyester (GRP) pipes are available in a range of pressure classes and diameters suitable for water distribution systems. Notable attributes of these pipes are low density and high resistance to corrosion.

(i) Polyvinyl Chloride – PVC (PVC-U, PVC-M and PVC-O)

Product specifications: Refer to the relevant South African National Standards for PVC products within the South African Plastic Pipe Manufacturers Association (SAPPMA) quality reassurance audit system:

- *SANS 966-1 Components of pressure pipe systems Part 1: Unplasticized Poly(vinyl chloride) (PVC-U) pressure pipe systems*[62]
- *SANS 966-2 Components of pressure pipe systems – Part 2: Modified poly(vinyl chloride) (PVC-M) pressure pipe systems*[63]
- *SANS 1283 Modified poly(vinyl chloride) (PVC-M) pressure pipe and couplings for cold water services in underground mining*[64]
- *SANS 16422 /ISO 16422 Pipes and joints made of oriented unplasticized poly(vinyl chloride) (PVC-O) for the conveyance of water under pressure-Specifications*[65]

Refer to the SAPPMA website for other relevant product standards.[66]

(ii) HDPE (high-density polyethylene) pipes and fittings

Product specifications: Refer to the relevant South African national standards for HDPE products within the SAPPMA quality reassurance audit system:

- *SANS 4427-1 /ISO 4427-1. South African National Standard, Plastics piping systems - Polyethylene (PE) pipes and fittings for water supply* [67]
- *SANS 21307 /ISO 21307. South African National Standard, Plastics pipes and fittings - Butt fusion jointing procedures for polyethylene (PE) pipes and fittings used in the construction of gas and water distribution systems* [68]

Refer to the SAPPMA website for other relevant product standards.[69]

J.4.7.3 Materials for communication pipes

The following materials should be used for communication pipes:

- High-density polyethylene (HDPE) or polypropylene (PP) with external compression-type joints
- Galvanised steel with screwed and socketed joints or flexible couplings

Metallic pipes should be protected against corrosion where laid in aggressive soils, especially where moisture is retained in the soil under a paved surface. Plastic pipes, and specifically HDPE, are more suitable under these conditions. PP is best suited in buried conditions and can resist higher temperatures.

J.4.7.4 Materials for reservoirs

The type of construction material most suitable for reservoirs and elevated tanks differs depending on the volume of the structure. Determine the optimal construction material for a specific case based on an economic analysis, bearing durability in mind.

(i) Ground-level reservoirs

Table J.20 gives general guidelines for ground-level reservoir construction materials.

Table J.20: Reservoir construction material

Storage volume (ML)	Construction material
> 3.0	Reinforced concrete
1.5 to 3.0	Reinforced concrete or precast concrete system
1.0 to 1.5	Reinforced concrete or precast concrete system or steel
0.5 to 1.0	Precast concrete system or steel
0 to 0.5	Ferrocement, masonry, galvanised iron, and certain plastic and rubber tanks

Polyethylene and fibreglass tanks, if used for potable water, should be constructed to prevent light penetration, which may encourage algal growth.

(ii) Elevated tanks

The optimal construction material for elevated tanks depends on the volume and the height of the tank. Use the following guidelines:

- Tanks higher than 15 m and larger than 0.5 Ml are typically more economical to construct from reinforced concrete.
- Where smaller, lower tanks are required, steel panels may be appropriate in areas away from the aggressive coastal environment.

(iii) Tanks in rural areas

It is often not possible, or desirable, to erect reinforced concrete water-retaining structures in remote rural areas because the cost may be prohibitive. Ferrocement can be considered as construction is possible without sophisticated equipment or a highly trained workforce. Also, ferrocement has a high strength-to-mass ratio when compared to reinforced concrete. On completion of the tank, it requires little or no maintenance. Masonry tanks have been constructed successfully and have been in use for many years. These tanks also do not require highly skilled builders.

Tanks made of galvanised steel can be erected in a short space of time. However, this type of tank is typically more expensive than other options and also requires specialist contractors. In addition, these tanks have poor thermal insulation and a relatively short service life.

Pre-fabricated plastic, fibreglass, polyethylene and rubber tanks can be implemented very quickly. These tanks provide only limited opportunities for the use of local workforce and transporting these tanks is usually challenging. Polyethylene tanks should only be considered as a temporary measure.

Glossary, acronyms, abbreviations

Glossary

Communication pipe
The pipe connecting the reticulation system to the user, typically running from the reticulation main to the user meter or stand boundary.

Distribution main
A distribution main refers to a large diameter pipe carrying water from a bulk source to reticulation network.

Greywater
The untreated household wastewater from all domestic processes other than toilet flushing. It therefore includes water from baths, showers, kitchens, hand wash basins and water used for laundry. Greywater from kitchen sinks and dishwashing machines are excluded as a potential resource for the purpose of this guideline.

Infrastructure Leakage Index
Infrastructure Leakage Index (ILI) is the generally accepted best-practice key performance indicator for quantifying real losses.

Potable water
Water of a quality that is compliant with the standards set out in *SANS 241-1 South African National Standard – Drinking Water, Part 1: Microbiological, physical, aesthetic and chemical determinants.*

Reclaimed water
Wastewater that is reused before it is returned to the natural water cycle. The process typically involves the treatment of sewage to the standard required for reuse, including potable standards.

Reticulation
Reticulation refers to the network of pipes that supply water to the user.

Rising main
The pipe located on the discharge side of a pump.

Unit demand
Average daily demand in kL/d for a stand, household or per capita, depending on the context.

Water conservation
The minimisation of loss or waste, the care and protection of water resources and the efficient and effective use of water.[70]

Water Demand Management
The adaptation and implementation of a strategy by a water institution or user to influence the water demand and usage of water in order to meet any of the following objectives: economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability.

Water hammer

A pressure wave that occurs when pressurised flowing water is subjected to a sudden stop or change in direction. In distribution systems it is commonly the result of a sudden valve closure.

Water Services Authority

The municipality responsible for ensuring access/provision of water and sanitation services within its area of jurisdiction.

Water Services Provider

Provider of water and sanitation services under contract to a Water Services Authority.

Acronyms and abbreviations

AADD	Average Annual Daily Demand
BCI	Business/Commercial/Industrial
CARL	Current Annual Real Losses
CBD	Central Business District
CCPP	Calcium Carbonate Precipitation Potential
DMA	District Metered Area
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
FAR	Floor Area Ratio
HDPE	High-density polyethylene
ILI	Infrastructure Leakage Index
ISO	International Organization for Standardization
IWRM	Integrated Water Resource Management
NEMA	National Environmental Management Act
NWRS2	Second National Water Resource Strategy
NW&SMP	National Water and Sanitation Master Plan
PE	Polyethylene
PF	Peak Factor
PMZ	Pressure Management Zone
PP	polypropylene
PRV	Pressure-Reducing Valve
PVC	Polyvinyl Chloride
PVC-M	Modified Polyvinyl Chloride
PVC-O	Bi-Orientated Polyvinyl Chloride
PVC-U	Unplasticised Polyvinyl Chloride
SABS	South African Bureau of Standards

SANS	South African National Standard
SAPPMA	South African Plastic Pipe Manufacturers Association
SuDS	Sustainable Drainage System
TAADD	Total Average Annual Daily Demand
UARL	Unavoidable Annual Real Losses
WC/WDM	Water Conservation/Water Demand Management
WRC	Water Research Commission
WSA	Water Services Authority
WSD	Water Sensitive Design
WSDP	Water Services Development Plan
WSUD	Water Sensitive Urban Design

Endnotes

1 *SANS 10400 - The application of the National Building Regulations (NBR)* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/

2 *SANS 241-1 South African National Standard – Drinking Water, Part 1: Microbiological, physical, aesthetic and chemical determinants* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/.

3 International Water Association (IWA). n.d. The *IWA Principles for Water Wise Cities*. International Water Association, London.

4 Global Water Partnership. 2017. *The Need for an Integrated Approach*. https://www.gwp.org/en/About/why/the-need-for-an-integrated-approach/

5 Wong, T.H.F. 2006. Water sensitive urban design - the journey thus far. *Australasian Journal of Water Resources*. 10(3),213–222. DOI: 10.1080/13241583.2006.11465296.

6 University of Cape Town. 2018. *UCT Urban Water Management: Water Sensitive Design*. http://www.uwm.uct.ac.za/

7 Armitage, N., Fisher-Jeffes, L., Carden, K., Winter, K., Naidoo, V., Spiegel, A., Mauck, B., Coulson, D. 2014. *Water Sensitive Urban Design (WSUD) for South Africa: Framework and Guidelines*. WRC Report No. TT 588/14. Water Research Commission, Pretoria.

8 Armitage, N., Vice, M., Fisher-Jeffes, L., Winter, K., Spiegel, A., Dunstan, J. 2013. *The South African Guidelines for Sustainable Drainage Systems*. Report TT558/13. Water Research Commission, Pretoria.

9 Boulenouar, J., Gibson, J. 2015. *Asset management in rural South Africa. A case study of Amatole and Chris Hani district municipalities*. IRC, The Hague.

10 Swartz, C.D., Thompson, P., Maduray, P., Offringa, G., Mwiinga, G. 2013. *WATCOST: Manual for a Costing Model for Drinking Water Supply Systems*. WRC Report No. TT 552/13. Water Research Commission, Pretoria.

11 Van Zyl, F., Manus, A., Pensulo, E. 2008. *Water Services Infrastructure Asset Management for Municipal Managers*. Department of Water Affairs and Forestry, Pretoria.

12 Adam, A.G. 2016. Urbanization and the Struggle for Land in the Peri-Urban Areas of Ethiopia. *Proceedings of the Annual Bank Conference on Africa*. The World Bank Group, Oxford.

13 Department of Water Affairs and Forestry (DWAF). 2004. *Guidelines on Protecting Groundwater from Contamination*. Toolkit for Water Services. Number 3.4. Department of Water Affairs and Forestry, Pretoria.

14 Nel, J., Nel, M., Dustay, S., Siwawa, S., Mbali, S. 2014. *Towards a Guideline for the Delineation of Groundwater Protection Zones in Complex Aquifer Setting*. WRC Report No. 2288/1/14. Water Research Commission, Pretoria.

15 South African National Biodiversity Institute. https://www.sanbi.org

16 *SANS 10090 South African National Standard - Community Protection against Fire* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/.

17 Swartz, C.D., Van der Merwe-Botha, M., Freese, S.D. 2013. *Energy Efficiency in the South African Water Industry: A Compendium of Best Practices and Case Studies*. WRC Report No. TT565/13. Water Research Commission, Pretoria.

18 *SANS 241-1 South African National Standard - Drinking Water, Part 1: Microbiological, physical, aesthetic and chemical determinants*.

19 Department of Water Affairs and Forestry (DWAF). 1996. *South African Water Quality Guidelines. Volume 1: Domestic Use*. Second Edition. Department of Water Affairs and Forestry, Pretoria.

20 Smet, J., Van Wijk, C. (eds.). 2002. *Small Community Water Supplies: Technology, People and Partnership*. Technical paper Series 40. IRC International Water and Sanitation Centre, Delft.

21 Van Zyl, K.E. 2011. *Introduction to Integrated Water Meter Management.* WRC Report No TT490/11. Water Research Commission, Pretoria.

22 Adapted from Van Zyl, 2011.

23 Department of Water and Sanitation (DWS). 2017. *National Norms and Standards for Domestic Water and Sanitation Services.* Government Gazette No. 41100, Notice 982 of 8 September 2017. Department of Water and Sanitation, Pretoria.

24 Heymans, C., Eales, K., Franceys, R. 2014. *The Limits and Possibilities of Prepaid Water in Urban Africa: Lessons from the Field.* International Bank for Reconstruction and Development / The World Bank, Washington DC.

25 Seago, C.J., McKenzie, R.S. 2007. *An Assessment of Non-Revenue Water in South Africa.* WRC Report No TT 300/07. Water Research Commission, Pretoria.

26 Available at: http://www.who.int/water_sanitation_health/hygiene/om/linkingchap3.pdf

27 Foster, S., Hirata, R., Gomes, D., D'Elia, M., Paris, M. 2002. *Groundwater Quality Protection: a Guide for Water Utilities, Municipal Authorities and Environment Agencies.* World Bank, Washington, D.C.

28 Department of Water Affairs and Forestry (DWAF). 2004. *Groundwater Protection - Guidelines for Protecting Springs.*Toolkit for Water Services. Number 3.2. Department of Water Affairs and Forestry, Pretoria.

29 Available at: http://www.who.int/water_sanitation_health/hygiene/om/linkingchap3.pdf

30 OXFAM. 2008. *Spring protection.* Oxfam Technical Briefing Notes. Oxfam, Great Britain.

31 Rydbeck, B.V., Guapi, R. n.d. *Improved Techniques for Spring Protection Developed by Rural Ecuadorian Communities.* http://www.lifegivingwaterinternational.org/uploads/3/8/2/3/38233329/2013_spring_protection.pdf.

32 Smet and Van Wijk. 2002.

33 *SANS 10299-4:2003 South African National Standard - Development, maintenance and management of groundwater resources – Part4: Test Pumping of water boreholes* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/.

34 Christian Ruz [CC BY-NC-SA 2.0 (https://creativecommons.org/licenses/by-sa/2.0)], from Wikipedia Commons

35 Mpheya, J.N., Pienaar, J.J., Galey-Lacaux, Held, G., Turner, C.R. 2004. Precipitation Chemistry in Semi-Arid Areas of Southern Africa: A Case Study of a Rural and an Industrial Site. *Journal of Atmospheric Chemistry, 47*: 1–24.

36 Mpheya, J.N., Pienaar, J.J., Galey-Lacaux, Held, G., Turner, C.R. 2006. Precipitation Chemistry and Wet Deposition in Kruger National Park, South Africa. *Journal of Atmospheric Chemistry,* 53: 169–183.

37 Armitage et al. 2013.

38 Duncker L., Lindeque, M. 2012. *Assessment of Rainwater Harvesting at Kharkams High School in Kharkams, Kamiesberg Local Municipality, Northern Cape.* CSIR report, GWDMS 225420. CSIR, Pretoria.

39 Carden, K. 2018. Lead author of the as yet unpublished *Guidelines for Greywater Use and Management in South Africa.* WRC project K5/2592. Personal communication.

40 Carden, K. 2018.

41 Swartz, C.D., Du Plessis, J.A., Burger, A.J., Offringa, J. 2006. A desalination guide for South African Municipal Engineers. *WaterSA,* 32(5): 641-647.

42 Turner, K.N., Naidoo, K., Theron, J.G., Broodryk, J. 2015. *Investigation into the cost and operation of Southern African desalination and water reuse plants.* WRC Report No. TT 638/15. Water Research Commission, Pretoria.

43 Swartz, C.D., Genthe, B., Menge, J.G., Coomans, C.J., Offringa, G. 2015. *Direct Reclamation of Municipal Wastewater for Drinking Purposes – Volume 1* (Guidance on Monitoring, Management and Communication of Water Quality), WRC Report No TT 641/15. Water Research Commission, Pretoria.

44 Muanda, C., Cousins, D., Lagardien, A., Owen, G., Goldin, J. 2017. *Direct Reclamation of Municipal Wastewater for Drinking Purposes - Volume 2* (Investigation into institutional and social factors influencing public acceptance of reclaimed water for potable uses in South Africa). WRC Report No. TT 734/17. Water Research Commission, Pretoria.

45 *SANS 241-1 South African National Standard - Drinking Water, Part 1: Microbiological, physical, aesthetic and chemical determinants.*

46 *SANS 241-1 South African National Standard - Drinking Water, Part 1: Microbiological, physical, aesthetic and chemical determinants.*

47 Van Duuren, F.A. (Ed). 1997. *Water Purification Works Design*. WRC Report No. TT92-97. Water Research Commission, Pretoria.

48 Voortman, W.J., Reddy, C.D. 1997. *Package Water Treatment Plant Selection*. WRC Report No. 450/1/97. Water Research Commission, Pretoria.

49 *SANS 241-1 South African National Standard - Drinking Water, Part 1: Microbiological, physical, aesthetic and chemical determinants.*

50 Okun, D.A., Schultz, C.R. 1983. Practical water treatment for communities in developing countries. *Aqua*, No.1: 23-26.

51 *SANS 241-1 South African National Standard - Drinking Water, Part 1: Microbiological, physical, aesthetic and chemical determinants.*

52 Schutte, F. (Ed). 2006. *Handbook for the Operation of Water Treatment Works*. WRC Report No. TT 265/06. Water Research Commission, Pretoria.

53 Van Duuren, 1997.

54 Voortman, W.J., Reddy, C.D. 1997.

55 Korlam, S., Thompson, P., Rajagopaul, R. 2016. *Package plants for drinking water treatment: Technology survey, operation and maintenance aspects*. WRC Report No. TT 665/16. Water Research Commission, Pretoria.

56 Van Duuren, 1997.

57 Herselman, J.E. 2013. *Guideline for the Utilisation and Disposal of Water Treatment Residues*. WRC Report No. TT 559/13. Water Research Commission, Pretoria.

58 Du Plessis, J.A., Burger, A.J., Swartz, C.D., Musee, N. 2006. *A Desalination Guide for South African Municipal Engineers*. WRC Report No. TT 266/06. Water Research Commission and Department of Water Affairs and Forestry, Pretoria.

59 Van Zyl, 2011.

60 Schutte, 2006.

61 SANS 10102-2 South African National Standard, Selection of pipes for buried pipelines Part 2: Rigid Pipes is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/.

62 *SANS 966-1 South African National Standard, Components of pressure pipe systems – Part 1: Unplasticized poly (vinyl chloride) (PVC-U) pressure pipe systems* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/.

63 *SANS 966-2 South African National Standard, Components of pressure pipe systems – Part 2: Modified poly (vinyl chloride) (PVC-M) pressure pipe systems* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/.

64 *SANS 1283 South African National Standard, Modified poly (vinyl chloride) (PVC-M) pressure pipe and couplings for cold water services in underground mining* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/.

65 *SANS 16422 /ISO 16422 Pipes and joints made of oriented unplasticized poly(vinyl chloride) (PVC-O) for the conveyance of water under pressure-Specifications* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/.

66 Southern African Plastic Pipe Manufacturers Association (SAPPMA). www.sappma.co.za

67 *SANS 4427-1 /ISO 4427-1. South African National Standard, Plastics piping systems - Polyethylene (PE) pipes and fittings for water supply* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/.

68 SANS 21307 /ISO 21307. *South African National Standard, Plastics pipes and fittings - Butt fusion jointing procedures for polyethylene (PE) pipes and fittings used in the construction of gas and water distribution systems* is available for purchase from the South African Bureau of Standards (SABS) at https://www.sabs.co.za/.

69 Southern African Plastic Pipe Manufacturers Association (SAPPMA). www.sappma.co.za

70 Department of Water Affairs and Forestry (DWAF). 2004. *Water Conservation and Water Demand Management Strategy for the Water Services Sector*. Department of Water Affairs and Forestry, Pretoria.

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